TEMPOROMANDIBULAR JOINT DISORDERS IN PATIENTS WITH SKELETAL DISCREPANCIES

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"I, Salma Al-Riyami confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis"

London, 19th November 2010

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Abstract

Chapter I Literature review on the Temporomandibular joint (TMJ) and Temporomandibular disorders (TMD)

Chapter II Systematic review of TMD in orthognathic patients

This review was conducted to investigate the prevalence of temporomandibular joint dysfunction (TMD) in orthognathic patients and to determine the effect of the surgical intervention on the status of the temporomandibular joint (TMJ). A methodological process was applied for study selection, data management and quality assessment and meta-analyses were conducted where appropriate. This review identified 53 papers for inclusion and there was heterogeneity in the diagnosis and classification of TMD between the studies. Patients undergoing orthognathic treatment for the correction of dentofacial deformity and suffering from TMD appeared more likely to see an improvement in their signs and symptoms than deterioration, particularly with respect to pain related symptoms. This information should be given to prospective patients during the consent process, but it should be stressed that no guarantees can be made.

Chapter III TMD in orthognathic patients and a control group with no skeletal discrepancies

Sixty eight orthognathic patients and 72 control subjects (with no anterior-posterior, vertical or transverse discrepancies) were recruited for this section of the PhD. Self-reported symptoms and clinical signs of TMD were recorded and compared between the two groups. A significant difference in TMD prevalence was observed between the controls (27.8%) and patients (44.1%), with the patients being more susceptible to TMD. However, although orthognathic patients appear more likely to suffer from TMD, whether treatment improves their TMJ condition is highly questionable. This issue should be highlighted in any informed consent process.

Chapter IV A longitudinal study of TMD in orthognathic patients

Twenty orthognathic patients were followed longitudinally throughout treatment to establish whether TMD signs and symptoms altered during the course of treatment. Although no significant differences were found when comparing the pre-treatment (T1) findings with those prior to surgery (T2), sufficient individual changes in TMD signs and symptoms were observed to question the suitability of the "prior to surgery" time point as a baseline for comparisons in future studies. When comparing pre (T1) and post-treatment (T3) TMD changes, no significant differences were observed. This study supports the theory that TMD is a dynamic condition and signs and symptoms are likely to fluctuate throughout treatment. However, the small sample size in this study was clearly a limiting factor.

Chapter V TMJ information course: Comparison of the instructional efficacy of an internet-based TMJ tutorial with a traditional face-to-face seminar

A TMJ tutorial was developed on a virtual learning environment (VLE) to enable students to enhance their examination and diagnostic skills and a randomised cross-over trial was then conducted. Thirty postgraduate students were recruited as participants and the success of this mode of teaching was compared with a conventional face-to-face seminar. This study found that both modes of teaching were equally effective in delivering information to students but teaching the topic twice enhanced the retention of knowledge. In addition the students reported positive perceptions of VLE learning and the feedback for this mode of teaching was comparable with traditional methods of teaching.

Publications Resulting from this Research

1. **Al-Riyami S, Moles DR, Cunningham SJC (2009)**
   Orthognathic treatment and temporomandibular disorders: A systematic review. Part 1. A new quality-assessment technique and analysis of study characteristics and classifications.
   Am J Orthod Dentofacial Orthop. 136:624.e1-624.e.15.
   (Appendix II)

2. **Al-Riyami S, Cunningham SJC, Moles DR (2009)**
   Orthognathic treatment and temporomandibular disorders: A systematic review. Part 2. Signs and symptoms and meta-analyses.
   Am J Orthod Dentofacial Orthop. 136:626.e1-624.e.16.
   (Appendix II)

3. **Al-Riyami S, Moles DR, Cunningham SJC**
   Comparison of the instructional efficacy of an internet-based temporomandibular joint (TMJ) tutorial with a traditional seminar.
   Accepted for publication by the British Dental Journal, April 2010. Manuscript reference: MSS-2009-721R
   (Appendix II)

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Chapter I: Literature Review on the Temporomandibular Joint and Temporomandibular disorders

1.1 Introduction

Temporomandibular joint disorders (TMD), and their relevance to dentistry, has been a highly debated topic in recent years. The temporomandibular joint (TMJ) syndrome was first described by Costen in 1934. Although Costen was not the first to ascribe ear pain, tinnitus, impaired hearing, and dizziness to TMJ dysfunction, he developed an integrated and systematic approach ascribing the symptoms to dental malocclusion. A few years after his original article, the term Costen's Syndrome came into general use.

The American Dental Association President's Conference on Temporomandibular Disorders (American Dental Association, 1983) (Laskin *et al.*, 1983) defined TMD as "a group of orofacial disorders characterised by pain in the preauricular area, TMJ, or muscles of mastication, limitations and deviations in mandibular range of motion, TMJ sounds during jaw function". Luther (1998a) used the term TMD to signify the variety of symptoms, signs and combinations thereof that have been assigned to the TMJ and its related structures. Thus it becomes apparent that clinicians cannot agree upon a precise definition for TMD. Dibbets and Van der Weele (1991) commented that "... many different definitions of TMJ dysfunction have come into existence and consequently, even in a single individual the diagnosis of TMJ dysfunction depends on the definition used". Some of the synonyms for conditions causing pain and dysfunction in the TMJ include: temporomandibular dysfunction syndrome, pain dysfunction syndrome, facial arthromylagia, TMJ dysfunction syndrome, myofacial pain dysfunction syndrome, craniomandibular dysfunction and myofacial pain dysfunction (Al-Ani *et al.*, 2004).

Temporomandibular disorders: are the commonly used all encompassing and comprehensive terms for conditions affecting the TMJ. This includes conditions such as pain in the TMJ or associated muscles, limitation of joint movement, disc displacement, disc dislocation, deviation of the mandible, osteoarthritis and arthralgias etc. It is also

the term favoured by current literature and TMD is used as an abbreviation throughout this study for this described condition.

Temporomandibular dysfunction: is a more traditional term (also abbreviated to TMD) which refers mainly to painful and dysfunction symptoms of the TMJ (e.g. disc derangements, limitation in movement and dislocations), this term has lost favour in recent years.

What can be agreed, however, is that patients suffering from disorders of the TMJ frequently experience the following combinations of symptoms:

- Painful Symptoms: Headaches, facial pain, dental pain, pain in the jaw joints or on jaw movement, ear pain, tinnitus, ear pressure, neck, back, shoulder and chest pain.
- Dysfunctional Symptoms: Limited jaw movement, deviated, slow or irregular jaw movement, limited range of motion, joint sounds such as clicking or crepitus and locked or dislocated jaw.
- Dental Destruction: Traumatic occlusion, clenching, grinding (bruxism); excessive wear and abrasion of the dentition.

To this end, conflict arises in the dental community when views are expressed about topics such as occlusion, condylar position, orthodontics and TMD. If the relevance of TMD to orthognathic treatment is questioned, the diverse viewpoints expressed include that orthognathic treatment may either resolve or induce TMD, or may have little or no effect on TMJ pain and dysfunction.

There have traditionally been two schools of thought regarding TMD, malocclusion and orthodontics. Protagonists of the first felt strongly about the cause and effect relationship of orthodontics and TMD and it was suggested that orthodontics might play a role in initiating TMD (Ricketts, 1966). On the other hand, proponents of the second school claimed that orthodontics might actually be effective in alleviating signs and symptoms of TMD (Luther, 1998a; Proffit, 2000). Many of the findings used to support these arguments, were based on clinical experience, uncontrolled observations and contrived logic.

This conflict really came to light when the results of the Michigan orthodontic/ TMJ law suit were announced. The case of Brimm *vs.* Malloy in 1987 (Luecke and Johnston, 1992) centred on whether a patients orthodontic treatment caused TMD. The case went against the orthodontist with the six-member jury finding in favour of the patient. As a result the American Association of Orthodontists (AAO) began a programme to support research on orthodontic treatment as it relates to TMD.

In the last two decades, a more comprehensive understanding of the TMJ and its associated structures has done little to diminish the controversy surrounding this issue. The main problem stems from the conflicting information in the literature. In actuality this "heated" conflict probably lies somewhere in the middle ground but the need for objective data and well conducted research is now stronger than ever.

1.2 Temporomandibular Joint Anatomy

The articulatory system comprises of a hinge (the TMJ), motors (the masticatory and accessory muscles) and the contacts between the teeth (occlusion).

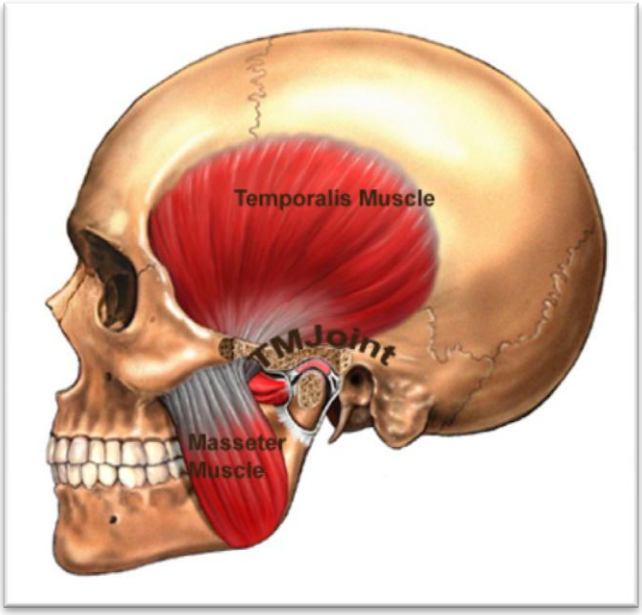

Figure 1.1 The Articulatory system
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The TMJ is the articulation between the condyle of the mandible and the squamous portion of the temporal bone. The condyle is elliptically shaped with its long axis oriented mediolaterally, whilst the articular surface of the temporal bone is composed of the concave articular fossa and the convex articular eminence (Johnson and Moore, 1997).

The TMJ is a bilateral synovial joint that functions in speech, mastication, and deglutition and allows movement of the mandible in three planes of space. It is atypical in that the articular surfaces are covered by white fibrocartilage (mostly collagen with only a few cartilage cells), rather than the more usual hyaline cartilage. Beneath the articular covering of the head of the condyle is a layer of hyaline cartilage (Johnson and Moore, 1997).

The TMJ consists of:

1. Mandibular condyle
2. Temporomandibular fossa
3. Articular disc
4. Joint capsule (lined by synovial membrane)
5. Ligaments
6. Muscles of mastication
7. Blood and nerve supply

Mandibular condyle

The mandible consists of a curved body and two vertical rami which project upwards. At the superior border of the ramus are the coronoid and condylar processes, separated by the mandibular incisure. The coronoid process is a triangular plate of bone which projects upwards (Johnson and Moore, 1997).

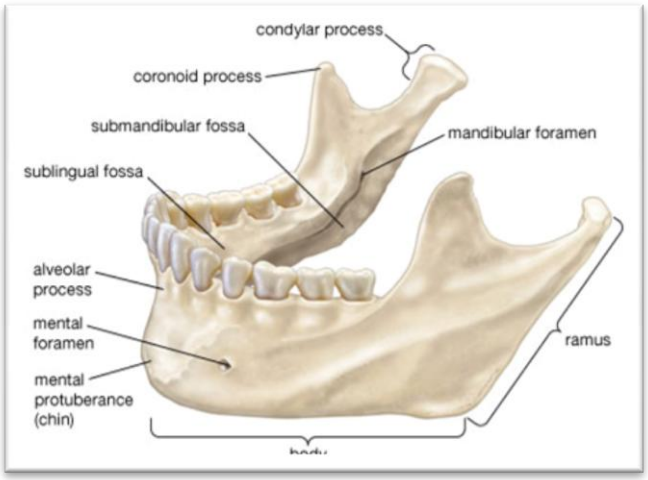

Figure 1.2 The Mandible
Adapted from Encyclopaedia Britannica 2007

The condyle is approximately cylindrical in shape, being expanded from side to side but narrowing from front to back (Johnson and Moore, 1997) and it measures between 13 and 25 mm mediolaterally (Bernard, 2001). The long axis is not quite in the transverse plane but is directed posteriorly and superiorly as well as medially. The constricted part of the condylar process below the head is termed the neck of the mandible. Part of the lateral pterygoid muscle is inserted into the anterior aspect of the condyle.

Temporomandibular fossa (glenoid fossa)

The temporomandibular fossa forms the superior articular surface of the TMJ and is located on the squamous part of the temporal bone. It is bounded anteriorly by the articular tubercle and posteriorly by the tympanic part of the bone; which separates it from the external acoustic meatus. The temporomandibular fossa is divided into two parts by a narrow fissure, which is termed the petrotympanic fissure (Johnson and Moore, 1997).

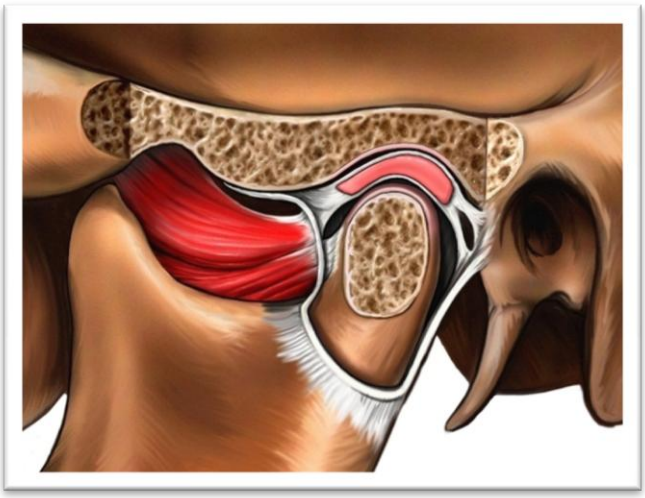

Figure 1.3 The Temporomandibular fossa
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Articular Disc (meniscus)

The meniscus is a fibrous, saddle shaped structure that separates the condyle and the temporal bone and it is separated into bands which vary in thickness (Bernard, 2001):

1. The thinner, central intermediate zone,
2. Thicker portions, called the anterior band, lying below the posterior edge of the articular eminence and
3. A thick posterior band that lays on top of the condyle.

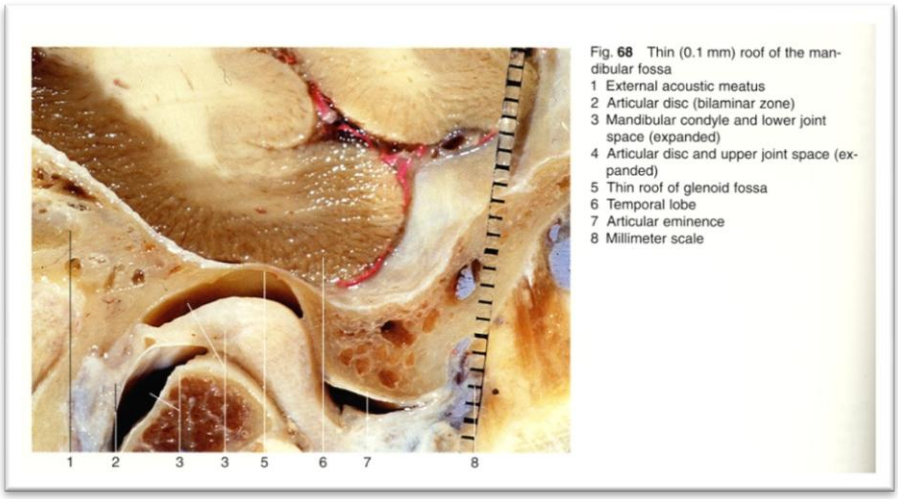

Figure 1.4 The Articular Disc of the TMJ
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Anteriorly, the disc is attached to the articular eminence above and to the articular margin of the condyle below. It also has an anterior attachment to the superior head of the lateral pterygoid muscle. Posteriorly, it is attached to the posterior wall of the glenoid fossa above and to the distal aspect of neck of the condyle below. This area is called the posterior bilaminar zone and was first described by Rees in 1954. The bilaminar zone is formed of a vascular, innervated tissue that plays an important role in allowing the condyle to move forward.

The meniscus and its attachments divide the joint into superior and inferior joint spaces. The superior joint space is bounded above by the articular fossa and the articular eminence and this allows translatory movement. The inferior joint space is bounded below by the condylar head, which allows a hinge or rotatory movement (Bernard, 2001). Both joint spaces have small capacities, generally in the region of 1cc or less. The TMJ is thus not considered a stationary hinge, as it allows both gliding and hinge actions, but is described as a synovial sliding joint (Bell, 1982).

Joint capsule

The articular capsule is a thin, loose envelope which is attached above to the circumference of the mandibular fossa, to the articular tubercle immediately in front

and, below, to the neck of the condyle of the mandible. The capsule encloses the joint and acts as a stabiliser which allows complex function.

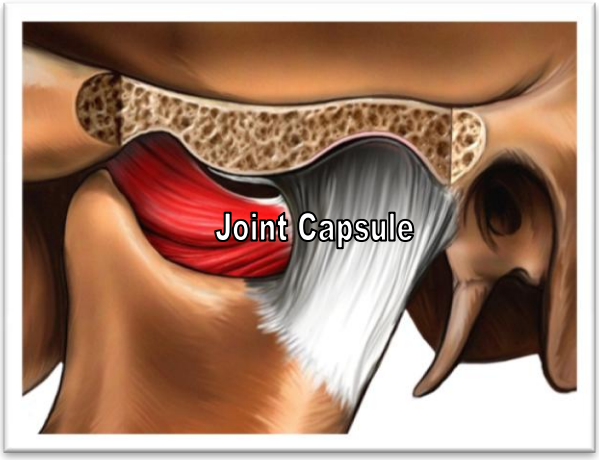

Figure 1.5 The Joint capsule of the TMJ
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The synovial membranes line the inner aspect of the joint capsule (Bell, 1982) and are located above and below the articular disc. The upper, which is the larger and looser of the two, is continued from the margin of the cartilage covering the mandibular fossa and articular tubercle onto the upper surface of the disc. The lower one passes from the under surface of the disc to the neck of the condyle. The synovial membrane consists of two layers, a cellular layer and a vascular layer. The cellular layer contains type A cells, which are phagocytic, and type B cells, which synthesise hyalorunate found in synovial fluid. The vascular layer consists of blood vessels and lymphatics within a loose connective tissue matrix. The synovial membrane secretes synovial fluid for lubrication and nourishment of the articular surfaces and the lining of both compartments.

Ligaments

There are three ligaments associated with the TMJ, one major and two minor. The temporomandibular ligament is a lateral thickening of the joint capsule which consists of two short, narrow fasciculi, one in front of the other. It is attached, above, to the lateral surface of the zygomatic arch and to the tubercle on its lower border and, below, to the lateral surface and posterior border of the neck of the mandible. It is broader above than below and its fibres are directed obliquely downward and backward. It is covered by the parotid gland and by the integument (Standring, 2004).

Two minor ligaments are classed among the ligaments of the TMJ, but can only be considered as accessory to it:

1. The sphenomandibular ligament is a flat, thin band which is attached above to the spina angularis of the sphenoid bone and becomes broader as it descends to the lingula of the mandibular foramen. Its lateral surface is in relation, above, with the lateral pterygoid whilst, below, it is separated from the neck of the condyle by the internal maxillary vessels. Below this, the inferior alveolar vessels and nerve and a lobule of the parotid gland lie between it and the ramus of the mandible. Its medial surface is in close relation with the medial pterygoid.

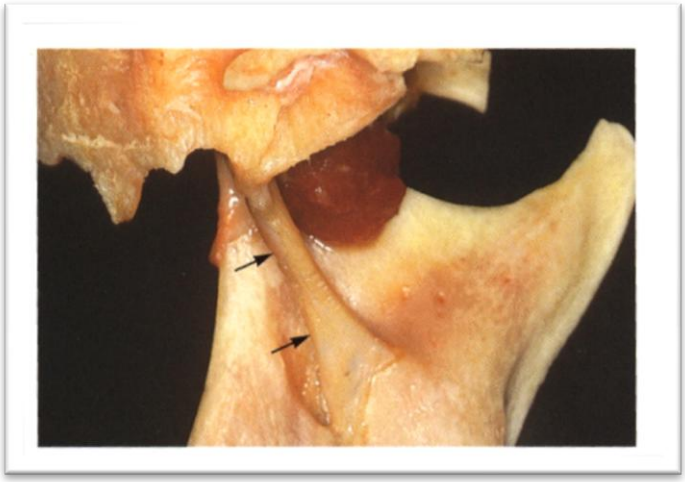

Figure 1.6 The Sphenomandibular ligament (indicated by the arrows)
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2. The stylomandibular ligament is a specialised band of the cervical fascia, which extends from near the apex of the styloid process of the temporal bone to the angle and posterior border of the ramus of the mandible, between the masseter and medial pterygoid. This ligament separates the parotid from the submaxillary gland and some fibres of the styloglossus take origin from its deep surfaces (Standring, 2004).

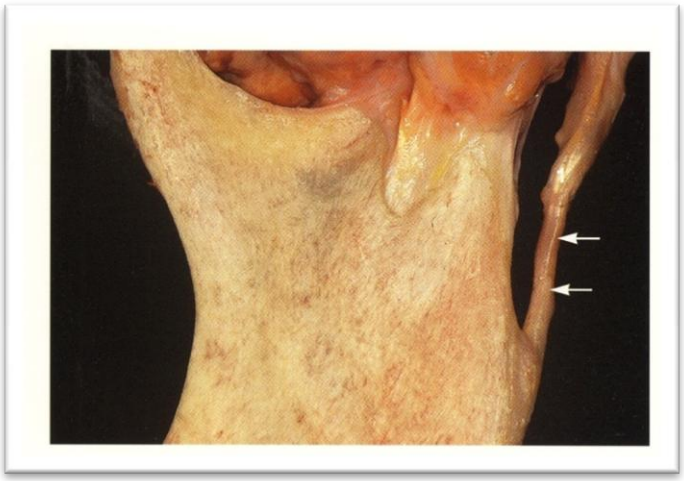

Figure 1.7 The Stylomandibular ligament (indicated by the arrows)
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Muscles of Mastication

Although many muscles are involved in mastication, the primary muscles of mastication are the temporalis, masseter, medial pterygoid and lateral pterygoid (other muscle of mastication include the suprahyoid, infrahyoid, digastric and geniohyoid muscles). These muscles attach to the mandible at various points and move the mandible in all directions. A summary of the origins and insertion are described in Table 1.1.

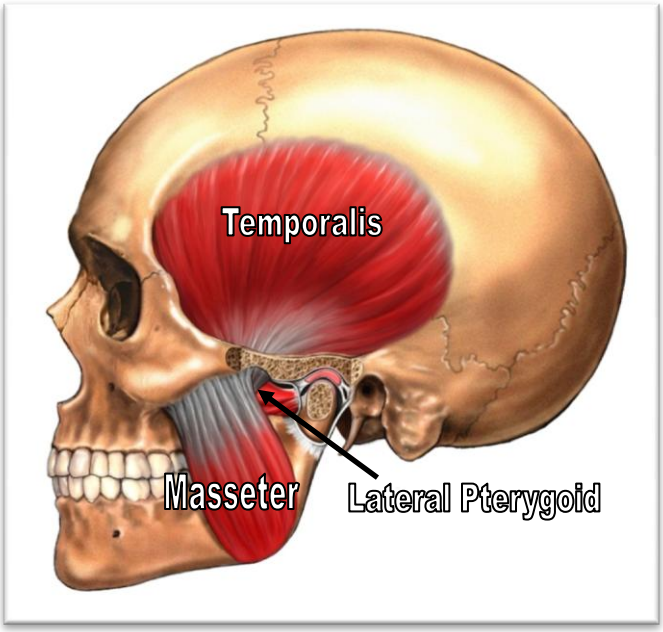

Figure 1.8 The muscles of mastication
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Muscles	Origin	Insertion
Masseter	Superficial head: Anterior two thirds of lower border of zygomatic arch Deep head: Posterior one third and medial surface of zygomatic arch	Superficial head: Angle of mandible Deep head: Ramus of mandible
Temporalis	Temporal fossa	Coronoid process of mandible
Lateral pterygoid	Superior head: Greater wing of sphenoid bone Inferior head: Lateral plate of sphenoid bone	Both heads: Pterygoid fovea of mandible
Medial pterygoid	Pterygoid fossa of sphenoid bone	Angle of mandible

Table 1.1 Origin and insertion of the muscles of mastication

The **masseter** is a thick, quadrilateral muscle, consisting of two portions, superficial and deep. The superficial portion is the larger and arises as a thick, tendinous aponeurosis from the zygomatic process of the maxilla and from the anterior two-thirds of the lower border of the zygomatic arch; its fibres pass downward and backward, to be inserted into the angle and lower half of the lateral surface of the ramus of the mandible. The deep portion is much smaller and denser in texture and it arises from the posterior third of the lower border and from the whole of the medial surface of the zygomatic arch; its fibres pass downward and forward, to be inserted into the upper half of the ramus and the lateral surface of the coronoid process of the mandible. The deep portion of the muscle is partly concealed by the superficial portion and, behind, it is covered by the parotid gland (Standring, 2004). The masseter elevates the jaw and allows clenching of the teeth.

The **temporalis** muscle arises from the temporal fossa and the deep part of temporal fascia. It inserts onto the coronoid process of the mandible and is covered by the

temporal fascia, also known as the temporal aponeurosis (Standring, 2004). The muscle can be felt by palpating the temple region while the subject clenches and unclenches their teeth.

The **lateral pterygoid** (or external pterygoid) is a muscle of mastication with two heads. The upper head originates from the infratemporal surface of the sphenoid bone and the lower head from the lateral surface of the lateral pterygoid plate. Both heads insert onto the pterygoid fovea under the condylar process of the mandible. The lateral pterygoid acts to lower the mandible, open the jaw, and help the medial pterygoid in moving the jaw from side to side during mastication (Standring, 2004).

The **medial pterygoid** (or internal pterygoid muscle), is a thick, quadrilateral muscle. It arises from the medial surface of the lateral pterygoid plate and the grooved surface of the pyramidal process of the palatine bone but also has a second slip of origin from the lateral surfaces of the pyramidal process of the palatine and the tuberosity of the maxilla. Its fibres pass downward, laterally, and posteriorly and are inserted by a strong tendinous lamina, into the lower and posterior part of the medial surface of the ramus and angle of the mandible, as high as the mandibular foramen (Standring, 2004).

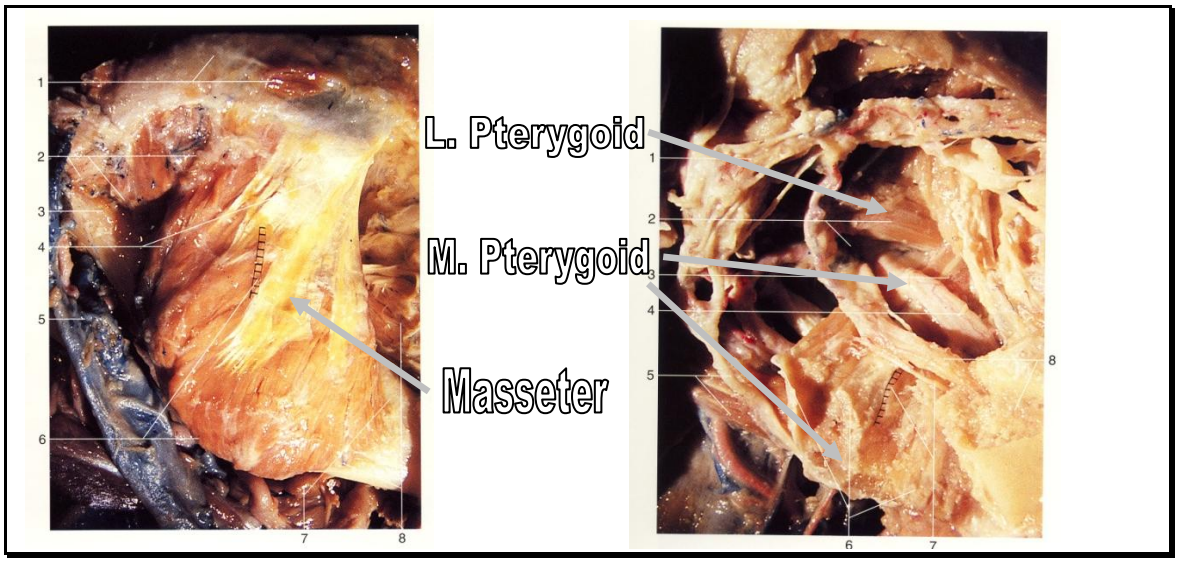

Figure 1.9 Dissection of the masseter and pterygoid muscles
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The medial pterygoid, masseter and temporalis muscles exert vertical forces in closing the jaw, whilst the lateral pterygoid muscle protracts the mandible and stabilises the joint (Bernard, 2001). Table 1.2 describes the actions of the muscles of mastication on the mandible.

Muscles	Mandibular Movements
Masseter	Elevation of mandible (during jaw closing)
Temporalis	Elevation of mandible (during jaw closing) Retraction of mandible (lower jaw backward)
Lateral pterygoid	Inferior heads: slight depression of mandible (during jaw opening) Unilateral action: lateral deviation of mandible (shift lower jaw to opposite side) Bilateral action: protrusion of mandible (lower jaw forward)
Medial pterygoid	Elevation of mandible (during jaw closing)

Table 1.2 Actions of the muscles of mastication on the mandible.

Thus the muscles of mastication are important in co-ordinating mandibular movements in all three dimensions; transverse, vertical and sagittal. A fourth dimension, time, also plays a part and is considered in the Bennett movement. The angle formed by the downward movement of the mandible is the condylar angle, whilst that formed by the medial movement is known as the Bennett angle (Davies and Gray, 2001). During the Bennett movement, the mandible shifts towards the working side and this shift is classified based on the time at which it occurs in relation to the lateral movements.

Blood and nerve supply

The joint is supplied with sensory fibres by branches of the auriculotemporal nerve and the masseteric nerve, both of which are branches of the mandibular division of the trigeminal nerve which also supplies the muscles acting on the joint.

Proprioception in the TMJ involves four receptors (Bell, 1982):

1. Ruffini endings function as static mechanoreceptors which deal with the posture of the mandible.
2. Pacinian corpuscles are dynamic mechanoreceptors which accelerate movement during reflexes.
3. Golgi tendon organs function as static mechanoreceptors for protection of ligaments around the TMJ.
4. Free nerve endings are the pain receptors for protection of the TMJ itself.

In order to facilitate functioning, there is neither innervation nor vascularisation within the central portion of the articular disc. Presence of nerve fibres or blood vessels would result in bleeding every time the jaw was moved and this would be extremely painful.

The blood supply for the TMJ is through the maxillary and superficial temporal branch of the external carotid artery.

1.3 Conditions affecting the Temporomandibular Joint

Some of the conditions that may affect the TMJ include:

1. Pain in the TMJ or associated muscles
2. Limitation of joint movement
3. Disc displacement
4. Condylar dislocation
5. Deviation
6. Systemic autoimmune diseases, connective tissue disorders, and arthritic conditions
7. Osteoarthritis
8. Neoplasm

1. Pain in the TMJ or associated muscles

Pain or tenderness can affect the TMJ and any of the associated muscles of mastication. Pain may come from the TMJ itself, the muscles or often a combination of the two. Symptoms are diverse and the pain can range from a mild ache to a chronic debilitating pain. It may present in many ways including jaw pain in the muscles near the mouth or as a headache at the temples (temporal headache) due to inflammation in the temporalis muscle (Bumann and Lotzmann, 2002).

Pain in the joint itself is usually due to inflammation within the structure but sometimes the symptoms are referred and are perceived to be in other facial structures; such as dull ear pain, toothache, or neck pain. TMJ pain disorders may occur because of unbalanced activity, spasm, or overuse of the jaw muscles. Symptoms tend to be chronic and treatment is aimed at eliminating the precipitating factors (Bumann and Lotzmann, 2002).

2. Limitation of joint movement

This term is used to describe either a reduction in maximum mouth opening or limited lateral excursions. The average range of jaw movements varies between individuals, but the incisal opening (measured from the upper incisal tip to the lower incisal tip) usually measures approximately 35mm for females and 40mm for males. However, this can range between 35 and 50mm (Harris *et al.*, 1993; Gray *et al.*, 1994b). Mouth opening reduces with age and is generally wider in individuals under 50 years of age (Gallagher *et al.*, 2004; Placko *et al.*, 2005). Lateral excursions are the ability to move the mandible laterally with the teeth in contact, with the average range of movement being approximately 8 mm in either direction (Gray *et al.*, 1994b). Lateral excursion is said to be reduced if the lateral movement which can be achieved in either direction is less than a lower incisor width (Harris *et al.*, 1993).

A reduction in vertical range of movement or the inability to fully open the mouth is also known as trismus. This may be due either to pain preventing the patient from fully opening or a physical obstruction. Pain may indicate a muscular problem whereas physical obstruction usually involves disc displacement. If trismus is persistent and permanent it may be called ankylosis; this can occur after condylar fracture and the aetiology is categorised into extra-auricular and intra-auricular causes (van der Waal, 1991).

Kazanjian (1938) classified ankylosis of the TMJ as true or false. True ankylosis was attributed to pathological conditions of the joint and false ankylosis was applied to restrictions of movement resulting from extra-articular joint abnormalities. It is this latter type of ankylosis that most clinicians describe as trismus (Luyk and Steinberg, 1990).

Several conditions may cause, or predispose, an individual to develop trismus. The aetiology of trismus may be classified as follows (Dhanrajani and Joneidel, 2002):

1. Infection: odontogenic infections. (e.g around a partially erupted third molar) or non odontogenic infections. (e.g tonsillitis or a parotid abscess)
2. Trauma: fractures, particularly those of the mandible, may cause trismus
3. Dental treatment: oral surgical procedures or extraction of teeth may result in trismus
4. TMJ disorders
5. Tumours
6. Drugs: Some drugs are capable of causing trismus as a secondary effect, succinyl chlorine, phenothiazines and tricyclic antidepressants being among the most common
7. Radiotherapy and chemotherapy
8. Congenital problems: Trismuspseudo-camptodactyly syndrome 30 is a rare combination of hand, foot and mouth abnormalities and trismus
9. Miscellaneous disorders such as psychogenic hysteria and lupus erythematosis

The range of jaw movement is the only measurable parameter which can be objectively recorded in relation to TMD. As such it is an important record for both severity of signs or symptoms and changes in signs and symptoms (Gray *et al.*, 1994b).

3. Disc Displacement

Disc displacement or internal derangement of the TMJ may be defined as a disruption within the internal aspects of the joint, in which there is a displacement of the disc from its normal functional relationship with the mandibular condyle and the articular portion of the temporal bone (Dolwick *et al.*, 1983).

Internal derangement of the TMJ is present when the posterior band of the meniscus is anteriorly displaced in front of the condyle. As the meniscus translates anteriorly, the posterior band remains in front of the condyle and the bilaminar zone becomes abnormally stretched and attenuated. Often the displaced posterior band will return to its normal position when the condyle reaches a certain point and this is termed anterior displacement with reduction.

When the meniscus reduces, the patient often feels a "pop" or click in the joint. In some patients, the meniscus remains anteriorly displaced at full mouth opening and this is termed anterior displacement without reduction. These patients often experience restricted mouth opening. It has been estimated that up to 25% of the entire population could be affected by TMJ internal derangements (Farrar, 1981). Traditionally, internal derangement of the TMJ has been described as a progressive disorder with a natural history that may be classified into four consecutive clinical stages (Kaplan, 1991):

1. Stage one has been described as disc displacement with reduction. It is characterised clinically by reciprocal clicking as a result of anterior disc displacement with reduction. Although it has been stated that the later (in the cycle of mandibular opening the opening) click occurs, the more advanced the disc displacement, diagnosis based on joint sounds has come under debate (Stohler, 1992). Anterior disc displacement with reduction can also exist without joint noises, i.e. false negatives (Rohlin *et al.,* 1985). The clinical sign of disc displacement with reduction is limited mouth opening, usually accompanied by deviation of the mandible to the involved side, until a "pop" or click (reduction) occurs. The patient is then able to open the mouth fully along the facial midline (thus a transient deviation). Arthrograms show anterior disc displacement in centric occlusion, but the disc is normally located in the open-mouth position (Kaplan, 1991).
2. Stage two is disc displacement with reduction and intermittent locking. It features all of the above characteristics, plus additional episodes of limited mouth opening which can last for various lengths of time. Patients may describe it as "hitting an obstruction" when opening is attempted. The "obstruction" may disappear spontaneously or the patient may be able to

manipulate the mandible beyond the interference. Arthrographically, stage two is similar to stage one (Kaplan, 1991).

3. Stage three has been described as disc displacement without reduction (closed lock). Closed lock occurs when clicking noises disappear but limited opening persists. The patient complains of joint pain and chronic limited opening, with the opening usually less than 30 mm. Examination reveals preauricular tenderness and deviation of the mandible to the affected side during mouth opening and protrusive movements. Arthrocentesis and arthroscopic surgery have documented consistently high success rates in relieving this particular pattern of internal derangement (Sanders, 1986). Arthrographic examination and magnetic resonance imaging (MRI) show anterior disc displacement in both centric occlusion and maximal mouth open positions. Limited condylar translation may also be evident (Kaplan, 1991). In chronic closed lock episodes, if the condition progresses the condyle may steadily push the disc forward to achieve almost normal ranges of mouth opening, in spite of the presence of a non-reducing disc.
4. Stage four is described as disc displacement without reduction and with perforation of the disc or posterior attachment tissue (degenerative joint disease). With continued mandibular function, the stretched posterior attachment slowly loses its elasticity and the patient begins to regain some of the lost range of motion. As retro-discal tissue continues to be stretched and loaded, it becomes subject to thinning and perforation (Kaplan, 1991). Anatomical studies have shown that this tissue may remodel before it succumbs, ill-adapted to the functional load, and perforates (Heffez *et al.*, 1990). Arthrograms have shown joint crepitus to be suggestive of, but not exclusive to, disc perforation.

The progressive nature of this disorder necessitates a thorough clinical history and it is especially important to ascertain whether a patient has had previous history of joint sounds, as this could assist in determining the current diagnosis. Absence of joint sounds should not necessarily be taken as absence of disease, or an improvement in TMD in patients with prior history of clicks. Rather there is a possibility that the disorder has progressed to stage three or stage four of internal derangements as discussed above.

Often classified as characteristic of a separate final stage, hard tissue remodelling may occur throughout all of these stages. Clinically, osteoarthrosis may be diagnosed because the remodelling often occurs unilaterally. The symptoms frequently worsen throughout the course of a day, crepitation as distinct from clicking is often present and radiographic evidence (flattening, sclerosis, osteophytes and erosion) may be seen (Zarb *et al.,* 1994).

Although in many patients internal derangement undergoes the progressive changes described, it is still not clear whether this progression happens in all cases and longitudinal epidemiological studies do not seem to support the idea of progression. Magnusson *et al.* (1986) studied 293 subjects with clicking over a 10 year period. At the five-year follow-up, clicking had not changed to locking in any of the subjects and at the 10-year follow-up, only one of the 293 subjects reported intermittent locking (Magnusson *et al.*, 1993). Additionally, the authors reported that half of the patients who exhibited clicking at 15 years of age no longer did so at 20 years, and about half of those who did not exhibit clicking at age 15 went on to develop clicking. Thus, the probability that TMJ clicking would disappear in a symptomatic individual was equal to the probability of it appearing in an asymptomatic individual. This lack of progression of internal derangement from a reducing disc to a non-reducing disc condition has also been shown in other studies (Greene and Laskin, 1988; Laskin, 1994).

Sato *et al.* (1998) studied the natural course of anterior disc displacement without reduction in 44 subjects who agreed to observation without treatment. The incidence of successful resolution of the condition was 68% at 18 months. This finding suggests that the signs and symptoms of anterior disc displacement without reduction tend to be alleviated during the natural course of the condition. The authors failed to mention what happened to the anteriorly displaced disc. They noted, however, that the maximal mouth opening increased from 29.7 mm to 38 mm and concluded that it was unlikely that the disc became self-reducing; it was felt to be more plausible that there was some stretching and remodelling of the retro-discal tissues, enabling the disc to be displaced more anteriorly by the translating condyle.

Thus, although clinical evidence suggests progressive worsening of the internal derangement in some patients, important clinical questions still remain. It is unclear what the progression rate is, nor is it clear which patients have the greatest risk of

progressing to the more advanced stages. As such, it is suggested that clinicians who justify aggressive treatment of asymptomatic TMJ clicking based on their belief in a high progression rate to a non-reducing state should instead exercise patience and clinical vigilance in their management of this condition (Barkin and Weinberg, 2000).

4. Condylar dislocation

Condylar dislocation occurs when the jaw locks in an open position and the mouth cannot be closed. The condition can cause significant discomfort until the joint returns to the correct position. Dislocation occurs when the ligaments that normally keeps the condyle in place are "loose", allowing the condyle to move beyond the articular eminence. The surrounding muscles often go into spasm and hold the condyle in the dislocated position. Subluxation, which is the partial dislocation of the jaws, is self reducing and requires no treatment. Alternatively recurrent joint dislocation may be managed by surgical intervention.

In the absence of an anatomical defect in the TMJ, dislocation is uncommon. It is usually associated with trauma, occurring when the patient is hit with the mouth open (Gray *et al.*, 1994a), although it can occur as a result of opening the mouth wide on yawning or eating when there is laxity of the capsule and ligaments (Perrini *et al.*, 1997). Intubation during surgical procedures and general anaesthetic has been known to cause jaw joint disorders and dislocation because the patient's mouth must be opened quickly, and widely, to insert the respiration tube and the jaw may remain fixed in position for a prolonged period of time (Ting, 2006).

Hypermobile TMJs and a high incidence of TMJ dislocation are also seen in patients with Ehler-Danlos and Marfan's syndrome due to the extra elasticity of the ligaments resulting from the collagen and connective tissue abnormality (De Coster *et al.*, 2005).

5. Deviation

Deviation in movement may occur in either an opening or closing cycle and is due to a variety of causes (Gray *et al.*, 1994b). Deviations can be either lasting or transient.

1. A lasting deviation (Figure 1.10) is a gradual deviation along a straight line axis, which may be caused by adhesions within the joint. Alternatively it may present as a predominantly vertical opening with a marked lateral

movement when maximum opening is achieved. This is usually caused by anterior disc displacement without reduction.

2. A transient deviation (Figure 1.11) can be described as a vertical opening with a lateral shift in the middle of the opening cycle which then returns to normal in the vertical plane. This may be associated with disc displacement with reduction.

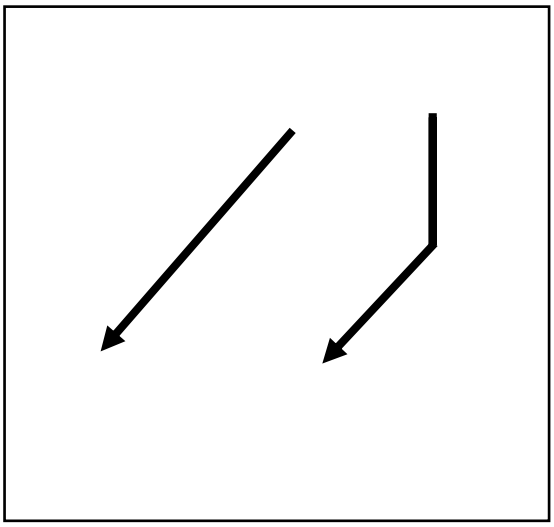


Figure 1.10 Path of lasting deviations

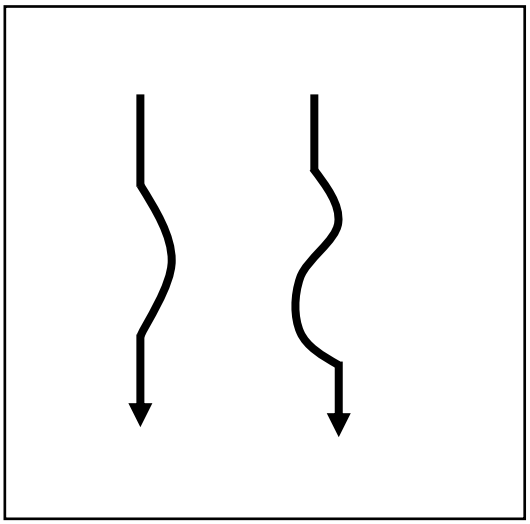


Figure 1.11 Path of transient deviations

Deviations may or may not be accompanied by painless joint sounds and, radiographically, mild structural bony changes may be detected. In a study by Uy-Co *et al.* (2000) the relationship between condylar bony change and mandibular deviation in orthodontic patients was assessed. Seventy-one patients were examined with helical computed tomography and magnetic resonance imaging to assess the condylar bony changes and/or disc displacement prior to acceptance for orthodontic treatment. Patients were classified into those with no condylar bony changes and those with unilateral condylar bony changes. They concluded that patients who presented with unilateral condylar bony changes were more likely to present with mandibular deviations and this could affect the cant of the maxillary basal bone, mandibular plane angle and lower dentition.

6. Systemic autoimmune diseases, connective tissue disorders, and arthritic conditions

Systemic autoimmune diseases are a group of disorders in which the body's immune system attacks a number of organs, tissues and cells. Examples of these conditions include:

- Systemic Lupus Erythematosis
- Rheumatoid Arthritis (RA)
- Scleroderma
- Sjőgrens syndrome

Connective tissue diseases are disorders of the body in which the primary target of pathology is the connective tissue. These disorders can be hereditary or auto immune and examples of hereditary connective tissue disorders include:

- Marfans syndrome
- Ehlers-Danlos syndrome.
- Sticklers syndrome

There is an overlap between autoimmune connective tissue disorders and autoimmune diseases, as many of the autoimmune diseases also affect the connective tissues. As such diseases such as Sjőgrens syndrome, systemic lupus erythematosis, scleroderma and rheumatoid arthritis can also be classified as connective tissue disorders.

Polyarthritis is any arthritic condition which involves five or more joints and is most frequently a consequence of an autoimmune disorder. Chronic inflammation of the joints, pain and limited movement are often observed. An inflammation of two, three or four joints is an oligoarthritis. Juvenile idiopathic arthritis (JIA) is the most common rheumatic disease presenting in childhood and is of unknown aetiology (Müller *et al.,* 2009). JIA which is present for longer than 6 weeks and occurs before the age of 16 years, can be classified into systemic arthritis, rheumatoid factor negative, positive poly arthritis, oligoarthritis, enthesis-related arthritis and psoriatic arthritis (Pirttiniemi *et al.,* 2009).

TMD is highly prevalent in individuals with autoimmune and connective tissue disorders (De Coster *et al.,* 2005; Ardic *et al.,* 2006). The TMJ has even been reported

to be the first joint involved in some individuals affected by rheumatoid diseases (Uotila, 1964). Reported frequencies of TMJ involvement in RA vary between 2% and 86% (Kopp and Rockler, 1979; Larheim *et al.,* 1990). Pain, crepitus and decreased movement of the TMJ are frequent clinical findings in patients with rheumatic disease and erosions and cysts of the mandibular condyle are typical radiological findings. In addition synovial proliferation and joint effusion can be observed by magnetic resonance imaging of the TMJ (Suenaga *et al.,* 2000; Melchiorre *et al.,* 2003). In JIA the reported frequency of TMJ involvement ranges from 17 to 87%, additionally it may be the initial presentation of the disease, if not the only joint involved (Müller *et al.,* 2009).

Larheim *et al*. (1990) studied 28 symptomatic patients with rheumatic diseases (21 with RA, four with psoriatic arthropathies, two with ankylosing spondylitis and one with Reiter's disease). MRI showed bony abnormalities in 27 of the 36 joints studied and the reported abnormalities included joint effusion, disc abnormalities and condylar degeneration.

A study by Helenius *et al*. (2006) investigated TMJ in patients with different rheumatic diseases and reported correlations between the clinical, radiographic and MRI findings. Sixty seven recruited patients were divided into four groups: 16 with rheumatoid arthritis (RA), 15 with mixed connective tissue disease (MCTD), 18 with ankylosing spondylitis (AS) and 18 with spondyloarthropathy (SPA). MRI showed a reduction in the articular cartilage in 25% of RA, 0% of MCTD, 17% of AS and 17% of SPA patients. Condylar changes observed included erosion, osteophytes and abnormal shape, while disc alterations included perforation, abnormal anterior position and decreased movement. These abnormalities were most common amongst RA patients and least frequently seen in MCTD and SPA patients. A correlation was observed between crepitus and reduced maximum opening of the mouth and abnormalities of the disc and articular cartilage as shown by MRI. In addition severe condylar erosion in panoramic tomograms significantly correlated with MRI findings of condylar erosion, diminished thickness of the condylar cartilage, abnormal condylar shape, and abnormal shape of the temporal surface of the TMJ. The presence of crepitus, limited mandibular movement and/or pain on movement of the jaw often indicated structural damage to the TMJ.

Müller *et al.* (2009) examined 30 consecutive patients with JIA. They found that 63% of patients had signs of TMJ involvement on the MRI, and this was also associated with condylar deformity in 47% of the patients. They recommended frequent measuring of the maximum mouth opening in patients with JIA, as restricted opening is a sign of TMJ involvement even in the absence of pain, tenderness or mandibular deviations.

7. Osteoarthritis

Osteoarthritis (OA) is defined as a degenerative condition of the joint characterised by deterioration and abrasion of the articular tissue and concomitant remodelling of the underlying subchondral bone (flattening of the articular surfaces). Osteoarthritis may cause the breakdown and eventual loss of the cartilage of one or more joints. It is especially prevalent among older people and is sometimes called degenerative joint disease or "wear and tear" disease of the elderly.

It may also cause damage to the disc of the TMJ, leading to erosion, reduction in disc space, and perforation of disc tissue (Castelli *et al.*, 1985; de Bont *et al.*, 1985). The occurrence of OA may be related to the adaptive capacity of the articular cartilage with regard to joint loading throughout life (Stegenga *et al.*, 1991). The loading of a joint beyond its capacity may lead to tissue breakdown in the cartilage and eventually result in OA (Stegenga *et al.*, 1991; de Bont *et al.*, 1993). The cause of OA, however, is not fully understood and it is thought that both local and general factors may play a role in the development and progress of the condition.

Osteoarthritis which affects the TMJ may cause changes in dental and skeletal structures and studies have suggested that, in children, it may potentially alter mandibular growth leading to mandibular retrusion and/or mandibular deviation. If TMJ OA appears during orthodontic treatment, the mandible usually rotates posteriorly resulting in an unsatisfactory profile, especially in patients with pre-existing mandibular retrusion (Yamada *et al.*, 2004).

8. Neoplasm

Tumours and tumour like conditions of the TMJ region are exceedingly rare (Benson and Ottis, 1994) and most of those which are presented in the literature are isolated case reports (Mock, 1999). Symptoms associated with neoplasia of the TMJ may include clicking, preauricular swelling, limited mandibular mobility/trismus, pain, jaw deviation

(Mock, 1999), progressive mandibular asymmetry, and malocclusion (Benson and Ottis, 1994). Unfortunately, these symptoms are often also associated with the more common pathologies affecting the joint, such as internal derangements, myofascial pain dysfunction syndromes, arthralgias, arthritidies and, traumatic injuries. Thus the possibility of other unusual causes needs to be carefully considered and imaging may be indicated. The most common tumour of the condyle is osteochondroma, although it occurs very rarely (Kerscher *et al.*, 1993). Tumours from the prostate, thyroid and breast may also occasional metastasise to the condylar head (De Boom *et al.*, 1985).

Although not strictly neoplastic in nature, condylar hyperplasia is the most common abherent growth condition affecting the mandible. In condylar hyperplasia, there is a pathological overgrowth of the condylar process leading to facial asymmetry. This has been differentiated into hemimandibular hyperplasia (HH) and hemimandibular elongation (HE) (Deleurant *et al.*, 2008). HH is distinguished by the asymmetrical enlargement of one side of the mandible (condyle, condylar neck, ramus and corpus) without a deviation of the mandibular midline. In HE there is elongation of one side of the mandible, the condylar neck, ramus and corpus may be affected but the condylar head does not appear to be involved. In addition, the lower dental midline is often shifted away from the affected side, while a crossbite is commonly observed on the unaffected side (Deleurant *et al.*, 2008).

1.4 Aetiology of TMD

Although the evidence suggests that TMD has an uncertain aetiology, most experts agree that there are multiple potential causes. However, with the exception of trauma and disease (e.g systemic arthritic conditions and connective tissue disorders), there is still much controversy regarding the extent to which possible causes may influence outcomes. It is unclear which of the proposed causes are actual causes, which are risk factors, and which are coincidental. The more factors involved, the more difficult it is to make this distinction. Consequently, many studies that attempt to identify aetiology are inconclusive and/or unscientific. A number of contrasting theories have evolved, some

of which appear to be tailored to fit the treatment administered rather than the evidence (Mew, 1997). Some of these potential theories include:

1. Trauma

Some clinicians have suggested that an injury either directly to the joint or to the head and neck area can trigger a TMJ problem (McCarty, 1980). For example, a heavy blow to the side of the face may cause fracture of the condyle or the disc may be displaced. A whiplash injury sustained during a car accident can stretch or tear tissues and ligaments, displace the disc, and even cause bleeding which leads to the formation of scar tissue, thereby decreasing mobility and causing pain (Salé and Isberg, 2007). Wilkes (1989) even suggested that trauma was the single most frequent cause of TMD. Some professionals believe, however, that even though specific traumatic events may seem to precipitate clinical symptoms, they may not always have initiated the disorder (Ryan, 1993).

2. Disease

The TMJ is susceptible to the same diseases as other joints in the body, such as osteoarthritis (progressive degeneration of the joint with bony changes, destruction of the disc, and muscle pain), rheumatoid arthritis, gout and neoplasia. Although relatively uncommon, they may affect the TMJ, causing pain and compromising function.

3. Genetic/Congenital

Some researchers have suggested that a relationship exists between the serotonin receptors or transporter genes and TMD. Mutlu *et al.* (2004) investigated the relationship between T102C polymorphism of the 5-HT2A receptor gene and TMD. Sixty-three patients with TMD and 54 healthy volunteer controls were included in the study. Molecular analysis of the T102C polymorphism of the 5-HT2A receptor gene was performed using the PCR technique. They found that the C/C genotype was over represented in the patient group, whereas the T/T genotype was over represented in the controls. Hence they concluded that T102C polymorphism may be involved in the aetiology of TMD. The over-representation of the C/C variant of the 5-HT2A receptor gene in TMD suggests a possible role of the serotonergic system in this disease,

particularly at the receptor level. However, the genotype distribution of the patients who had TMD was not different from those who did not have TMD.

Little research has been conducted in these areas and the results of other studies have been inconclusive (Herken *et al.,* 2001). There is no scientific evidence to suggest that TMD can be inherited. There is also great variation in craniofacial structures and a wide range of "normal" TMJs. As such, a consensus has not been reached on an "ideal" condyle/fossa structure or position and it is unknown if a certain condylar position or anatomical form is more likely to cause TMD.

4. Habits and posture

Some clinicians believe that habits such as tongue thrusting, mouth breathing, excessive mouth opening, and nail, lip, or cheek biting can precipitate a TMJ problem. Their argument is that putting the jaw in an abnormal position may weaken the structures of the joint, eventually leading to damage as a result of continuous stress.

Changes in head posture have been associated with changes in the stomatognathic system, thus head posture is presumed to have an influence on the biomechanical behaviour of the TMJ and its associated structures (Olivo *et al.,* 2006). There is some evidence to suggest closed mouth postures are beneficial, and that forward growth patterns which are less likely to present as open bites are associated with reduced signs of TMD (Dibbets and van der Weele, 1996). Some studies have reported that the position of the head affects the resting position of the mandible (Solow and Tallgren, 1976; Goldstein *et al.*,1984; Gonzalez and Manns, 1996), thus increasing muscular activity (Funakoshi *et al.*,1976) and altering the internal arrangement of the TMJ (Visscher *et al.,* 2000).

There are many everyday tasks and activities that may lead to pain and muscle spasm, either in the muscles of the jaw or those of the head, neck or shoulders. These include cradling a telephone between the ear and shoulder, talking excessively, carrying a heavy shoulder bag, playing a violin or woodwind instrument, singing, or activities that promote a forward head position such as hunching forward to read. The majority of people seeking treatment for TMD experience myofascial pain dysfunction (resulting from the later causes) rather than a problem within the joint itself. As such a TMD

patient usually experiences varying degrees of pain involving the muscles of the head, neck and upper back. Several studies have found a significant overlap between TMD and pain conditions in other parts of the body including back pain (Allebring and Hagerstam, 1993; Hagberg *et al.*, 1994; Turp *et al.*, 1998). In addition, high rates of co morbidity between myogenous facial pain and fibromyalgia have been noted in several studies (Marbach, 1995; Plesh *et al.*, 1996; Hedenberg-Magnusson *et al.*, 1999).

It has been proposed that the most physiological position of the condyle within the temporomandibular fossa is in the so-called Gelb 4/7 position, in which the condyle is located in the most anteriorly recommended position (Gelb, 1977). It has been suggested that in cases of disc displacement the condyle is positioned too far posteriorly and anterior repositioning of the condyles to the Gelb 4/7 position will allow for recapturing of the disc to a normal position (Gelb, 1977). In recent years this concept has come under scrutiny, and it is believed that condylar position is not a specific point, but like other biological systems there is a bioadaptive range of normal function (Okeson, 1996).

Although there is a difference of opinion concerning the extent to which habits and posture affect the development of TMD, it makes sense to avoid anything that aggravates a pre-existing condition. Olivo *et al.* (2006) carried out a systematic review to assess the evidence concerning the association between head and cervical posture and temporomandibular disorders. They concluded that most of the studies included in the review were of poor methodological quality and the findings of the studies should be interpreted with caution. The association between intra-articular and muscular TMD and head and cervical posture therefore remains unclear, and better controlled studies with comprehensive TMD diagnoses, larger sample sizes, and objective posture evaluation are necessary.

5. Diet consistency/Hard Foods

Although Helkimo (1974) stated that a hard diet was not an aetiological factor, this is a poorly researched area and it seems possible that food consistency or content may influence TMD. Many clinicians advise patients who have a TMJ disorder to avoid biting into anything that forces the mouth wide open or anything that is hard, crunchy, or chewy. Raphael *et al.* (2000) found that patients with severe myofascial pain were

likely to reduce their intake of dietary fibre, thus masticatory activity, to avoid exacerbating facial pain. Irving *et al.* (1999) conducted a study on 35 patients attending an oral and maxillofacial surgery department due to facial pain. They found that thirty-one subjects reported that eating was a problem, 15 prepared food differently and 24 considered that their choice of food was limited. The five foods most often reported to be difficult to eat were meat, apples, bread, toast and toffees. However, it must be borne in mind that these dietary changes are just as likely to be a consequence of TMD as a causative factor.

6. Bruxism, Stress and Psychosocial factors

1. Bruxism: Bruxism is a diurnal or nocturnal tooth contact parafunctional activity, incorporating clenching and grinding (Mohl *et al.,* 1988). Sleep bruxism has been defined by the American Sleep Disorders Association (ASDA) in its International Classification as a "stereotyped movement disorder characterised by grinding or clenching of the teeth during sleep" (Thorpy, 1990). The prevalence of bruxism in the general population ranges from 8 to 21 % when assessed by a questionnaire and from 48 to 58 % when clinical oral examination is employed (Seligman *et al.,* 1988). The aetiology of bruxism is unclear and it has been suggested to be a multifactorial psychosomatic phenomenon (Olkinuora, 1972). Bruxers are suggested to have increased levels of stress and tension, disturbed sleep, and depression (Dao *et al.,* 1994). At present, bruxism is considered a phenomenon of centrally mediated neurologic activity related to sleep disorders (Lobbezoo and Lavigne, 1997).

   Patients are often told they have TMD because they grind their teeth and that they grind their teeth because they are stressed. It has yet to be proven whether stress is the cause of bruxism and the resulting pain or merely the result of dealing with a chronic pain condition. There are studies, however, which have found that bruxism and other parafunctional habits are associated with head and facial pain (Dao *et al.,* 1994; Molina *et al.,* 1997; Glaros *et al.,* 1998).

   Up to 20% of the population with or without TMD grind their teeth at night, however, not all people with TMD grind their teeth, and not all habitual tooth-

grinders have TMD. Van der Muelen *et al.* (2006) examined the relationship between different types of self reported oral parafunction and the intensity of the TMD pain complaints taking into account factors such as age and gender. They found no significant relationship between bruxism and TMD and concluded that if a causal relation between TMD pain intensity and bruxism exists, it is probably minor.

2. Psychosocial factors: Some authors believe that psychosocial factors play an important role in the development of TMD, in adaptation to pain and eventual recovery. TMD patients exhibit a variety of behavioural characteristics including increased somatisation, stress, anxiety and depression (Pankhurst, 1997). The perception of pain is highly dependent upon psychological state (Price, 1988). The importance of psychological factors has also been emphasised in TMD (Kight *et al.*, 1999; Rollman and Gillespie, 2000). Psychological factors are thought to have a role in the cause or maintenance of TMD (Rugh, 1992) and may predispose the condition to chronicity (Gatchel *et al.*, 1996). Categorisation of the patients into diagnostic subgroups of TMD suggests that myogenous patients may have more psychological difficulties than patients with arthrogenous TMD (McCreary *et al.*, 1991; Jaspers *et al.* 1993; Scholte *et al.*, 1993; Lobbezoo-Scholte *et al.*, 1995). On the other hand, it has been stated that psychological disturbances may be a direct consequence of pain-related life events in TMD patients (Rugh, 1992; Murray *et al.*, 1996).

   Pallegama *et al.* (2005) tested the hypothesis that muscle related TMD patients, with cervical muscle pain exhibited a greater degree of psychological distress compared with patients without cervical muscle pain and controls. Thirty-eight muscle related TMD patients (including 10 patients with cervical muscle pain) and 41 healthy controls participated in their study. State and trait anxiety levels and personality traits (extroversion, neuroticism, psychoticism and social desirability) were assessed. The TMD patients, in general, exhibited significantly higher degrees of neuroticism and trait anxiety. Those patients with cervical muscle pain demonstrated a significantly higher level of psychoticism compared with the patients without cervical muscle pain and the controls and a significantly higher state anxiety level than the controls. They also demonstrated

higher pain intensities in the masseter and temporalis muscles compared with patients without cervical muscle pain, however as there were only 10 patients with cervical muscle pain, these results should be treated with some caution. Their main conclusions were that subjects with psychological distress are prone to temporomandibular disorders, or psychological distress is a manifestation of existing chronic pain conditions.

3. Somatisation: Somatisation is defined as "a tendency to experience and communicate somatic distress in response to psychosocial stress and to seek medical help for it" (Lipowski, 1988). Somatoform disorders are conditions in which the patient reports somatic complaints, yet no physical evidence of organic disease is present (American Psychiatric Association, 1994). Somatisation has been correlated with frequent use of health services (Jyväsjärvi, 2001) and about 20 % of frequent attendees have been classified as chronically somatising patients (Karlsson *et al.,* 1997). Somatising patients have a negative perception of their health (Katon *et al.,* 1991) and often have psychosocial difficulties (Mechanic, 1992), substantial distress (Noyes *et al.,* 1995), and show enhanced sensitivity to normal physical sensations (Blackwell and DeMorgan, 1996). In addition, they are characterised by abnormal illness behaviour (Noyes *et al.,* 1995). TMD patients have been found to have increased somatisation scores (Wilson *et al.,* 1991; McGregor *et al.,* 1996). It has been suggested that patients with masticatory muscle pain may be more prone to report symptoms as compared with normal controls (Wilson *et al.,* 1991) and are likely to be more sensitive to painful stimuli (Reid *et al.,* 1994), although these findings were disputed by Carlson *et al.* (1998).

4. Depression: Depression is a disorder that can be defined as a collection of symptoms such as depressed mood, loss of interest or pleasure, weight loss or gain, insomnia or hypersomnia, feelings of worthlessness, and a diminished ability to concentrate (American Psychiatric Association, 1994). Epidemiological studies have shown that depression is the most common mental disorder, with the prevalence of a clinically significant depressive disorder around 4% among males and 8% among females. It affects at least 20% of women and 10% of men during their lifetimes (Kessler *et al.,* 1994). There is

evidence of a greater prevalence of depressive symptoms in subjects with chronic pain than in controls (VonKorff *et al.,* 1988; Dworkin *et al.,* 1990). Numerous studies have also shown a high rate of depression in patients with facial pain and TMD (Gallagher *et al.,* 1991; Korszun *et al.,* 1996; Carlson *et al.,* 1998; Madland *et al.,* 2000), whilst a number of population-based studies have implied a connection between depression and TMD (VonKorff *et al.,* 1988; Dworkin *et al.,* 1990; Vimpari *et al.,* 1995). In contrast, McGregor *et al.* (1996) found no difference in depression between orofacial pain patients and normal controls.

7. Malocclusion and Muscle parafunction

Another aetiological theory which has been proposed for the development of TMD is malocclusion. This is an extremely controversial theory and despite its popularity, the causal relationship between malocclusion and TMJ disorders has not been scientifically proven. The role of malocclusions in TMD and the evidence for and against this theory will be discussed in greater detail later in this literature review.

8. Dental Treatment

It has been suggested that certain clinical procedures may cause TMD symptoms and it is not uncommon for patients to experience trismus after oral surgical procedures or extractions (Dhanrajani and Joneidel, 2002). To avoid causing or exacerbating an existing problem, dentists should not apply too much pressure on the jaw, push the mandible posteriorly, or leave restorations "high". Lengthy dental work requiring the patient's mouth to be open for extended periods of time can aggravate a TMD problem. Some patients experience their first symptoms after root canal treatment, whilst other patients may suffer muscle spasms after extraction of third molars.

General Summary:

The lack of real explanation for temporomandibular joint disorders has set the stage for current aetiological theories. Many professionals utilise treatments which are based on what they perceive to be the cause, as well as their belief in certain treatments. Thus a

proportion of patients present with iatrogenic disturbance because of inappropriate surgery, unnecessary occlusal equilibration, unwarranted restorations, orthodontics and incorrect splint therapy (Perry, 1991). It is imperative that aetiological studies from the molecular, biomechanical, neuro-endocrine, physiological, and clinical perspectives be carried out. Discovering the causes of TMJ disorders will aid in the development of safe and effective treatments. Furthermore, if the causes of TMD are understood and risk factors can be identified perhaps TMD can be prevented in some patients.

1.5 TMD Epidemiology

1. Prevalence

The reported prevalence of TMD differs between studies, probably because of variations in methodology and definitions. Proffit (2000) suggested that the true incidence of TMD ranged between 5 and 35% depending on the signs and symptoms recorded. In a group of 7337 Japanese children, Motegi *et al.* (1992) reported that 12.2% of six to eighteen year olds experienced TMD. This increased with age and was slightly higher in girls (13%) than in boys (11.1%), but this difference was not statistically significant. Joint sound as the only symptom was more common in younger subjects. TMD symptoms seemed more complicated with age, when pain and abnormal jaw movement were often combined with joint sounds. Joint sounds were the most common symptom (89.3 %), followed by a combination of sounds and pain (2.2%).

Nilsson *et al.* (2005) studied the prevalence of TMJ pain and subsequent dental treatment in Swedish adolescents. The participants included all patients between the ages of twelve and nineteen who attended public dental clinics during 2000. They found that, of the 28,899 youths who participated, 4.2% reported TMD pain. The prevalence increased with age and a significant difference was seen between boys (2.7 %) and girls (6.0%). As such they concluded that the prevalence of self-reported TMD pain was relatively low, increased with age, and was higher among girls than boys. In contrast, Williamson (1977) concluded that 35 % of six to sixteen year olds in a sample of 304 adolescents experienced TMD.

Gray *et al.* (1994a) made a distinction between signs and symptoms when researching TMD. They defined a sign as a clinical finding recorded by the examiner of which the patient may have been unaware and a symptom was classed as a finding of which the patient was aware, e.g. pain. They reported that 50-70% of populations surveyed have signs of TMD at some stage. An estimated 20-25% of the population have symptoms of TMD, with approximately 3-4% of the population (approximately one fifth of those with symptoms) seeking treatment.

LeResche (1997a) carried out a review of the literature on the epidemiology of TMD. She found that, despite methodological and population differences, many consistencies were apparent in the epidemiologic literature. Pain in the TMJ region appears to be relatively common, occurring in approximately 10% of the population over the age of eighteen. It is also primarily a condition of young and middle-aged adults, rather than of children or the elderly, and is approximately twice as common in females as in males. Most signs and symptoms (e.g. joint sounds and pain in the joint) also appeared to be more prevalent in females than in males, although age patterns for these signs and symptoms were not as clear as for TMJ pain.

Gender

Both males and females suffer from TMJ diseases and disorders. Although earlier population studies found the prevalence of symptoms and signs of TMD to be similar in males and females (Helkimo, 1974; 1976), later studies have reported a higher prevalence among females (Dworkin *et al.,* 1990; Magnusson *et al.,* 1993; Magnusson *et al.,* 2000). Several studies with representative general population cohorts indicate that females experience more TMD-related pain than males, usually at a ratio in the region of two to one (Dworkin *et al.,* 1990; Lipton *et al.,* 1993; LeResche 1997a).

The predominance of females with TMD is even higher in surveys of people seeking treatment for TMD with a ratio in the region of 4:1 to 5:1 (Dworkin *et al.,* 1990; Bush *et al.* 1993; Dworkin and LeResche 1993; McNeill, 1997). Furthermore, it has been shown that females seek treatment for their TMD problems two to three times more frequently than males (Agerberg and Inkapööl 1990; Kuttila *et al.,* 1998).

Although figures from patient studies have reported the female to male ratio as ranging between 4:1 and 5:1, epidemiological studies show that clinical signs and symptoms are present in both genders in equal proportions. As such the commonly held belief that females suffer from TMD more than males may be a fallacy. It does however appear that females outnumber males in seeking treatment and there is wide speculation as to why this is so. Some studies have said that women utilise the health care system more than men, others state that women have a lower tolerance to pain or are more willing to admit to pain than men (Gray *et al.*, 1994a).

Recent research has focused attention on the relationship between sex hormones and pain. A study conducted by LeResche *et al.* (1997b) demonstrated that the odds of suffering from TMD were approximately 30% higher among those receiving oestrogens compared with those not exposed to these hormones and women on hormone replacement therapy were 77 % more likely to seek treatment for jaw pain than those not undergoing such treatment. Also, women on oral contraceptive therapy were 20% more likely to seek treatment. Oestrogen administration may increase the incidence of chronic pain (Dao and LeResche, 2000) and this can be explained by actions brought about at a central and peripheral level. For example oestrogen has be shown to increase nerve growth factor, activate MAP-kinase and excite neurons in the cerebral cortex (McEwen and Alves, 1999; Toran-Allerand *et al.*, 1999; Lanlua *et al.*, 2001) all of which can increase nociception and pain.

In addition it has been found that the pain perception in women varies across the menstrual cycle, with temporomandibular pain at its highest in the pre-menstrual period and during menses (LeResche *et al.*, 2003). Evidence is emerging in support of a biological explanation for why there may be more women than men suffering from TMD pain but this is still in the relatively early stages of research.

Age

Gray *et al*. (1994b) reported the age range for those suffering from TMD as 15 to 30 year olds for dysfunctional syndromes and forty years and upwards for degenerative joint diseases, with any age potentially suffering from internal derangement.

Magnusson *et al.* (1985) undertook a longitudinal study of clinical signs and subjective symptoms of mandibular dysfunction in 119 children (initially either 7 or 11 years at the first assessment) with a 4 year interval between the first and second assessments. At the second assessment the results showed that 66% of subjects in both age groups had clinical signs, while 62 % of the 11 year olds and 66 % of the 15 year olds reported subjective symptoms. In most cases the signs were mild, but 11% of the 11 year olds and 17% of the 15 year olds had moderate or, in a few cases severe, signs of dysfunction. Most of the children with subjective symptoms had occasional symptoms but 3% in the younger and 11% in the older age group had frequent symptoms. When comparisons were made with the findings four years earlier at the first assessment, it was noted that the subjective symptoms were greater in frequency in the younger children and the clinical signs had increased in both groups.

Salonen *et al.* (1990) studied the prevalence of signs and symptoms of dysfunction in the masticatory system as a part of an epidemiological survey on oral health. Nine hundred and twenty Swedish subjects were examined and the questions and clinical examination parameters were in accordance with those suggested by Helkimo in 1974. They found that reported symptoms decreased with age, whilst clinical signs increased.

Many other studies have shown that the highest prevalence of TMD occurs amongst adults under 45 years of age, with lower levels at earlier ages (Locker and Slade, 1988; Dworkin, 1990; Agerberg and Inkapööl, 1990; LeResche, 1997a). Therefore, the adult population is of special interest as far as TMD is concerned and studies regarding the prevalence of TMD and related factors should perhaps be directed at this group.

1.6 Measuring TMD and Classification

Research and epidemiological studies need to be defined on the basis of clinical signs, or on the basis of a combination of clinical signs and symptoms. Over the years, many classification schemes for TMD have been proposed (Okeson, 1996).

Helkimo Indices

Helkimo Indices were first developed for epidemiological purposes in the diagnosis of TMD (Helkimo 1974). They have been widely used in studies measuring TMD and are still frequently used today (Carlsson & LeResche, 1995).

Helkimo Anamnestic Index (Ai) comprises three classifications which are: symptomless (Ai0), mild symptoms (AiI), and severe symptoms (AiII).

The Clinical Dysfunction Index (Di) is based on the evaluation of five clinical signs: impaired range of movement, impaired function of the TMJ, muscle pain, TMJ pain, and pain on movement of the mandible. The Di index comprises four classifications which are: no signs (Di0), mild dysfunction (DiI), moderate dysfunction (DiII), and severe dysfunction (DiIII).

Thus, these indices are used by looking at the presenting signs and symptoms of patients suffering from TMD and allocating a severity grade if a certain set of clinical signs and symptoms are present.

Helkimo Indices are not without flaws (Clark *et al.*, 1993). The Indices do not contain several key operational definitions, such as muscle and joint palpation pressures, nor does it endorse a method for scoring joint sound severity. Other problems associated with the Indices relate to the validity and reproducibility (van der Weele and Dibbets, 1987). However, Helkimo Indices were developed specifically for epidemiological surveys and were never intended to be used by clinicians as a TMD classification system for individual patient diagnosis and treatment and this was clearly stated in his original work (Clark *et al.*, 1993).

Craniomandibular Index (CMI) (Fricton and Schiffman, 1986)

In recognition of the shortcomings of the Helkimo Indices, the Craniomandibular Index (CMI) was developed for use in epidemiological and clinical outcome studies to provide a standardised measure of severity of limitations of mandibular movement, TMJ sounds, and muscle and joint tenderness. The instrument was designed to have clearly defined objective criteria, simple clinical methods, and ease in scoring. It is divided into the Dysfunction Index and the Palpation Index and the reliability of both indices was evaluated in the original study (Fricton and Schiffman, 1986). The CMI requires a

score to be calculated by adding the score of the Dysfunction Index (DI), which examines TMJ functional problems, to the score of the Palpation Index (PI), which looks at tenderness on palpation of the TMJ capsule and surrounding muscles. This resulting score does not "intuitively" describe the patient however (Clark *et al.*, 1993).

Fricton and Schiffman (1987) evaluated the validity of the CMI and found that it appeared to be valid for use in clinical studies, but that users need to be aware of the methodological guidelines to ensure accuracy and reproducibility of results. The subjective nature of some items demands that the same rater, who is unaware of the management status of the patient, perform both evaluations. If multiple raters are used, it is recommended that the raters discuss all items and compare scoring of "demonstration subjects" before the study and use a pressure algometer for muscle palpation. These strict standardisation procedures are cumbersome in nature, hence the CMI has not proved to be popular in clinical patient care (Clark *et al.*, 1993).

American Academy of Orofacial Pain (AAOP) Classification

In 1990, the American Academy of Orofacial Pain (AAOP) established the first well-defined diagnostic classification for TMD, and this was subsequently revised in 1993 (McNeill, 1993). The AAOP classification divides TMD broadly into 2 categories:

1. Muscle-related TMD (myogenous TMD): This is sometimes called TMD secondary to myofacial pain and dysfunction (MPD). In its pure form, it lacks apparent destructive changes of the TMJ on radiographic examination and can be caused by multiple aetiological factors such as bruxism and jaw clenching in a stressed and anxious person. The myogenous classification is often further subdivided into muscular hyperarousal due to stress and muscular abnormality associated with parafunctional oral habits (e.g. bruxism).

2. Joint-related (arthrogenous) TMD: This is TMD secondary to true articular disease. Arthrogenous TMD can be further specified as disc displacement disorder, chronic recurrent dislocations, degenerative joint disorders, systemic arthritic conditions, ankylosis, infections, and neoplasia. The arthrogenous category is subdivided on the basis of specific structural abnormalities (e.g. internal derangement of the TMJ or degenerative disease).

The two types of TMD can be present at the same time, making diagnosis and treatment more challenging. In addition these classifications are not always clear, and there can be a considerable overlap or progression from one category to the other (Kuttila *et al.*, 1998).

The Research Diagnostic Criteria (RDC) (Dworkin and LeResche, 1992).

Problems regarding classification and measurement of TMD were demonstrated by Dworkin *et al.* (1990). Four experienced dental hygienists, who were field examiners for a large epidemiological study of TMD, and three experienced clinical TMD specialists, who were co-investigators in the same study, followed carefully detailed specifications and criteria for examination of TMD patients and pain-free controls. Excellent reliability was found for the vertical range of motion measures and for summary indices measuring the overall presence of a clinical sign that could arise from several sources (for example, summary indices of muscle palpation pain). However, many clinical signs which are important in the differential diagnosis of subtypes of TMD were not measured with high reliability. In particular, assessment of pain in response to muscle palpation and identification of specific TMJ sounds only had modest, sometimes marginal, reliability. These modest reliabilities could arise from examiner error because clinical signs themselves are unreliable and change spontaneously over time, thus making it difficult to find the same sign on successive examinations. They also found that, without calibration, experienced clinicians showed low reliability with other clinicians. This emphasised the importance of establishing reliable clinical standards for the examination and diagnostic classification of TMD.

In an attempt to address the shortcomings of previous indices, the Research Diagnostic Criteria for Temporomandibular Disorders (RDC/TMD) were developed and made available to researchers and clinicians for scientific evaluation (Dworkin and LeResche, 1992). The RDC/TMD was developed by a team of international clinical researchers who met to develop, an empirically-based and operationalised system for diagnosing and classifying TMD, based on the best available scientific evidence.

With the RDC/TMD approach subjects are assigned specific TMD diagnoses that recognise not only the physical conditions (Axis I), including muscle disorders, disc displacements and other types of joint conditions, but also the psychosocial issues (Axis

II) that contribute to the suffering, pain behaviour, and disability associated with the patient's pain experience. The RDC/TMD uses a dual axis system:

- Axis I - a physical diagnosis based on pathophysiology; combined with
- Axis II - an assessment of TMD-pain and related parafunctional behaviours, psychological distress and psychosocial dysfunction

The RDC/TMD uses clinical examination and history-gathering methods, with scientifically demonstrated reliability, for gathering clinical signs of TMD. It also includes assessment of behavioural, psychological and psychosocial factors. The scheme is non hierarchical, so subjects can receive more than one diagnosis. The RDC/TMD also provides standardised examination criteria of known reliability, so that findings from different studies using the RDC/TMD can be compared directly.

This dual-axis classification approach has recently been incorporated in a diagnostic scheme not only for TMD but for all orofacial pain disorders (Okeson, 1996). The RDC have been shown to be reliable for diagnosing TMD in U.S. and Swedish populations (Wahlund *et al.,* 1998). The classification was approved by the European Academy of Craniomandibular Disorders (EACD) in 2002 and it is now widely used in both research and clinical studies.

In a recent study, however, the RDC was shown to provide insufficient reliability for the determination of arthrogenous TMD such as the presence of TMJ internal derangement and osteoarthrosis (Emshoff and Rudisch, 2001). Emshoff and Rudisch (2001) looked at the validity of the RDC/TMD when comparing clinical versus MRI diagnosis of TMJ internal derangement and osteoarthrosis. One clinician used the RDC/TMD to classify 163 consecutive patients with TMD on physical diagnosis and the radiologist then performed MRIs. The diagnostic agreement was determined for the absence of internal derangement, disc displacement with reduction, disc displacement without reduction, and osteoarthrosis. Use of the Kappa statistic test indicated a poor diagnostic agreement between the clinician and the radiologist. This suggests that in patients who present with signs of TMJ derangement, MRI imaging should also be carried out if at all possible for a comprehensive diagnosis as this is the ideal imaging technique for identifying disc derangements.

1.7 TMD and Occlusion

Orthodontic treatment aims to create an ideal occlusion (Andrews, 1972). This is based mainly on the description of arch form, tooth position and tooth contacts in the intercuspal position. As such, considerable emphasis is placed on this static occlusal relationship (Clark and Evans, 1998). It has been assumed that an ideal static occlusion is synonymous with an ideal functional occlusion (Andrews, 1976; Roth, 1976), however this may not necessarily be the case. Thus it is important to evaluate the features that are thought to be harmonious with an ideal functional occlusion and those which may be detrimental.

Centric Relation-Centric Occlusion (CR-CO)

Centric relation (CR) is the occlusal position when the first tooth contact occurs on the mandibular path of closure, with the condyles in the retruded axis position. Centric occlusion (CO) is the occlusal position with the teeth in maximum intercuspation (Clark and Evans, 2001). It is generally accepted that in most individuals there is a short slide between CR and CO, in an antero-posterior direction. Studies have reported this discrepancy to be between 0.5 and 1.5mm (Agergberg and Sandstrom, 1988; Utt *et al.*, 1995).

Numerous authors have suggested that for an ideal treatment goal to be achieved, CR should be coincident with CO (Williams, 1971; Roth, 1981; Williamson, 1981) and some cross sectional studies have reported a relationship between CR-CO discrepancies and TMD (Solberg *et al.,* 1979; Ingervall *et al.,* 1980; Pullinger *et al.,* 1988).

In contrast, Clark and Evans (2001) reported that the evidence for this was inconclusive, few of the mentioned studies used control groups, and the signs and symptoms used to asses TMD were inconsistent and diverse. If epidemiological studies fail to find this occlusal relationship in the natural dentition, the question arises why should this be the goal following orthodontic treatment?

A sensible interpretation of the current evidence would suggest that a CO that does not exactly coincide with the CR, but is within approximately 1mm, can be considered normal. Hence, evidence suggesting that there is a direct correlation between occlusal

studies with TMD is weak. Whilst every effort should be made to achieve this goal, treatment need not be unduly lengthened in order to do so.

Posterior relationships during lateral excursions

Posterior lateral excursions can be either group function or canine guided. Group function occurs when the buccal cusps of the posterior teeth on the working side are in contact during the entire lateral movement and there is no tooth contact on the non-working side. Canine guidance is said to occur during lateral excursion, when contact occurs between the upper and lower canine and the first premolar on the working side only. The theory of this canine protected occlusion is attributed to Nagao (1919). It is based on the concept that the canine is the most suitable tooth to guide mandibular excursions for the following reasons:

1. The canine has a good crown: root ratio, capable of tolerating high occlusal load.
2. The canine root has a greater surface area than adjacent teeth, providing greater proprioception.
3. The shape of the palatal surface of the canine is concave and is suitable for guiding lateral movements (Clark and Evans, 2001).

Various epidemiological studies have assessed the types of lateral excursions occurring in the untreated natural dentition. Weinberg (1964) found that 81 % of his sample had group function, whilst 5 % had canine guidance. Scaife and Holt (1969) examined 1200 individuals and found that the majority had either unilateral or bilateral canine guidance. As no single type of occlusal pattern has been shown to occur in natural dentitions, studies have attempted to clarify which occlusal scheme is preferable.

Roth (1981) advocated canine guidance, referring to this as the mutually protected occlusion. Williamson and Lundquist (1983) examined electromyographic activity of the temporalis and masseter muscles during lateral excursion in individuals with canine guidance and group function and found that considerably less muscle activity was observed in those individuals with canine guidance. Belser and Hannam (1985) conducted a similar study and concluded that canine protected occlusions did not

significantly alter muscle activity during mastication, but significantly reduced muscle activity during clenching.

Taskaya-Yilmaz *et al.* (2004) investigated the relationship between condyle and disc positions and occlusal contacts on lateral excursions of the mandible in patients with TMD. A total of 122 TMJs in 61 patients with TMD were evaluated using MRI and clinical occlusal analyses. The researchers found that the non-working side contacts occurred significantly more often in patients who had anterior disc displacement affecting their TMJ. However, no significant correlation was found between the severity of the disc displacement and the non-working side contacts in either canine guidance or group function. As such it was concluded that non-working-side contacts had some effect on disc position in TMD, but the presence of these contacts in both canine guidance and group function did not correlate statistically with anterior disc displacement.

A more recent case-control study by Selaimen *et al.* (2007) examined occlusal factors in the aetiology of TMD. The study controlled for socio-demographic factors (employment, age, cigarette and alcohol consumption) and the results confirmed that some occlusal factors (overbite, overjet, number of anterior and posterior teeth and protrusive movements) including the absence of canine guidance, may be considered risk factors for TMD.

It is generally agreed that both canine guidance and group function occlusion are acceptable (McAdam 1976; Belser and Hannam, 1985). The evidence of one occlusal scheme being preferable to the other is scarce; however it is of note that a canine guided occlusion is less likely to be associated with non-working side occlusal interferences (Clark and Evans, 2001).

Occlusal Interferences

Occlusal interferences are defined as "occlusal contact relationships that interfere in a meaningful way with function or parafunction" (Ash and Ramfjord, 1998). Some of these features are thought to give rise to TMD signs and symptoms. These include:

1. Occlusal contacts on the non-working side (Mohlin and Thilander, 1984)

2. Unilateral contacts in the CR (Seligman and Pullinger, 1991)
3. Slides from CR to CO which are greater than 1mm (Pullinger *et al.*, 1988)
4. Asymmetric slide between CR and CO (Pullinger *et al.*,1988)

Roth (1973) examined 9 patients with symptoms of TMD aged 15 to 24 years. The patients were seen between 6 months and 7 years after they had completed orthodontic treatment. Results showed that 7 of the patients experienced variable TMD symptoms as well as balancing interferences and two of the patients did not have any symptoms. Patients who had symptoms underwent occlusal equilibrium using splints and this relieved the symptoms due to the occlusal changes that were introduced. It was concluded that patients should be treated to a mutually protected occlusion, devoid of interferences as there appeared to be a close correlation between occlusal disharmony and symptoms of TMD. This study however had a small sample size and weak study design, so the conclusions should be treated with some caution.

A double blind study was carried out by Magnusson and Enbom (1984) where non-working side interferences were artificially induced in patients. A group that had no intervention acted as a control group and both groups of participants were re-examined after 2 weeks. Ten of the twelve individuals in the experimental group reported one or more subjective symptoms during the 2 weeks, whereas seven exhibited clinical signs of dysfunction. The most common symptom was headache and the most common clinical sign was muscle tenderness on palpation. In the control group, three out of the twelve individuals reported subjective symptoms and three had clinical signs of dysfunction. Thus the researchers found the signs and symptoms of TMD were twice as high in the patient group as in the controls. One week after elimination of the interferences, signs and symptoms had disappeared in all but two of the experimental group. In these two subjects it took 6 weeks for pre-experimental conditions to be restored. The authors concluded that there is no simple relationship between interferences and signs and symptoms of dysfunction and how the individual reacts to local factors is variable. In some individuals, addition of balancing-side interferences is sufficient to create dysfunction. The findings thus underline the importance of local factors in the aetiology of TMD but also show that a relationship is not obligatory.

Liu and Tsai (1998) investigated the role of the functional occlusion on temporomandibular joint disorders in untreated orthodontic patients. A total of 508

orthodontic patients were enrolled and the functional occlusion scheme and clinical signs of TMD were assessed before treatment. TMD were assessed existed in 44.2% of patients with retruded position interferences and in 38.1 % of those without such interferences. The frequency of TMD in patients with protrusive interferences was greater than those without (32.2 % *vs* 18.4 %) and patients with balancing interferences also had a significantly higher frequency of TMD than those without (49.2 % *vs* 23.9 %). Thus it was concluded that patients with balancing or protrusive interferences have an increased risk for developing TMD.

More recently Barker (2004) examined a randomly selected group of 60 orthodontic patients with occlusal interferences for signs and symptoms of TMD. They used a mandibular orthotic to balance the occlusions at centric relation. When the occlusions of symptomatic patients were balanced in centric relation, there was a significant reduction or elimination of the TMD complaints, suggesting a relationship between balancing the occlusion in centric relation and optimum management of TMD.

TMD pain resulting from occlusal interferences may also be influenced by changes in oestrogen levels. Oestrogen administration can increase the incidence of chronic pain conditions and, as such, may precipitate or exaggerate any pain if occlusal interferences exist (Dao and LeResche, 2000). Thus an individual's oestrogen levels could also explain the variability in the findings.

There are however many limitations to these studies. There is a lack of control groups in some and a clear definition of TMD is often not stated, in addition the features that comprise TMD are often subject to disagreement. There are also inconsistencies in diagnosing occlusal interferences (Clark and Evans, 2001). Occlusal interferences are widespread in the population and there are more people with non ideal functional occlusions than those with signs or symptom of TMD (Agerberg and Sandstrom, 1988). In addition non-working side contacts are common, occurring in 91% of patients (Sadowsky and BeGole, 1980). In fact Rinchuse and Sassouni (1983) found that patients with Andrews' 6 Keys (considered by many to be the ideal static occlusion) had the highest prevalence of non working side contacts during function.

The current evidence suggests that although occlusal interferences may play a role in TMD, the aetiology is multifactorial in nature. McNamara *et al.* (1995) estimated that

the contribution of occlusal factors to TMD is approximately 10-20%. This should be taken in an association context and does not imply a cause and effect relationship. Thus, although a stable occlusion is a reasonable orthodontic treatment goal, not achieving this does not necessarily result in the development of TMD signs and symptoms.

1.8 TMD and Malocclusion

Malocclusion is also a potential aetiological factor for TMD. Proponents of this theory believe that malocclusion may prevent "normal" functioning of the masticatory system and put extra stress on the muscles, causing them to go into spasm, which subsequently causes pain and more spasm. Electromyographic studies show that TMD patients often have abnormal patterns of muscle activity (Moss, 1975), although this may be the result of patients attempting to avoid premature contacts. Others believe that although malocclusion may not cause TMD, it can exacerbate an existing problem. There is conflicting evidence in the literature with regards to this topic.

Williamson (1977) undertook a survey of 304 adolescent patients who were being screened for orthodontic treatment at the Ohio State University Orthodontic Department. It was found that 107 of the subjects (35.2%) had TMJ clicking and pain affecting the pterygoid muscles. In addition, he found that 72% of the symptomatic patients either had a deep bite or an open bite. He recommended that orthodontists should attempt to identify patients with risk factors for TMD before embarking on any orthodontic treatment as it may contribute to the dysfunctional problem. These findings were echoed by Mohlin and Thilander (1984) who found a link between certain occlusal features and TMD. They undertook a study comparing 58 patients with temporomandibular joint dysfunction with 661 non-symptomatic individuals (389 males and 272 females). Their results showed that there was a positive correlation between Class III malocclusion, cross-bites and temporomandibular joint dysfunction.

A study by Mohlin *et al.* (1980) investigated at a group of 389 Swedish males between the ages of 21 and 54 years. The relationship between the type of malocclusion, occlusal interferences and temporomandibular joint symptoms was studied. They found that certain malocclusions, particularly Class III and anterior open bites, were strongly

linked to symptoms of temporomandibular joint dysfunction. There was no correlation between crossbites and TMD however and, despite these findings, it was emphasised that malocclusion plays only a small part in the multifactorial aetiology of TMD.

Egermark *et al.* (2003) noted that, over a long period of time, subjects with malocclusion tended to report more TMD symptoms and to show a higher dysfunction index, compared with subjects with no malocclusion. They included 402 subjects in their study, of which 85% were subsequently traced 20 years later. There were no statistically significant differences in the prevalence of TMD signs and symptoms between subjects with or without previous experience of orthodontic treatment. This 20-year follow-up also supported the opinion that no single occlusal factor is of major importance in the development of TMD, but a lateral forced bite (the mandible is forced laterally into a non-optimal intercuspal position due to premature contacts) between retruded contact position and intercuspal position, as well as unilateral crossbite, may be potential risk factors.

Thilander *et al.* (2002) also found a relationship between malocclusion and TMD. They examined a sample of 4724 children between the ages of 5 and 17 years. The children were classified by chronological age and also by stage of dental development (deciduous, early mixed, late mixed and permanent dentition). The parameters studied included functional occlusion, anterior and lateral sliding occlusal interferences, dental wear, mandibular mobility, maximal opening, deflection, and TMJ and muscular pain recorded by palpation. Headache was the only symptom of TMD reported by the children. They found the prevalence of TMD increased during the developmental stages and girls were affected more frequently than boys. The significant associations found between TMD and the occlusal features included posterior crossbite, anterior open bite, a Class III malocclusion, and an increased overjet.

In contrast to the previous studies, other large cross sectional studies have found a weak correlation between malocclusion and TMD, when assessing anterior open bites, deep bites and both decreased and increased overjets (Riolo *et al.*, 1987; Motegi *et al.*, 1992). Gesch (2004) also found few associations between malocclusion, functional occlusion and TMD, and these associations were not uniform. No particular morphological or functional occlusal factors became apparent.

A survey by Pullinger and Seligman (1991) studied occlusal factors, including overbite and overjet, to examine if there was a correlation between these features and TMD. Patients with myalgia and osteoarthritis were compared with a control group and results showed that patients with osteoarthritis exhibited features including reduced overbite and open bite when compared with the control group. This was however attributed to the joint itself. They concluded that a deep overbite or increased overjet was not in itself diagnostic of an underlying TMD condition and no strong relationship existed between TMD and these occlusal features.

1.9 TMD and Orthodontics

Does orthodontic treatment cause TMD?

There has been much controversy over the relationship between orthodontic treatment and TMJ disorders and orthodontists remain divided over the concept. Evidence supporting the claim that orthodontics causes TMD, particularly the earlier studies, were usually based on anecdotal evidence, weak study designs and small sample sizes. Others have claimed that subjects with a history of orthodontic treatment do not run a higher risk of developing TMD later in life, compared with subjects with no such experience (Egermark, 2003).

Ricketts (1966) was one of the first researchers to publicly state that orthodontic treatment could be a cause of TMD. As the occlusion is changed during orthodontic treatment, symptoms of joint derangement may be noticed and he attributed this to the various forces applied during therapy that may predispose patients to TMJ problems. His suggestions, however, do not appear to be based on scientific evidence.

In contrast, Larsson and Ronnerman (1981) looked at TMD symptoms in orthodontically treated patients ten years after the completion of treatment. They followed 23 patients and assessed them for signs and symptoms of TMD using the Helkimo Indices and found that there was no relationship between orthodontic treatment and TMD. The results of this study however must be interpreted with some caution due to the small sample size.

Many other studies with larger sample sizes have failed to find a relationship between TMD and orthodontic treatment. Hirata *et al.* (1992) compared 102 orthodontically treated patients with 41 subjects from a non-orthodontically treated control group. They evaluated the effects of orthodontic treatment on signs and symptoms of TMD, as well as the prevalence and incidence of TMD. Subjects answered a questionnaire covering medical health, history of trauma and their personal experience of TMD. In addition, a clinical examination was undertaken by a trained examiner to determine missing teeth, range of mandibular motion, overjet and overbite, and joint sounds. Data was collected at baseline (pre-treatment) and at 12 to 24 month intervals for the treatment group and twice at the same time intervals for the control group. The results indicated no significant differences between the two groups, suggesting that patients undergoing orthodontic treatment were at no greater risk of developing TMD.

Mohlin *et al.* (2004) examined a total of 1018 subjects at the age of 11 years. Of these, 791 were re-examined at 15 years, 456 at 19 years, and 337 at 30 years. Anamnestic and clinical recordings of TMD were made. Other information recorded included Peer Assessment Rating (PAR) scores, previous history of orthodontic treatment and muscular endurance (muscular endurance was calculated using bite force, and was defined as the time taken by the individual to bite with 50% of the maximal bite force until pain or obvious discomfort arose). The subjects also completed four psychological measures: The Life Events Inventory, General Health Questionnaire (GHQ-30), Eysenck Personality Inventory-Neuroticism (EPIN) and Rosenberg Self-Esteem (RSE) Scale. The malocclusion prevalence, occlusal contacts, psychological factors, and muscular endurance in subjects with no recorded signs and symptoms of TMD were compared with those with the most severe dysfunction at 19 years of age. Future development of TMD up to 30 years of age was also recorded. PAR scores were significantly higher in the subjects with the most severe dysfunction. With the exception of crowding of teeth, no other significant differences were found between the groups with regard to malocclusion tooth contact pattern, orthodontic treatment, or extractions. A greater proportion of subjects with low muscle endurance were found in the TMD group. Significant associations were also found between TMD and general health and psychological well-being, as well as the personality dimension of neuroticism and self-esteem. During the period from 19 to 30 years, the prevalence of muscular signs and symptoms reduced, whereas clicking showed a slight increase. Locking of the joint

showed a decrease from 19 to 30 years and a quarter of the TMD subjects showed complete recovery. Thus, it appears that orthodontic treatment is neither a major preventive factor, nor a significant cause, of TMD.

A recent study by Egermark *et al.* (2005) also supported the opinion that orthodontic treatment in childhood does not result in an increased risk of developing signs or symptoms of TMD in later life. This was based on a prospective long term study of TMD signs and symptoms in patients who received orthodontic treatment in childhood. The original sample consisted of 50 orthodontic patients (27 girls and 23 boys) different malocclusions. The prevalence of signs and symptoms of TMD was low both before and after the active phase of orthodontic treatment, as well as at long-term follow-up after 15 to 18 years. The authors found that patients developed severe TMD (requiring treatment) at an incidence of 1% per year and this low figure suggests that there is no elevated risk for developing TMD after orthodontic treatment.

Other studies have investigated the effects of orthodontic treatment on the condylar position and TMD. Roth (1981) favoured the rearmost, midmost and upper most position for condyles to avoid occlusal interferences but this recommendation appears to be based on his own personal opinions rather than any scientific evidence. This condylar position favoured by Roth and functional orthodontists could not be verified in a study undertaken by Lueck and Johnston, (1992).

Ártun *et al.* (1992) studied the relationship between orthodontic treatment, condylar position and internal derangement in the TMJ. The study included 29 female patients with Class II division I malocclusions who were treated with extractions of maxillary premolars and 34 patients with Class I malocclusions treated on a non-extraction basis. The condylar position was measured using tomography and a clinical examination was also undertaken. The results showed that there were no signs of degenerative changes in the TMJ. The condylar position was more posterior in patients who had undergone extractions and in the non extraction group there appeared to be an anterior displacement. Patients who had clicking sounds, however, had significant posterior displacement. The study concluded that there was no correlation between TMJ pain and condylar position.

A longitudinal study by Sadowsky *et al.* (1991) investigated orthodontic treatment and TMJ sounds in order to examine changes in the occurrence and resolution of these sounds in patients before and after orthodontic treatment with full upper and lower fixed appliances. One hundred and sixty patients were examined before and after orthodontic treatment. When joint sounds were reported or detected clinically, these patients underwent an audiovisual examination to more precisely and objectively record the occurrence and timing of the sound during mandibular opening and closing. Results showed no statistically significant differences in the occurrence of joint sounds between patients treated with extraction and non-extraction strategies. Overall, fewer patients had joint sounds at the end of the active stage of orthodontic treatment than before and fewer patients demonstrated reciprocal clicking after treatment than before. Therefore it appeared that orthodontic treatment did not pose an increased risk for developing TMJ sounds, irrespective of whether extraction or non-extraction treatment strategies were used. A progression of signs or symptoms to more serious problems was not apparent over the time period studied.

Henrikson and Nilner (2003) carried out a prospective, longitudinal study of signs and symptoms of TMD and occlusal changes in girls with Class II malocclusions receiving fixed appliance treatment. The subjects were compared with untreated Class II and Class I (normal occlusion) subjects. Sixty five girls with Class II malocclusions received orthodontic treatment, 58 girls with Class II malocclusions received no treatment, and 60 Class I (normal occlusion) subjects acted as a control group. The girls were examined for signs and symptoms of TMD and then re-examined 2 years later. Additional records were taken in the orthodontic group during active treatment and 1 year after treatment. It was found that all three groups included subjects with TMD and there was individual fluctuation during the study. In the orthodontic group, the prevalence of muscular pain associated with TMD was significantly less post-treatment. In contrast, TMJ clicking increased in all three groups over the 2 years, but was less common in the control group. The control group also had a lower overall prevalence of TMD than the treated and untreated Class II groups at both assessments. Functional occlusal interferences decreased in the orthodontic group, but remained the same in the other groups over the 2 years. Thus they concluded from this study that:

1. Orthodontic treatment, either with or without extractions, did not increase the prevalence or worsen pre-treatment signs and symptoms of TMD.

2. Individually, TMD fluctuated over time with no predictable pattern. However, on a group basis, the type of occlusion may play a role as a contributing factor for the development of TMD.
3. The large fluctuations in signs and symptoms of TMD over time lead the authors to suggest a conservative treatment approach when stomatognathic treatment in children and adolescents is considered.

There is a further consideration in this field of study and that is the evidence that the incidence of TMD increases with age and on-going orthodontic treatment may coincide with this increase (Pilley *et al.*, 1997). This is why it is important to include a control group in studies of this kind.

Does Orthodontic treatment improve TMD?

A number of authors have suggested that TMD can be improved as a result of orthodontic treatment. Egermark and Ronnermann (1995) looked at TMD in patients undergoing active orthodontic treatment. Subjective symptoms and clinical signs of TMD as well as the presence of headaches, bruxism and occlusal interferences, were examined in 50 patients (mean age 12.9 years) before, during and immediately after orthodontic treatment. In general, signs and symptoms of TMD, and the presence of headache reduced during treatment, although joint sounds increased. The major factor for the decrease in the Dysfunction Indices during treatment was tenderness to palpation of the masticatory muscles. Although there was a high prevalence of occlusal interferences during treatment, they seemed to have little impact on the development of TMD. One explanation may be that teeth which are being moved orthodontically are sensitive to contact resulting in a decrease of oral parafunction. A decrease in clenching and grinding was also reported by the patient group, which support this theory.

A randomised controlled trial of Class II children receiving early functional appliance treatment was carried out by Keeling *et al.* (1995). Seventy one patients received treatment with headgear and a bite plane; sixty received treatment with a bionator appliance and sixty patients acted as a control group. TMJ sounds, joint pain on palpation, and muscle pain on palpation were scored as binary responses (present/absent prior to treatment). Determinations were made by blinded, calibrated examiners initially and after a Class I molar correction was achieved or 2 years had elapsed. They found

that subjects with TMJ sounds, joint pain, and/or muscle pain at follow-up tended to have these signs at baseline and that early treatment with a bionators and headgear/bite planes did not place healthy children without signs at risk. It was, concluded that treatment with the bionator or headgear neither improved nor worsened TMJ function. It was, however, noted that patients treated using the bionator appliance showed some improvement in TMJ pain.

Proffit (2000) suggested that orthodontic treatment may relieve TMD symptoms due to the sensitivity of teeth resulting in a reduction in grinding habits. However, he stated that orthodontic treatment should not be undertaken on the grounds of treating TMD symptoms and that TMD prevention should not be a major motivating factor for orthodontic treatment (Mohlin *et al.,* 2002). Luther (1998a) reviewed the TMD literature and proposed that, there is a tendency in longitudinal studies for orthodontically treated patients to have fewer signs of TMD. Of the four longitudinal studies identified, one found no relationship between the onset or change in TMD and the course of orthodontic treatment (Rendell *et al.,* 1992). The other three studies all reported an improvement in TMD after orthodontic treatment (Kremenak *et al.,* 1992a; Kremenak *et al.,* 1992b; Olsson and Lindqvist, 1995) and one study suggested that orthodontics may even prevent TMD from occurring (Olsson and Lindqvist, 1995).

McNamara (1997) carried out a review of the literature and his findings can be summarised as follows:

1. Signs and symptoms of TMD may occur in healthy persons.

2. Signs and symptoms of TMD increase with age and therefore TMD which originates during orthodontic treatment may not be related to the treatment.

3. In general, orthodontic treatment performed during adolescence does not increase or decrease the chances of developing TMD later in life.

4. The extraction of teeth as part of an orthodontic treatment plan does not appear to increase the risk of TMD.

5. There is no increased risk of TMD associated with any particular type of orthodontic mechanics.

6. Although a stable occlusion is a reasonable orthodontic treatment goal, not achieving an ideal gnathologic occlusion does not necessarily result in signs and symptoms of TMD.

7. Thus far, there is little evidence that orthodontic treatment prevents or improves TMD, although the role of unilateral posterior crossbite correction in children may warrant further investigation.

1.10 Summary

Much confusion and controversy still exists regarding TMD and its relevance to the dental profession as a whole and this stems partially from the conflicting definitions and classifications that are used in the literature. Many theories have been suggested as to what causes TMD, however the precise aetiology remains unknown and is probably multi-factorial in origin, with no single aetiological factor playing a role. Correlation between features of malocclusion and TMD does not imply causality, nor does the current research concerning TMD and orthodontics, thus these assumptions should be avoided in future literature.

More information on the aetiology, diagnosis and assessment of TMD is needed. In addition improved on study designs are required to reduce bias, as is standardisation of research methodology will provide the best available evidence in this field.

Summary of the Research

Chapter II Systematic review of TMD in orthognathic patients

In order to fully comprehend the research currently published in the field of TMD and orthognathic treatment, a systematic review of the literature was conducted to investigate the percentages of orthognathic patients affected by TMD, how it affects their quality of life and to establish clinical signs and/or symptoms. In addition the studies which followed patients longitudinally throughout treatment were examined in order to determine whether interventions to correct jaw discrepancy affected TMD symptoms.

Chapter III TMD in orthognathic patients and a control group with no skeletal discrepancies

Chapters III and IV in this PhD report on the recruitment of orthognathic patients with severe skeletal discrepancies. Chapter III involved the recruitment of control subjects with no anterior-posterior, vertical or transverse skeletal discrepancies in order to compare TMD signs and symptoms with the patient group. The TMD signs and symptoms (if any) and range of jaw movements in these individuals were investigated and the percentage of subjects with TMD in the control group was compared with that in the orthognathic group. The signs and symptoms were also compared between the two cohorts.

Chapter IV A longitudinal study of TMD in orthognathic patients

Chapter IV was a longitudinal study which followed orthognathic patients through the course of treatment, to establish whether TMD signs and symptoms altered during the course of the orthognathic treatment. The percentage of pre-treatment orthognathic patients affected by TMD was determined and changes in TMD signs and symptoms during the course of treatment were recorded. The TMD signs and symptoms at the different time points were compared with those recorded prior to treatment.

Chapter V TMJ information course: Comparison of the instructional efficacy of an internet-based TMJ tutorial with the more traditional seminar

A TMJ tutorial was developed on a virtual learning environment (VLE) to enable students to enhance their examination and diagnostic skills. A randomised cross-over trial was conducted and the success of this mode of teaching was compared with conventional face-to-face teaching. The students' perception of VLE learning when compared with traditional methods of teaching was also determined.

Chapter II: Systematic review of TMD in orthognathic patients

2.1 Review of the Literature

2.1.1 Introduction

Temporomandibular joint disorders (TMD) can be defined as multifactorial disturbances of the masticatory system (Riolo *et al.,* 1987), with occlusion appearing to play only a minimal part. Little is known about the precise aetiology and mechanisms of action of the condition and, as disagreement is still evident regarding the diagnosis and classification of the various subtypes of TMD, this inevitably impacts on research in this field.

It should therefore come as no surprise that TMD, and its relevance to dentistry, has been a highly debated topic in recent years (Rinchuse *et al.,* 2005). To this end, conflict arises in the dental community when views are expressed about topics such as condyle position, malocclusion, orthodontic treatment and temporomandibular disorders.

The evidence in the literature as to whether malocclusion can cause TMD is conflicting. Proffit (2000) stated "The prevalence of TMD in the population is between 5% and 30%, which is less than the 50% of the population exhibiting a moderate degree of malocclusion. As such some argue that it is unlikely malocclusion is a major cause of TMD". It is of note, however, that some studies have found that certain malocclusions (for example, Class III, deep bites and anterior open bites) are significantly associated with symptoms of TMD (Williamson, 1977; Mohlin *et al.,* 1980; Mohlin and Thilander, 1984). In contrast, other large cross sectional studies have found only weak associations between malocclusion and TMD (Riolo *et al.,* 1987; Motegi *et al.,* 1992). Pullinger and Seligman (1991) studied occlusal features, including overbite and overjet and their association with TMD. Symptomatic patients were compared with a control group of symptom free individuals and the results showed that a greater proportion of symptomatic patients exhibited a reduced overbite or open bite when compared with the control group ($P<0.02$). This was, however, attributed to changes within the joint itself

and they concluded that a deep overbite or increased overjet were not in themselves diagnostic of underlying TMD. As such no strong relationship was found to exist between TMD and these occlusal features.

As discussed in the review of the literature there is also much controversy over the relationship between orthodontic treatment and temporomandibular joint disorders and orthodontists remain divided over this concept. Evidence supporting orthodontic treatment as a causative factor for TMD, particularly the earlier research, tends to be based on anecdotal evidence, weak study designs and small sample sizes.

Ricketts (1966) was a major proponent of the theory that orthodontic treatment could be a cause of TMD. However, his suggestions do not appear to be based on empirical evidence and longitudinal studies have suggested that patients undergoing orthodontic treatment are at no greater risk of developing TMD than those who remain untreated (Sadowsky *et al.*, 1991; Hirata *et al*., 1992; Mohlin *et al.*, 2004; Egermark *et al.*, 2005). These studies have all concluded that orthodontic treatment seems to be neither a major preventive nor a significant cause of TMD.

2.1.2 Orthognathic treatment and TMD

Orthognathic treatment is undertaken to correct skeletal discrepancies and involves a combination of orthodontics and maxillofacial surgery. There is little high quality research published on the association between major skeletal disharmonies and their effects on TMD. If the relevance of TMD to orthognathic treatment is considered, the viewpoints expressed are diverse and include that orthognathic intervention may resolve or induce TMD, or may have little or no effect. The following studies are examples of the differing viewpoints expressed.

Wolford *et al.* (2003) undertook a retrospective study on 25 patients with pre-existing TMD who had undergone orthognathic surgery. This study concluded that orthognathic patients may experience worsening of their condition post-operatively. In contrast, a study by White and Dolwick (1992) found that the majority of patients undergoing orthognathic treatment showed an improvement in symptoms. The study assessed 75

patients of whom 49% had pre-operative TMD symptoms. Of those with symptoms, 89.1% showed an improvement, whilst 10.8% either had increased symptoms post-surgery or remained the same.

In a longitudinal study of 52 orthognathic patients by Egermark *et al.* (2000), 51% of the patients reported improvement in TMD post-surgery, while 37% reported no change. Therefore the results of this study supported the theory that orthognathic treatment could have some beneficial effects on TMD.

As the influence of orthognathic surgery on TMD is unclear, there is a definite need for further investigations evaluating TMD in patients undergoing orthognathic intervention. Luther (1998b) stated "We are still awaiting the perfect study to assess the relationship between malocclusion and TMD. More steps should be taken when carrying out studies to eliminate bias". Thus current research in the field of TMD should be as objective as possible and utilise reliable clinical standards for the examination and diagnostic classification of TMD.

2.1.3 Systematic reviews

Definition

A systematic review is a review of a clearly formulated question that uses systematic and explicit methods to identify, select and critically appraise relevant research, and to collect and analyse data from the studies that are included in the review (Chalmers and Altman, 1996). The procedures involved are explicit and transparent, so that others may replicate the review, and they are defined in advance of the review.

Systematic reviews provide the most reliable evidence for decision making in health care. As such an understanding of systematic reviews and how to implement them in practice is mandatory for all professionals involved in the delivery of health care (Egger *et al.,* 2001).

Importance of Systematic Reviews

Over 3 million articles are published in biomedical journals annually and a practitioner needs to consider a large volume of material in order to keep up to date (Egger *et al.,* 2001). Review articles can assist in addressing the above issue, but unfortunately narrative reviews are often of poor quality and expert reviewers can make conflicting recommendations, hence conventional reviews can be an unreliable source of information (Egger *et al.,* 2001).

A systematic review therefore aims to be:

1. Systematic in its identification of literature
2. Explicit in its statement of objectives, materials and methods
3. Reproducible in its methodology and conclusions

Systematic reviews are needed to efficiently integrate valid information and provide a basis for rational decision making. The use of these explicit systematic methods limits bias and reduces chance effects, thus providing more reliable results upon which to draw conclusions and make decisions (Higgins and Green, 2009). The stages of a systematic review project are:

1. Planning the review: identifying the need for a review and documenting the methodology
2. Conducting the review: finding, selecting, appraising, extracting and synthesising primary research studies
3. Reporting and dissemination: writing up and disseminating the results of the review

At the initial stage, reviewers begin by formulating the problem to be addressed which involves determining the focused questions for the review that is to be conducted. A poorly formulated focused question leads to uncertainty in the research which is included in the subsequent summaries, as such the most important decision in conducting a review is to determine the focus of the review. The principal components of the focused question are often referred to as PICO (**Participants, Interventions, Comparison and Outcome**). Thus a clearly defined question should specify the types

of participants, interventions or exposures and the outcomes that are of interest to the review. Additionally, where it is applicable, the types of comparisons that are to be made should also be clearly described.

In subsequent stages of a systematic review a comprehensive search of the literature is performed. Studies are then selected according to the original inclusion criteria and an assessment of the quality of these selected studies is carried out. Data are extracted from the included studies and synthesised in an appropriate manner, either quantitatively (in the form of a meta-analysis), or qualitatively (in tables). This allows conclusions to be formed both for practice and for future research (Higgins and Green, 2009).

Systematic reviews are an integral part of evidence based medicine (EBM). Evidence based medicine is "An approach to decision making in which the clinician uses the best available evidence, in consultation with the patient, to decide upon the option which suits that patient best" (Greenhalgh, 1997). One aspect of EBM is to categorise different types of clinical evidence and rank them according to their strength (the extent to which they are protected against the various biases often associated with medical research). The Oxford Centre for Evidence-based Medicine suggests the following levels of evidence (LOE) according to the study designs and critical appraisal of prevention, diagnosis, prognosis, therapy, and harm studies:

1. Level A: consistent randomised controlled trials, cohort studies, all or none, clinical decision rule validated in different populations.
2. Level B: consistent retrospective cohort, exploratory cohort, ecological study, outcomes research, case-control study; or extrapolations from level A studies.
3. Level C: case-series study or extrapolations from level B studies
4. Level D: expert opinion without explicit critical appraisal, or based on physiology, bench research or first principles

Bickley and Harrison (2003) considered systematic reviews as the foundation stone in the pyramidal hierarchy of evidence (Figure 2.1).

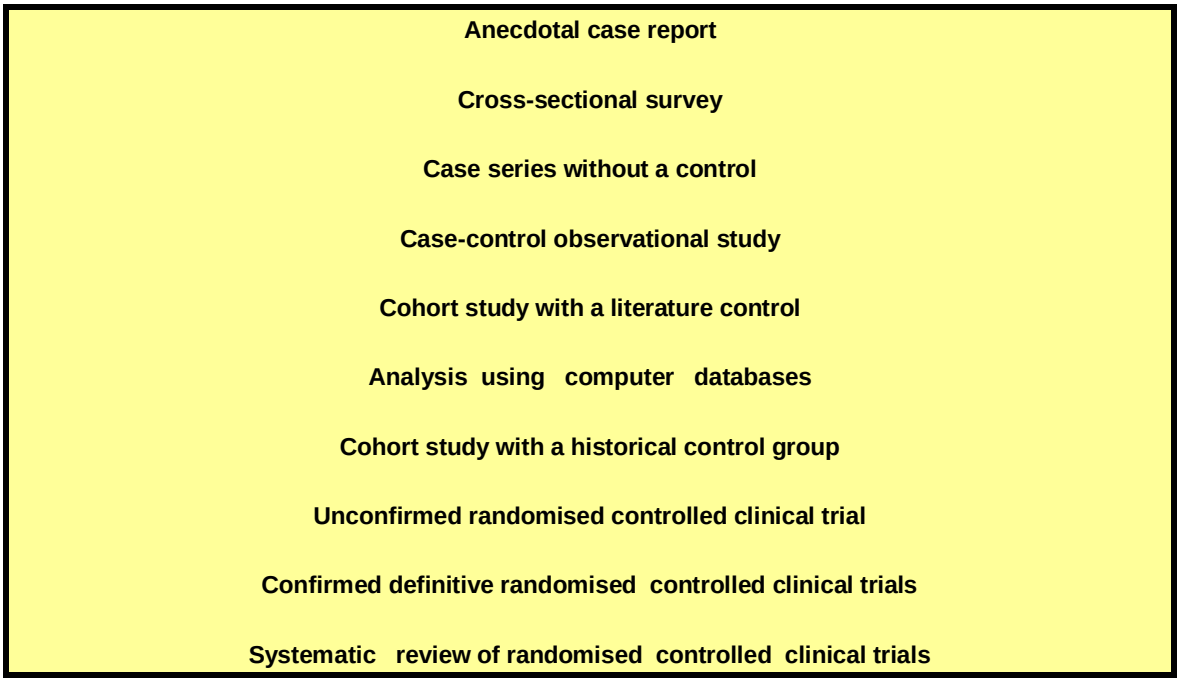


Figure 2.1 Hierarchy of Evidence (Reproduced from Clarkson *et al.*, 2003)

History of Systematic Reviews

Reviews play an important role in synthesising and disseminating the results of research and the recognition of this prompted researchers to consider their validity. In the 1970s and early 1980s, psychologists and social scientists drew attention to the systematic steps needed to minimise bias and random errors in reviews of research (Glass, 1976). Around the same time Professor Archie Cochrane (a medical researcher who contributed greatly to the development of epidemiology as a science) wrote "It is surely a great criticism of our profession that we have not organised a critical summary, by specialty or subspecialty, adapted periodically, of all relevant randomised controlled trials" (Cochrane, 1979). Thus two fundamental shortcomings of research were highlighted:

1. The validity and bias associated with research and study design needed to be identified when considering evidence.
2. Critical summaries or reviews of evidence and trials were very much needed. People wanting to make informed healthcare decisions did not have access to reliable reviews of available evidence at that stage (Cochrane, 1979).

By the mid 1980s, healthcare professionals had begun to recognise that it was impossible to interpret the results of any one study in isolation and that critical summaries were needed to put results into context. Unfortunately because a systematic approach to assessing research on the effects of healthcare interventions was not being utilised, patients were not always being offered the best possible care and some may have been suffering unnecessarily. This was evident in a comparison of the conflicting advice from textbooks in relation to the results of published clinical trials. Relevant and sound information could have been available in many areas of medicine had a scientifically defensible approach been used to cumulate evidence as it emerged (Antman *et al.*, 1992).

These shortcomings led to advancements in the field of perinatal medicine. In the mid 1980s, work began on developing registers of controlled trials of interventions during pregnancy, labour and early infancy (Grant and Chalmers, 1981; Chalmers et *al*., 1986). This was based at the National Perinatal Epidemiology Unit in Oxford, with the aim of coordinating systematic reviews in pregnancy and childbirth.

During this time, advances in computer technology were making it possible to consider more ambitious projects. In a letter to The Lancet regarding the publication of a trial, Chalmers (1986) recognised that space is limited in printed journals and consequently the amount of detail that could be included was limited. Electronically however, there are no restrictions, thus allowing people to consider new approaches to presenting and summarising research evidence, an example of which was The Oxford Database of Perinatal Trials (ODPT). The ODPT was said to be "a milestone in the history of randomised controlled trials and evaluation of care" (Cochrane, 1987 cited in Chalmers *et al*., 1989). ODPT was funded by Oxford University Press and provided a computerised register of randomised controlled trials in perinatal medicine. The systematic reviews in ODPT known as "overviews" were highly structured and were all presented in the same format (Starr and Chalmers, 2003). It was the first electronic publication to present regularly updated systematic reviews of research on the effects of healthcare interventions.

By 1992, many policy makers, practitioners, and consumers had come to recognise the importance of systematic reviews for making decisions about healthcare. Although the

ODPT had proved popular, Oxford University Press found the electronic publication costly to maintain and concluded that it was not economically viable. In 1992, Oxford University Press decided to discontinue ODPT as a commercial product (Starr and Chalmers, 2003).

The Research and Development Programme of the UK National Health Service recognised the value of the work being done at the National Perinatal Epidemiology Unit and provided funds for a new centre. This centre was subsequently named the UK Cochrane Centre and was aimed at promoting an extension of the process to other areas of healthcare. The UK Cochrane Centre opened in October 1992 and was followed by The Cochrane Collaboration which was inaugurated in October 1993 (Chalmers, 1993). Six further Cochrane Centres were established internationally by the end of 1994 and, in addition, ten groups were founded to prepare reviews within the different areas of healthcare and assess methodological factors (Egger *et al.*, 2001).

It was clear from the start of the Cochrane Collaboration in 1993 that it would be many years before the majority of research studies assessing the effects of healthcare interventions could be placed in the context of a systematic review. A marked increase in activities surrounding the Cochrane Collaboration followed, and the efforts of the collaboration focused on producing an output medium for maintaining up-to-date systematic reviews which would be widely available. In April 1996, the first issue of the Cochrane Library was presented. This incorporated:

- The Cochrane Database of Systematic Reviews (CDRS). CDRS consists of regularly-updated systematic reviews and protocols for reviews. This is the primary product of the Cochrane Collaboration
- The Database of Abstracts of Reviews of Effectiveness (DARE). This aims to include structured abstracts and quality appraisals of all non-Cochrane systematic reviews of the effects of healthcare interventions and diagnostic test accuracy published in journals and elsewhere. The UK National Health Service Centre for Reviews and Dissemination (CRD) at the University of York critically appraises the reviews.
- The Cochrane Controlled Trials Register (CCTR). CCTR is a bibliography of controlled trials, assembled by the Update Software Company from registers

submitted by Cochrane Centres and Cochrane review groups, together with entries downloaded from MEDLINE and Embase.

- The Cochrane Review Methodology Database (CRMD). This is a register and bibliography of articles and books on the science of reviewing evidence, research synthesis and evaluations on the effects of healthcare
- Information about the Cochrane Collaboration. This is a compilation of descriptions of each entity within the collaboration maintained by the respective entities.
- Other sources of information. This includes lists of internet sites relevant to evidence based practise, complied by the School of Heath and Related Research (ScHARR) at the University of Sheffield (Egger *et al.*, 2001).

Many aspects of the Cochrane Library can be viewed as part of the hierarchy of evidence, ranging from regularly updated reviews to high-quality reviews published elsewhere, and to reports of individual controlled trials (Starr and Chalmers, 2003).

In 1998 the Cochrane Library was made available on the World Wide Web (http://www.cochrane.org, www.thecochranelibrary.com) and, by 2003; Cochrane Reviews were available from most major information providers. The Cochrane Library, to date, comprises over 4,000 completed reviews and 2,000 protocols (Cochrane Collaboration, 2010).

Many healthcare journals now publish systematic reviews, but the best known source remains The Cochrane Collaboration. The Cochrane Collaboration has tended to limit its remit to reviews of the effects of healthcare interventions and thus focuses on the synthesis of evidence drawn predominantly from clinical trials. The Cochrane Collaboration also undertakes methodological developments including work to develop the methodology for synthesising evidence of effectiveness of diagnostic/screening tests and procedures. There are other organisations, however, that also conduct systematic reviews, some of which have a wider focus than The Cochrane Collaboration.

The Centre for Reviews and Dissemination (CRD) at the University of York was established in January 1994 and is now the largest group in the world engaged exclusively in evidence synthesis in the health field. The centre undertakes high quality systematic reviews that evaluate the effects of health and social care interventions and

the delivery and organisation of health care. The centre has played a leading role in the development and promotion of evidence informed decision- making in health policy and practice. The findings of CRD reviews are widely disseminated and have impacted on the quality of healthcare delivered.

The Campbell Collaboration (C2) was created with support from a large number of social and behavioural scientists and some social practitioners following an idea which was initially discussed at a meeting in London in July 1999. With partnerships developing in a number of countries, Campbell began its tradition of annual Colloquia in Philadelphia, USA in February 2000. The Campbell Collaboration was founded on the principle that systematic reviews looking out the effects of interventions will inform and improve policy and services. Through its reviews and annual colloquia, the Collaboration strives to make the best social science research available and accessible. The Campbell collaboration is a sibling organisation to the Cochrane Collaboration.

Despite the existence of a number of different organisations publishing the results of systematic reviews, they are all united in implementing strict criteria and methodology for conducting reviews to ensure reliability and quality of the published results.

2.2 Methodology

2.2.1 Aims of this Systematic Review

In order to fully comprehend the research currently published in the field of TMD and orthognathic treatment, a systematic review of the literature was conducted with the following aims:

1. To investigate the percentage of orthognathic patients affected by TMD, how it affects their quality of life and to establish the most common signs and/or symptoms.
2. To examine those studies which follow patients longitudinally throughout treatment in order to determine whether intervention to correct their skeletal discrepancy affects TMD signs and symptoms.

2.2.2 Conducting a systematic review of the literature

In view of the fact that it was anticipated that there would be few randomised controlled trials in this area, it was not considered appropriate to register the title with the Cochrane Oral Health Group. However, a similar methodological process was followed.

Objectives of this systematic review

The focused questions and null hypotheses for this review were as follows:

Focused Questions

1. In individuals undergoing orthognathic treatment to correct dento-facial deformities, what is the percentage of patients who present with pre-treatment TMD?
2. What proportion of orthognathic patients who do not have signs or symptoms of TMD pre-operatively, develop TMD signs or symptoms post-surgery?
3. In patients who presented with signs or symptoms of TMD pre-operatively how do these signs or symptoms change post- treatment?

4. In individuals undergoing orthognathic treatment and presenting with signs and symptoms of TMD, how does this affect their quality of life when compared with orthognathic patients with no signs or symptoms of TMD?

First Null Hypothesis

In patients who are affected by TMD there is no difference in pre and post-treatment signs and symptoms (i.e. there is no change in their signs or symptoms).

Second Null Hypothesis

There is no difference in asymptomatic patients pre-treatment when compared with post-treatment (i.e. patients who do not suffer from TMD pre-treatment are unlikely to develop TMD after treatment).

Third Null Hypothesis

There is no difference in the quality of life of orthognathic patients in those affected by TMD and those who are not affected by TMD.

Criteria for considering studies

Types of studies:

1. Randomised controlled trials (RCT)

   Due to logistical and ethical considerations it was anticipated that few, if any, randomised control trials (RCT) would be available in this area.
2. Cohort Studies and Case-Control Studies

   These were included if there were at least 10 patients included in the study. This criterion was applied in order to attempt to distinguish between genuine cohorts as opposed to case series.

Types of participants:

Male or female patients (14 years or over) of any ethnicity who have undergone orthognathic surgery. Although orthognathic treatment is not ordinarily carried out prior to the age of 17 years in the UK, 14 years was chosen as it is not uncommon for surgeries to be performed on younger patients in the North America. This would then allow inclusion of the relevant American based studies in this review.

Exclusion criteria were:

1. Craniofacial syndromes
2. Cleft lip and/or palate
3. Individuals with a history of facial fractures due to trauma
4. Individuals undergoing orthognathic surgery purely to correct TMD
5. Subjects who had orthognathic treatment and concomitant temporomandibular joint surgery
6. Animal studies

Types of interventions:

Orthognathic treatment to correct severe jaw discrepancies, including:

1. Maxillary advancement
2. Superior repositioning (impaction) of the maxilla
3. Inferior repositioning of the maxilla
4. Surgical maxillary expansion (SARPE)
5. Mandibular advancement
6. Mandibular set-back
7. Segmental procedures
8. Distraction osteogenesis
9. Any combination of these reported in the literature.

Outcome measures:

1. The percentage of patients with TMD signs and symptoms. This was examined at all intervals reported, pre and post-treatment (up to 5 years post-treatment).
2. Changes in TMD status. Did the signs and symptoms improve, worsen or remain the same?
3. Patient satisfaction and quality of life.

Search strategy for identification of studies

Attempts were made to identify relevant studies irrespective of language.

1. Electronic searching. Detailed search strategies (Table 2.1) were developed for MEDLINE.
2. References. The bibliographies and reference lists of identified publications and reviews were checked for references to any other relevant studies.

3. Personal communication with experts and specialists in the field, in order to obtain further information about unpublished and ongoing studies.

Search Strategy for MEDLINE via OVID

1	(Jaw adj1 joint adj1 (pain or click or lock$ or nois$ or sound))
2	(Jaw adj1 (pain or click or lock$ or nois$ or sound))
3	pterygoid hypersensitivity dysfunction
4	(intra?auricular adj1 (Pain or ache or tender))
5	(jaw or oral or mouth)
6	((limited or reduced or restricted or decreased) adj1 (opening or lateral excursion$ or excursion$ or interincisal or vertical$))
7	5 and 6
8	((pterygoid or masseter or temporalis) adj1 (Pain or ache or spasm or tender$))
9	(muscle adj1 (Pain or ache or spasm or tender$)).
10	5 and 9
11	exp Temporomandibular Joint Dysfunction Syndrome
12	exp Temporomandibular Joint Disorders
13	TMD
14	exp Trismus
15	exp Facial Pain
16	myofacial pain
17	lateral pole
18	crepitus
19	exp Jaw Fractures
20	((jaw$ adj2 fracture$) or (condyl$ adj2 fracture$))
21	exp Osteotomy, Le Fort
22	exp Mandibular Advancement
23	(maxilla$ adj1 advancement)
24	(orthognathic adj1 surg$)
25	(orthognathic adj1 treatment)
26	(jaw$ adj1 surg$)
27	(mand$ adj2 surg$)
28	(maxill$3 adj2 surg$)
29	BSSO
30	(sagittal adj2 split adj2 osteotom$)
31	(retrognathi$ and (surgery or surgical$))
32	(prognathi$ and (surgery or surgical$))
33	superior maxillary repositioning
34	maxillary impaction
35	inferior repositioning of maxilla
36	mandibular setback
37	BVSS
38	(vertical adj2 subsigmoid adj1 osteotomy)
39	(distraction adj1 osteogen$)
40	1 or 2 or 7 or 8 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18
41	19 or 20 or 21 or 22 or 23 or 24 or 25 or 26 or 27 or 28 or 29 or 30 or 31 or 32 or 33 or 34 or 35 or 36 or 37 or 38 or 39
42	40 and 41

Table 2.1. Electronic search strategy for identification of studies

Methods of review

Selection of studies

The results of the search, as determined by the search strategy were compiled. The reviewers assessed titles and abstracts to determine whether each article might meet predetermined eligibility criteria for inclusion in this study. Two reviewers took part (SA, SJC) as this reduced the possibility that relevant reports were discarded.

At the first stage, if an article definitely failed to meet the inclusion criteria, it was rejected. If the title or abstract raised doubt, the article could not be rejected and the full text of the article was obtained. At the second stage, the full articles were read to establish the eligibility definitively. Reading the full text led the reviewers to exclude some studies that did not meet the inclusion criteria. Agreement was assessed using the Kappa statistic (Table 2.2). Any disagreement between the reviewers was resolved by discussion.

κ	Interpretation
< 0	Poor agreement
0.0 — 0.20	Slight agreement
0.21 — 0.40	Fair agreement
0.41 — 0.60	Moderate agreement
0.61 — 0.80	Substantial agreement
0.81 — 1.00	Almost perfect agreement

Table 2.2. Interpretation of Kappa Values (Landis and Koch, 1977)

A total of 480 studies and abstracts were identified for possible inclusion in the study as determined by the search strategy. This was not dissimilar to a review by Abrahamsson *et al.* (2007) looking at TMD before and after orthognathic surgery in which 467 articles were identified. At the first stage, 350 articles/abstracts were excluded as they did not fulfil the inclusion criteria. The examiner agreement was assessed using Kappa scores and this was found to be substantial (Kappa=0.723 Table 2.3). After discussion it was agreed to include 130 articles for full text evaluation at the second stage.

		Examiner 2 (SJC)	
		Include	**Exclude**
Examiner 1 (SA)	**Include**	98	39
	Exclude	12	331

Kappa = 0.723 (95% CI 0.651 to 0.795)

Table 2.3. Kappa scores for the first stage of study selection

After obtaining the articles, 29 of the 130 articles were in foreign languages (the majority of which were in Chinese). Logistically, it was not possible to make a decision regarding inclusion/exclusion and, as obtaining translations proved impossible, it was decided to exclude them at this stage. The remaining 101 articles were then assessed for eligibility for inclusion. The kappa scores for this second stage also indicated substantial agreement (Table 2.4). After discussion, it was agreed to include 60 English language articles for the final review stage.

		Examiner 2 (SJC)	
		Include	**Exclude**
Examiner 1 (SA)	**Include**	60	9
	Exclude	2	30

Kappa = 0.762 (95% CI 0.630 to 0.895)

Table 2.4. Kappa scores for the second stage of study selection

Data extraction and Management

The next stage in the process was to design a form for data extraction (Appendix 1). This also incorporated information on patient characteristics such as the number of patients in the study, the gender of the patients, age range, as well as information on the malocclusion types and interventions. The form also permitted the TMD classification methods to be recorded, as well as the observational time points. Primary outcome

measures and the results were recorded in table format, and a distinction was made between patient reported findings (symptoms) and clinical findings (signs). The table listed common signs and symptoms that would be reported in TMD studies, but also allowed further items to be added as appropriate. Where possible a tick box format was included for ease of use. Additional findings such as radiographic and imaging findings and quality of life assessments could also be recorded.

The inclusion criteria were pilot tested on a sample of articles (seven papers), including some that were thought to be definitely eligible, definitely not eligible and questionable. The pilot was used to refine the data extraction form and clarify the inclusion criteria, whilst training the reviewers and ensuring that the criteria could be applied consistently.

Data extraction was then performed on all 60 eligible full text articles. This process was independently carried out by both reviewers (SA and SJC). At this stage a further 7 articles were found not to meet the inclusion criteria and were therefore excluded. The data extraction forms completed by both investigators were compared; any discrepancies between the forms were identified and discussed until agreement was reached. A total of 53 articles were finally summarised for inclusion in this review. This was in contrast to Abrahamsson *et al.* (2007) where only 3 articles were included and this may be explained by the different aims stated in the two studies.

Assessment of methodological quality of included studies

Quality assessment of individual studies included in systematic reviews is necessary to limit bias, gain insight into potential comparisons, and guide interpretation of findings. From the results of the search it became apparent that, the majority of the articles obtained were case control and cohort studies. As such it was initially decided to use the Newcastle-Ottawa Scale (NOS) (http://www.ohri.ca/programs/clinical_epidemiology/oxford.htm) which was developed to assess the quality of non-randomised studies. However, on piloting of this scale it became evident that there were many restrictions associated with its use for the type of studies that had been included. This scale could not be applied accurately and consistently to studies involving TMD research and was better suited for epidemiological studies. This presented a challenging situation, and it was decided that a quality assessment scale would be developed specifically for this study, which would be better suited for the research in question.

The principles for developing the quality assessment form were based on identifying the main forms of bias (Sackett, 1979):

1. Selection bias (allocation bias). This is the systematic differences between comparison groups in prognosis or responsiveness to treatment. Randomisation of large numbers of patients with concealment of their allocation to different groups reduces this bias. Whether inclusion/exclusion criteria were reported and appropriate and how the subjects were recruited into the study (e.g. volunteers or consecutive patients) all helped to determine the level of bias in this review.
2. Performance bias. This includes systematic differences in care provided, apart from the intervention being evaluated. Standardisation of the care protocol and blinding (masking) of clinicians and participants minimises this bias. The number of operators involved in the studies and grouping of the interventions were some of the criteria examined to evaluate this bias.
3. Measurement bias (detection bias, ascertainment bias). This is the systematic difference between comparison groups in how the outcomes are ascertained. Blinding of study participants and outcome assessors reduces this bias. For the purpose of this research the use of standard measures (e.g. the Helkimo Index) was considered important to reduce bias.
4. Attrition bias (exclusion bias). This is the systematic difference between comparison groups in terms of withdrawal or exclusion of participants (e.g. because of side effects from the intervention). Inclusion of such participants in the analysis (in combination with a sensitivity analysis) reduces this bias. In this study, a follow up period of greater than 6 months was selected to reduce bias. In addition it was decided that the number of patients lost to follow up should not exceed 20%.

Once the main types of bias were identified they were included as subsections of a quality assessment form (Selection, Performance, Measurement/Outcome and Attrition). This was refined by incorporating principles of other quality assessment tools; for example, studies that were planned in advance and followed prospectively should show less bias than studies undertaken retrospectively. Checklists which were available from epidemiological studies were also modified for inclusion in the assessment form (Fleiss and Gross, 1991; Levine *et al.*, 1994). For example:

- Were the groups assembled at a similar point in their disease progression?
- Was the intervention/treatment reliably ascertained?
- Was the group comparable on all important confounding factors?
- Was there adequate adjustment for the effects of these confounding variables?
- Was outcome assessment blind to exposure status?
- Was follow-up long enough for the outcomes to occur/be assessed?
- Was the case definition explicit?
- Was the disease state of the cases reliably assessed and validated?
- Were the criteria for inclusion explicit?
- Was the outcome assessed using objective criteria or was blinding used?

After several iterations of testing, a quality assessment form was ultimately developed which was relatively easy to use and reproducible (Appendix 2).

First Stage testing of quality assessment forms

The quality assessment form was used on all 53 eligible articles, with both reviewers (SA and SJC) independently carrying out this process. The results from both reviewers were summarised into tables and the agreement calculated using the Kappa statistic (Table 2.5a-d).

		Examiner 2 (SJC)		
		Low bias	**High Bias**	***Total***
Examiner 1 (SA)	**Low bias**	10	10	29
	High bias	5	29	34
	Total	15	38	53

Kappa = 0.398 (95% CI 0.127 to 0.668)

Table 2.5a Agreement and Kappa scores for Selection (1st stage of testing)

		Examiner 2 (SJC)		
Examiner 1 (SA)		**Low bias**	**High Bias**	***Total***
	Low bias	8	16	24
	High bias	1	28	29
	Total	9	44	53

Kappa = 0.316 (95% CI 0.048 to 0.584)

Table 2.5b Agreement and Kappa scores for Performance (1st stage of testing)

		Examiner 2 (SJC)		
Examiner 1 (SA)		**Low bias**	**High Bias**	***Total***
	Low bias	5	9	14
	High bias	2	37	39
	Total	7	46	53

Kappa = 0.364 (95% CI 0.030 to 0.699)

Table 2.5c Agreement and Kappa scores for Measurement/Outcome (1st stage of testing)

		Examiner 2 (SJC)		
Examiner 1 (SA)		**Low bias**	**High Bias**	***Total***
	Low bias	17	3	20
	High bias	8	25	33
	Total	25	28	53

Kappa = 0.579 (95% CI 0.358 to 0.801)

Table 2.5d Agreement and Kappa scores for Attrition (1st stage of testing)

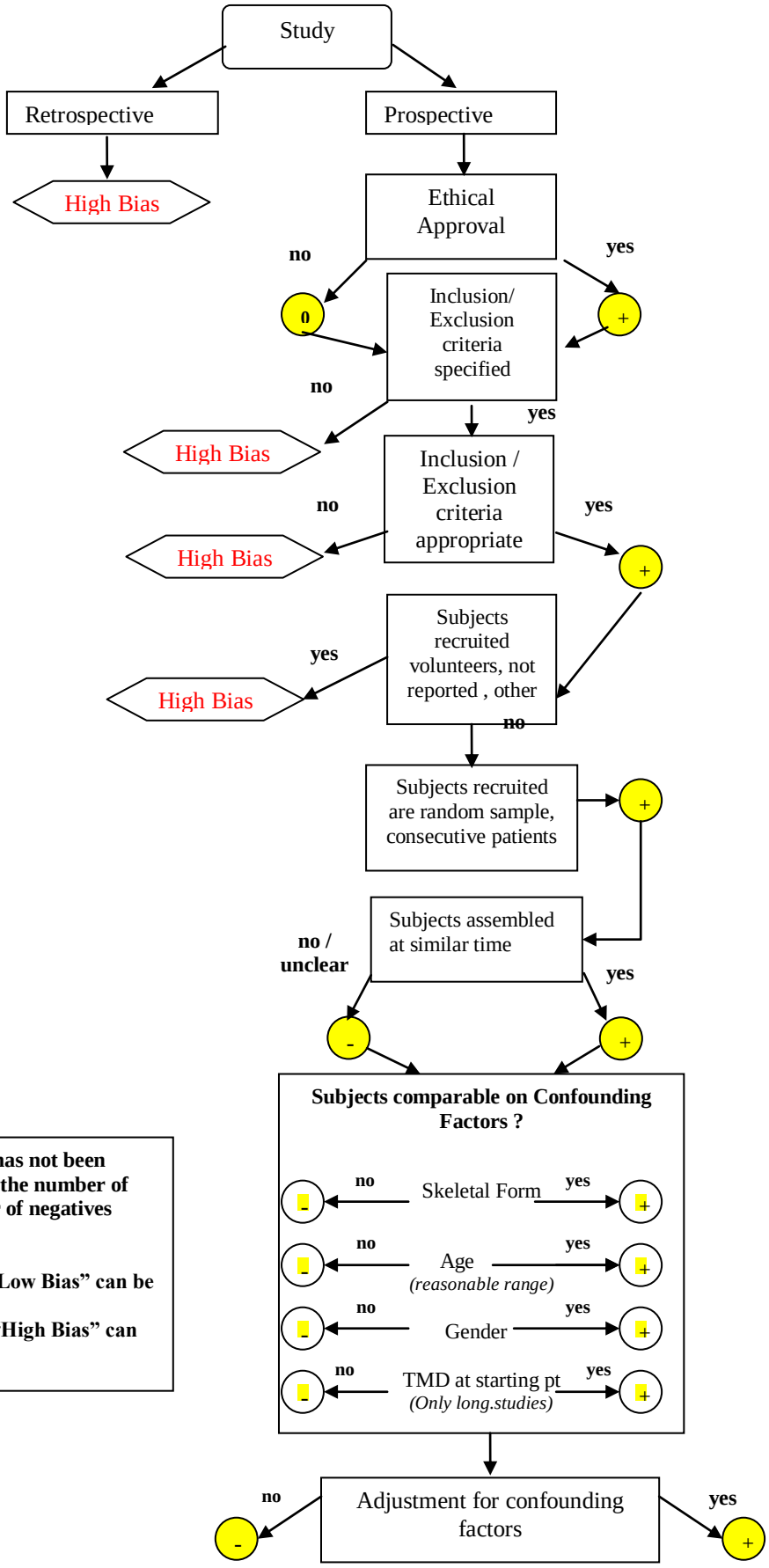
The Kappa score results were not acceptable (moderate agreement only for all four sections) and this indicated that there was variability between the two reviewers in interpreting the quality assessment forms and identifying bias. Hence, it was essential to improve the definitions of the criteria on which to assign levels of bias for the quality

assessment forms. By setting criteria, it was hoped both investigators would carry out the process of quality assessment consistently and reproducibly.

Second stage testing of quality assessment forms

A set of criteria were developed for all four sections, in the form of flow charts (Figures 2.2 to 2.5) and both investigators met to discuss the flow charts and calibrate themselves. The flow chart system was then pilot tested on 9 randomly selected articles. Agreement was assessed by percentage agreement (and the Kappa statistic where possible) and the scores were considerably improved, with substantial agreement (Table 2.6a to d). On discussion of the discrepancies it was found that with regard to Attrition (Table 2.6d) the disagreement was minor and was the result of one investigator rounding up a value, whilst the other reported the value to a decimal point. An agreement of 100% would otherwise have been achieved in this case.

Selection

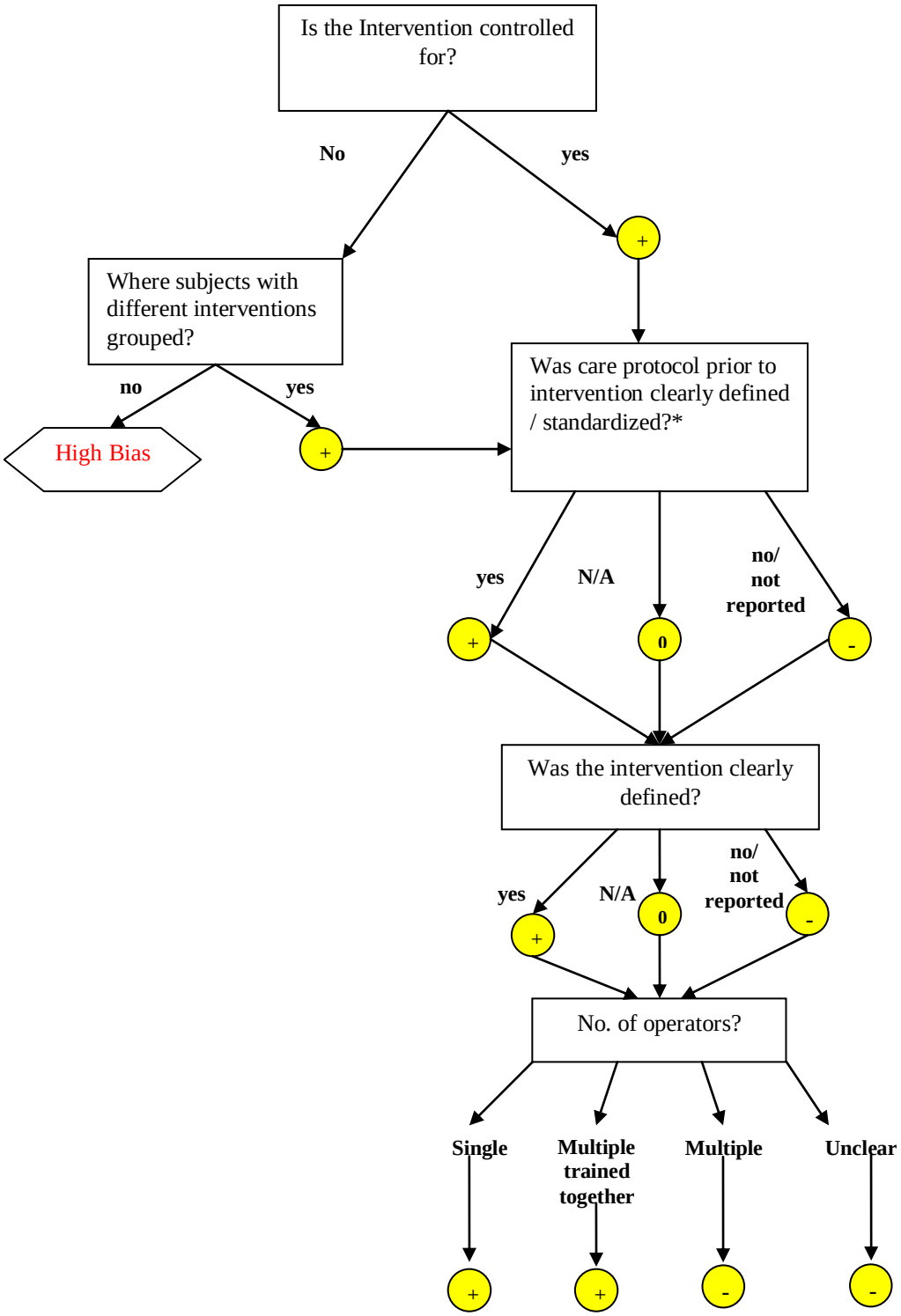


If automatic high bias has not been assigned then compare the number of positives to the number of negatives scores assigned.

If (+) > (-) Then "Low Bias" can be assigned
If (+) < (-) Then "High Bias" can be assigned

Figure 2.2 Flow chart for assigning bias for the selection criteria of the included studies

Performance



If automatic high bias has not been assigned then compare the number of positives to the number of negatives scores assigned.
If (+) > (-) Then "Low Bias" can be assigned
If (+) < (-) Then "High Bias" can be assigned
*** This implies that there has been some mention of all subjects having orthodontic treatment pre-operatively for care protocol to be clearly defined. If some patients have not had ortho whilst other have, then care protocol was not standardized. In addition if some form of TMD relief therapy has been used, such as physio, or splints, then all subjects are to have been included or enrolled in this procedure for standardization.**

Figure 2.3 Flow chart for assigning bias for the performance of the included studies

Measurement/ Outcome

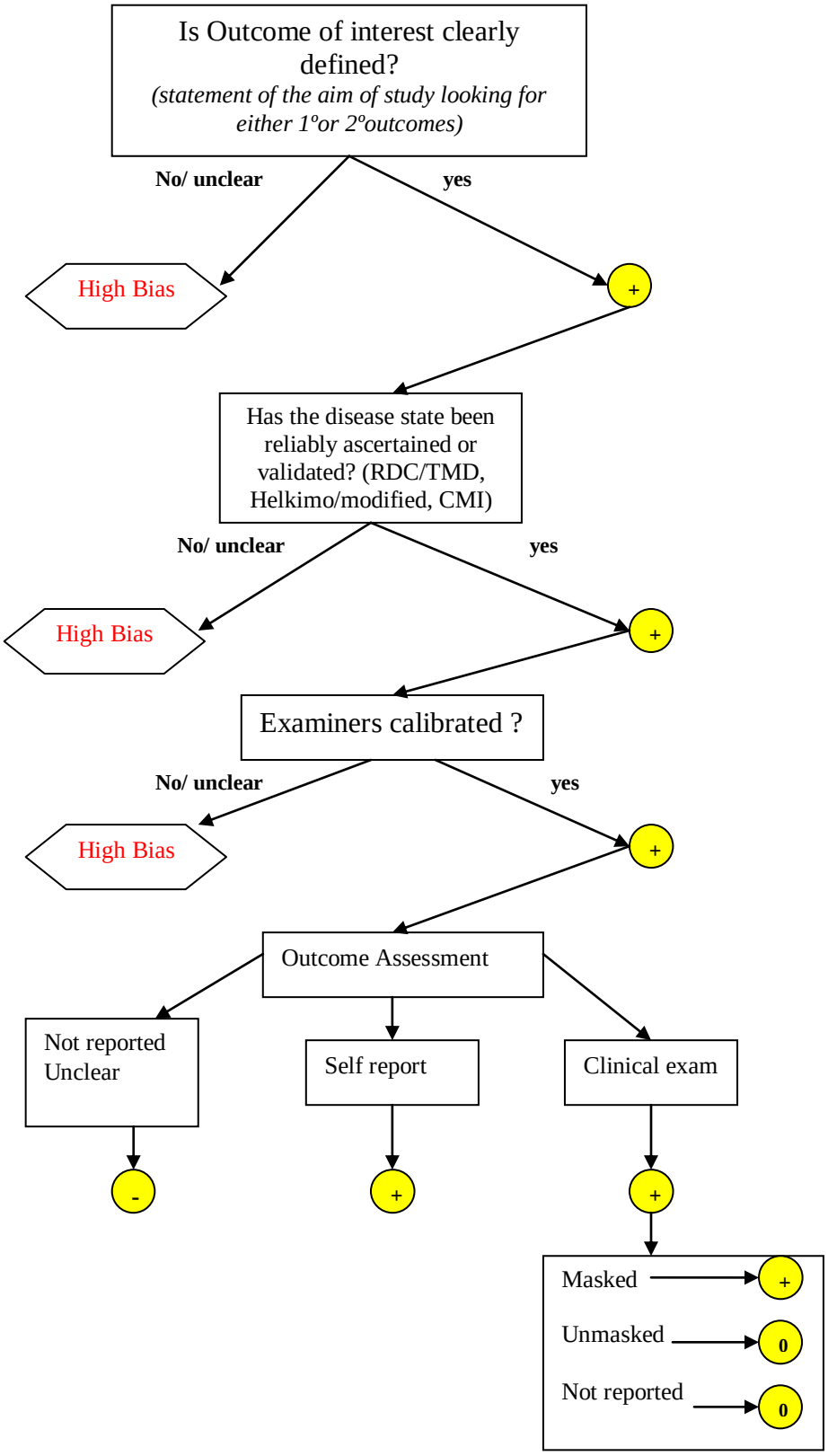


Figure 2.4 Flow chart for assigning bias for the measurement/outcome of the included studies

Attrition

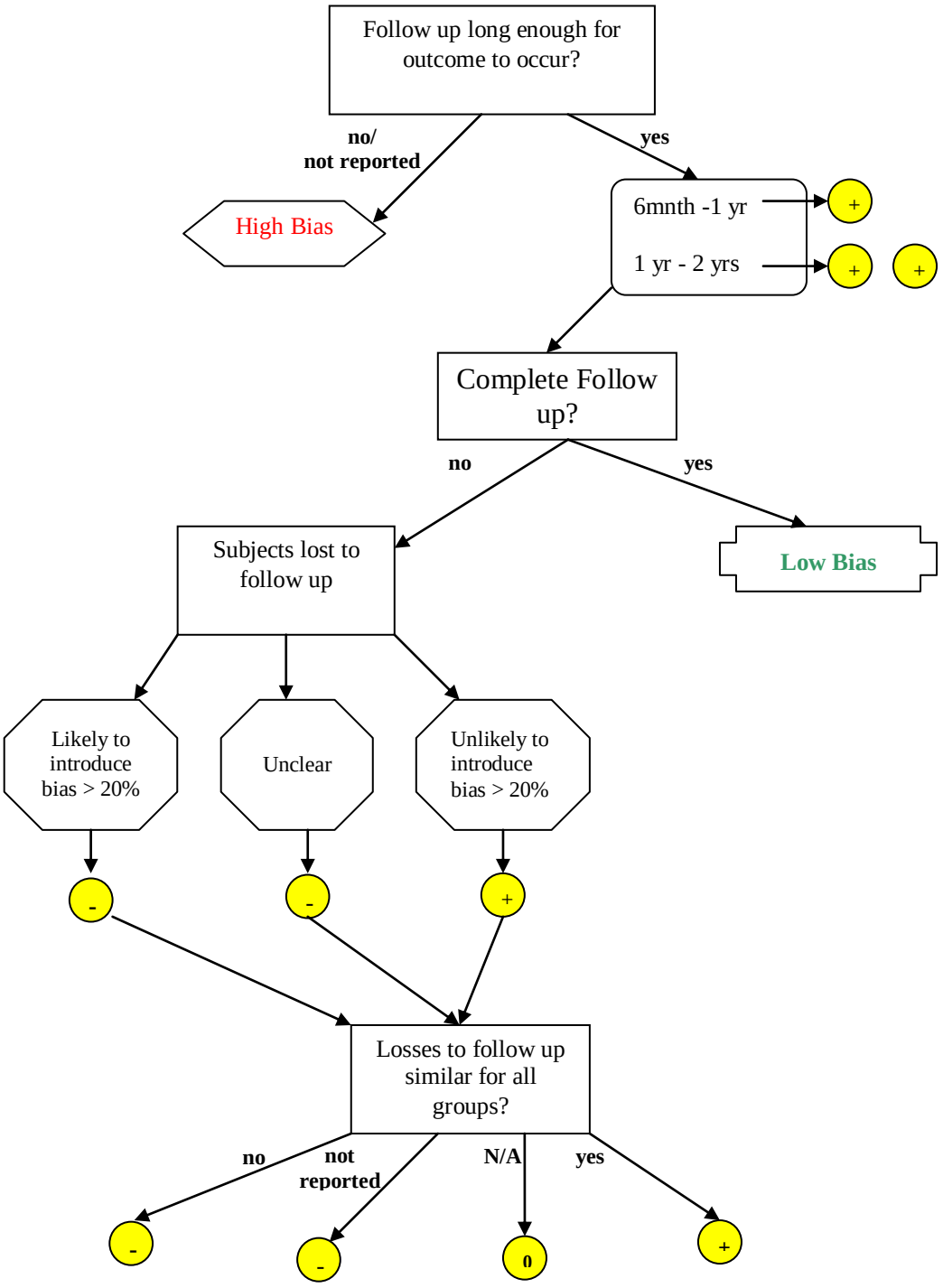


Figure 2.5 Flow chart for assigning attrition bias for the included studies

		Examiner 2 (SJC)		
Examiner 1 (SA)		**Low bias**	**High Bias**	***Total***
	Low bias	0	0	0
	High bias	1	8	9
	Total	1	8	9

Agreement on 8/9 articles = 89%

Kappa score could not be calculated as only one investigator (SJC) entered a low bias value

Table 2.6a Agreement for Selection (2nd stage of testing)

		Examiner 2 (SJC)		
Examiner 1 (SA)		**Low bias**	**High Bias**	***Total***
	Low bias	2	1	3
	High bias	0	6	6
	Total	2	7	9

Kappa = 0.727 (95% CI 0.223 to 1)

Table 2.6b Agreement and Kappa scores for Performance (2nd stage of testing)

		Examiner 2 (SJC)		
Examiner 1 (SA)		**Low bias**	**High Bias**	***Total***
	Low bias	0	0	0
	High bias	0	9	9
	Total	0	9	9

Kappa could not be calculated, but agreement was 100%

Table 2.6c Agreement and Kappa scores for Measurement/Outcome (2nd stage of testing)

		Examiner 2 (SJC)		
Examiner 1 (SA)		**Low bias**	**High Bias**	***Total***
	Low bias	8	1	9
	High bias	0	0	0
	Total	8	1	9

Agreement on 8/9 articles = 89%Kappa score could not be calculated as only one investigator (SJC) entered a high bias value

Table 2.6d Agreement and Kappa scores for Attrition

Final stage of quality assessment

The flow chart method was finally used for quality assessment of all 53 eligible articles and Kappa scores were calculated. As anticipated, the Kappa scores had improved greatly, and agreement was good between the two reviewers (Table 2.7a-d).

Examiner 2 (SJC)

Examiner 1 (SA)	**Low bias**	**High Bias**	***Total***
Low bias	1	0	1
High bias	4	48	52
Total	5	48	53

Kappa = 0.312 (95% CI 0 to 0.960)*

* NB Percentage agreement is 90.6% (see later comment)

Table 2.7a Agreement and Kappa scores for Selection (Final stage of testing)

Examiner 2 (SJC)

Examiner 1 (SA)	**Low bias**	**High Bias**	***Total***
Low bias	15	2	17
High bias	2	34	36
Total	17	36	53

Kappa = 0.827 (95% CI 0.664 to 0.990)

Table 2.7b Agreement and Kappa scores for Performance (Final stage of testing)

Examiner 2 (SJC)

Examiner 1 (SA)	**Low bias**	**High Bias**	***Total***
Low bias	5	1	6
High bias	2	45	47
Total	7	46	53

Kappa = 0.737 (95% CI 0.448 to 1.000)

Table 2.7c Agreement and Kappa scores for Measurement/Outcome (Final stage of testing)

		Examiner 2 (SJC)		
		Low bias	**High Bias**	***Total***
Examiner 1 (SA)	**Low bias**	41	2	43
	High bias	1	9	10
	Total	42	11	53

Kappa = 0.822 (95% CI 0.626 to 1.000)

Table 2.7d Agreement and Kappa scores for Attrition (Final stage of testing)

The kappa scores for performance, measurement and attrition (0.827, 0.737 and 0.822) were substantial or "almost perfect". On first impressions, the kappa score for selection (0.312) did not appear to be acceptable. However, on closer examination of the tables, there was disagreement between the two reviewers on only 4 out of the 53 articles. This is equivalent to a percentage agreement of 90.6% which is indeed acceptable and in line with the other results. This can be explained by the difficulties associated with the use and interpretation of kappa scores. The value of kappa depends upon the proportion of subjects in each category. Hence in this case although there were disagreements in only 4 articles, the direction of the difference was one sided and not evenly spread (they were all found to be high bias by SA and low bias by SJC). As such there were different proportions in the two categories when compared with the performance (Table 2.7b). Here there was also disagreement for 4 articles, but the differences were evenly spread between high and low bias. The reason for this difference is that the chance expected frequencies are very different (Altman, 1991). This highlights a shortcoming of using kappa scores and suggests that, at times, results should be interpreted with caution. As such it is also important to show the raw data where this is possible (Altman, 1991).

2.2.3 Analysis of the results of the systematic review

Analysis of the results of systematic reviews may be narrative or quantitative (involving statistical analysis) and it is acceptable for a systematic review not to contain a meta-analysis (O'Rourke and Detsky, 1989). The results of this review were analysed predominantly in a narrative manner which involved a structured summary and discussion of the study characteristics and findings. Hence the narrative synthesis used subjective rather than statistical methods to determine the direction of the effect, the

size of the effect, whether the effect was consistent across studies, and the strength of evidence for the effect. This was because, for the majority of studies included, a meta-analysis was neither feasible nor appropriate.

Meta-analysis is a statistical analysis of the results from independent studies, which generally aims to produce a single estimate of effect (Huque, 1988). Meta-analysis should only be carried out after assessing the methodological quality of studies and only if there is sufficient homogeneity to warrant pooling the estimates from the studies. Studies should ideally be free from clinical and methodological diversity, for example studies using different classification systems for TMD provide a biased comparison for establishing the effects of an intervention. Only a small number of subgroups in this review were sufficiently homogenous to enable a meta-analysis to be undertaken. The majority of the studies did not use a validated scale to measure TMD and as such it was not possible to include them for meta-analysis.

2.2.4 Methodology for the Meta-analysis

Meta-analysis is a two-stage process involving the calculation of an appropriate summary statistic for each of a set of studies followed by the combination of these statistics into weighted averages. The selection of a meta-analysis method should take into account the data type, choice of summary statistic, observed heterogeneity and the known limitations of the computational methods (Egger *et al.*, 2001). Based on this statement, the basic principles of conducting a meta-analysis as described by the Cochrane Handbook are as follows (Higgins and Green, 2009):

1. A summary statistic is calculated for each study which describes the treatment effects, or the effect size, observed in each individual study.
2. A pooled treatment effect estimate/effect size estimate is calculated as a weighted average of the treatment effect/effect size estimated in the individual studies.
3. The combination of treatment effect estimates across studies may incorporate an assumption that the studies are not all estimating the same treatment effect, but estimate treatment effects that follow a distribution across studies. This is the

basis of a random effects meta-analysis. Alternatively, it may be assumed that each study is estimating exactly the same quantity, and a fixed effect meta-analysis is performed.

4. The standard error of the pooled treatment effect/effect size can be used to calculate a confidence interval which communicates the precision of the pooled estimate

Summary statistics

In order to carry out a meta-analysis two pieces of information are required for each included study: 1) the estimated effect size and 2) a measure of the precision of the effect size.

Only the studies that used standardised methods for diagnosing and classifying TMD (in this instance, classification according to the Helkimo Index) were eligible for inclusion in the meta-analyses. The proportion of patients with TMD, and the change in proportion of patients with TMD were the basis for data analysis. For the purpose of this review only dichotomous data were used (TMD or no TMD). The effect size for each included study at each time point was calculated as:

$$\frac{\text{Number of patients with TMD}}{\text{Total number of patients}}$$

It was also necessary to calculate the standard error as a measure of the precision of the estimate for each study to be included in the meta-analysis. The standard error of the proportion [SE (p)]was calculated for each study as:

$$SE(p)=\sqrt{\frac{p(1-p)}{n}}$$

Where p is the proportion of patients with TMD, and n is the total number of patients.

Assessing Homogeneity

Assessing homogeneity between the studies is a very important aspect of carrying out a meta-analysis and may impact on the decision whether to use a fixed or random effects model. Thus it was important to consider to what extent the results of the studies were

consistent (homogenous). A heterogeneity test was undertaken prior to each meta-analysis; the heterogeneity statistic was given by:

$$\mathbf{Q= \sum w_i (\theta_i - \theta_{IV})^2}$$

For the purpose of these calculations the summary statistic, which in this case is the proportion (p) with the characteristic in each study, is denoted by $\boldsymbol{\theta_i}$ where i is the study index. Thus SE (p) will be denoted by SE ($\boldsymbol{\theta_i}$). The weights for each study **(w_i)** are a reciprocal of the squared standard error thus calculated as $\mathbf{w_i = 1/}$ SE $(\boldsymbol{\theta_i})^2$. The pooled proportion is denoted by $\boldsymbol{\theta_{IV}}$ and this is calculated by:

$$\boldsymbol{\theta_{IV} = \sum w_i \ \theta_i / \sum w_i}$$

N.B. this is also referred to as the Generic Inverse Variance method for calculating a pooled treatment effect or proportion (see later discussion).

This test assessed whether observed differences in results are compatible with chance alone. A low P-value provides evidence of heterogeneity of treatment effects/ effect size (variation in effect estimates beyond chance). Care must be taken in the interpretation of the test, a statistically significant result may indicate a problem with heterogeneity, but a non-significant result must not be taken as evidence of no heterogeneity. Some argue that, since clinical and methodological diversity continually occur in a meta-analysis, statistical heterogeneity is unavoidable and therefore that the test for heterogeneity is irrelevant to the choice of analysis and heterogeneity will always exist whether or not we detect it using a statistical test. Methods have been developed for quantifying inconsistency across studies that move the focus away from testing whether heterogeneity is present and rather on assessing its impact on the meta-analysis (Higgins *et al.*, 2003).

Fixed effect and random effects models

Once homogeneity was established, a decision was made on the type of meta-analysis model to be followed. A fixed effect meta-analysis provides a result that may be viewed as a typical treatment effect from the studies included in the analysis. In order to

calculate a confidence interval for a fixed effect meta-analysis the assumption is made that the true effect of treatment (in both magnitude and direction) is the same in every study (i.e. fixed across studies). This assumption implies that the observed differences among study results are due solely to chance, i.e. that there is no statistical heterogeneity (Egger *et al.,* 2001, Deeks *et al.,* 2008).

When there is heterogeneity that cannot readily be explained, a random effects approach is used. This involves an assumption that the effects being estimated in the different studies are not identical, but follow a distribution. The centre of this symmetrical distribution describes the average of the effects and its width describes the degree of heterogeneity. The conventional choice of distribution is a normal distribution. It is difficult to establish the validity of any distributional assumption, and this is a common criticism of the random effects meta-analysis (Deeks *et al.,* 2008). By using the random effects model it should not be assumed that heterogeneity is no longer an issue and the possible causes of heterogeneity should be explored where feasible (Deeks *et al.,* 2008). Heterogeneity was found in all of the results for this review and as such random effect models were used.

Generic inverse variance method

The analyses for the dichotomous variables were conducted using the generic inverse variance method where the weight given to each study was the inverse of the variance of the effect estimate (i.e. **1/** SE^2) (Deeks *et al.,* 2008). Thus, larger more precise studies, which have smaller standard errors are given more weight than smaller less precise studies, which have larger standard errors. This choice of weight minimises the imprecision (uncertainty) of the pooled effect estimate. The inverse variance method is widely applicable and can be used to combine any estimates that have standard errors available (Egger *et al.*, 2001).

For a fixed effect meta-analysis using the inverse variance method the weighted average is, as previously stated, calculated by:

Generic inverse variance weighted average $(\boldsymbol{\theta_{IV}}) = \sum \mathbf{w}_i \ \boldsymbol{\theta}_i / \sum \mathbf{w}_i$

However, more applicable to this review, the random effects, sometimes known as the DerSimonian and Laird model was used to present the results. This is a variation of the generic inverse variance method. Here the standard errors of the study-specific estimates SE($\boldsymbol{\theta_i}$) were adjusted to incorporate a measure of the extent of variation, or heterogeneity, among the treatment effects observed in different studies. The size of this adjustment can be estimated from the treatment effects and standard errors of the studies included in the meta-analysis (Deeks *et al.,* 2008). The formula for this calculation is not included as it beyond the scope of this review.

All calculations stated above were carried out using Stata™. This is a general purpose, command-line driven, programmable statistical package. Several meta-analytic methods can be carried out using Stata commands and outputs are then produced (Egger *et al.,* 2001).

2.3 Results

The results of the systematic review were summarised into evidence tables. These are listed below:

1. Study characteristics (Table 2.8)
2. Study participants (Table 2.9)
3. Orthognathic Intervention (Table 2.10)
4. Classification of TMD (Table 2.11)
5. Self reported TMD symptoms (Table 2.12)
6. Clinical TMJ signs (Table 2.13)
7. Percentage of patients presenting with confirmed TMD at the various time points (Table 2.14)
8. Change in TMJ signs and symptoms (Table 2.15)
9. TMD findings in studies using the Helkimo index (Table 2.16)
10. TMD findings in studies using the CMI index (Table 2.17)
11. Quality Assessment (Table 2.18)

Table 2.8 Study characteristics

Author, Year	Study Design	Prospective/Retrospective*	Description	Site†
Aghabeigi *et al.*, 2001	Cohort	Retrospective	83 patients surveyed. Records examined and survey sent to patients	Eastman Dental Institute, London, UK
Aoyama *et al.*, 2005	Cohort	Retrospective	37 consecutive patients compared before and after BSSO	Tokyo Medical and Dental University, Tokyo, Japan
Athanasiou and Melsen, 1992	Cohort	(Prospective)	36 adult patients followed longitudinally pre-surgery and again 6 months later	Royal Dental College, Aarhus, Denmark
Athanasiou and Yücel-Eroğlu, 1994	Cohort	(Prospective)	82 consecutively treated adults with various dentofacial deformities received combined orthodontic-surgical management	Royal Dental College, Aarhus, Denmark
Athanasiou *et al.*, 1996	Cohort	(Prospective)	43 patients studied to assess functional alteration in stomatognathic system following orthodontic-surgical management	Royal Dental College, Aarhus, Denmark
Azumi *et al.*, 2004	Cohort	(Retrospective)	13 patients evaluated to assess short term effects of mandibular distraction osteogenesis	Tohoku University, Sendai, Japan

Author, Year	Study Design	Prospective/Retrospective*	Description	Site†
Bailey *et al.*, 2001	Cohort	Retrospective	2074 patients records examined to evaluate trend in referral patterns for orthognathic surgery and acceptance of treatment	University of North Carolina, Chapel Hill, North Carolina, USA
Borstlap *et al.*, 2004a	Cohort	Prospective	222 patients undergoing BSSO evaluated pre and post-operatively for clinical parameters	Multi centre study. UMC St. Radbound, Nijmegen, The Netherlands
Borstlap *et al.*, 2004b	Cohort	Prospective	222 patients analysed for radiological changes in the TMJ after BSSO	Multi centre study. UMC St. Radbound, Nijmegen, The Netherlands
Cutbirth *et al.*, 1998	Cohort	(Retrospective)	100 mandibular deficiency patients who underwent BSSO - records evaluated	University of Texas, San Antonio, USA
Dahlberg *et al.*, 1995	Cohort	Prospective	53 consecutive patients examined clinically and with bilateral arthrography	University Hospital of Lund, Lund, Sweden
De Boever *et al.*, 1996	Cohort	(Prospective)	102 patients assessed for the relationship between TMD and malocclusion	Multi centre study. University of Texas Health Science Center, San Antonio, Texas, USA

Author, Year	Study Design	Prospective/Retrospective*	Description	Site†
De Clercq *et al.*, 1995	Cohort	Retrospective	317 consecutive patients who underwent orthognathic surgery - records evaluated pre and post-op	General Hospital St-John, Bruges, Belgium
De Clercq *et al.*, 1998	Cohort	Retrospective	296 patients questioned post-operatively	General Hospital St-John, Bruges, Belgium
Dervis and Tuncer, 2002	Case control	(Prospective)	50 orthognathic patients investigated for alterations in signs and symptoms of TMD compared with healthy controls	University of Istanbul, Istanbul, Turkey
Egermark *et al.*, 2000	Cohort	Retrospective	52 patients examined for signs and symptoms of TMD 5 years after surgery	Department of Oral and Maxillofacial Surgery, Halmstad, Sweden
Feinerman and Piecuch, 1995	Cohort	Retrospective	66 patients examined after BSSO	University of Connecticut, Farmington, USA
Flynn *et al.*, 1990	Cohort	N/R	40 patients who had received mandibular advancement surgery evaluated for TMD	Indiana University, Mesa, Arizona, USA
Forssell *et al.*, 1998	Cohort	Prospective	100 consecutive patients interviewed concerning regarding their surgery	Turku University, Turku , Finland

Author, Year	Study Design	Prospective/Retrospective*	Description	Site†
Gaggl *et al.*, 1999	Cohort	Prospective	25 patients examined before and after orthognathic surgery	University Hospital, Graz, Austria
Hackney *et al.*, 1989	Cohort	(Prospective)	18 patients studied for changes in intercondylar width and angle and correlated with TMJ symptoms after BSSO	University of Texas Health Science Centre, San Antonio, Texas, USA
Herbosa *et al.*, 1990	Cohort	(Prospective)	29 patients treated with Le Fort 1 osteotomy or segmental procedures and changes in condylar position compared	St Mary's Health Center, St Louis, MO, USA
Hoppenreijs *et al.*, 1998	Cohort	Retrospective	259 patients with VME and AOB analysed regarding TMJ sounds, condylar remodeling, and resorption	Multi centre study. Rijnstate Hospital Arnhem, The Netherlands
Hu *et al.*, 2000	Cohort/Case Control ?	(Prospective)	50 patients investigated for changes in TMJ function and condylar position after mandibular setback	West China University of Medical Sciences, Chengdu, China
Hwang *et al.*, 2000	Cohort	(Retrospective)	11 patients evaluated for condylar resorption post-orthognathic surgery	Department of Cranio-Maxillofacial Surgery, University Hospital, Zurich

Author, Year	Study Design	Prospective/Retrospective*	Description	Site†
Hwang *et al.*, 2004	Case control	(Retrospective)	34 patients studied to identify non-surgical risk factors for condylar resorption after orthognathic surgery	Seoul National University Dental Hospital, Seoul, South Korea
Kallela *et al.*, 2005	Cohort	Retrospective	40 consecutive patients who underwent BSSO advancement monitored 2.2 years post-operatively	Department of Oral and Maxillofacial Surgery, Helsinki University, Finland
Karabouta and Martis, 1985	Cohort	N/R	280 patients evaluated for TMD before and after BSSO	Department of Oral and Maxillofacial Surgery, University of Thessalonika, Thessalonika, Greece
Kerstens *et al.*, 1989	Cohort	N/R	480 patients observed for pre and post-operative TMJ symptoms. Patients had various dentofacial deformities and operated for dysgnathia	Department of Oral and Maxillofacial Surgery, Free University of Amsterdam, Amsterdam, The Netherlands
Lai *et al.*, 2002	Cohort	(Prospective)	23 patients operated by BSSO analysed for skeletal stability and TMJ signs and symptoms	Niigata University Graduate School of Medical and Dental Sciences, Niigata, Japan

Author, Year	Study Design	Prospective/Retrospective*	Description	Site†
Landes, 2004	Case Control	(Prospective)	30 patients evaluated - dynamic proximal segment positioning by intraoperative sonography versus splint and plate technique. Clinical dysfunction and disc dislocation also compared pre and post-operatively	Goethe University Medical Centre, Frankfurt, Germany
Link and Nickerson, 1992	Cohort	(Prospective)	39 patient undergoing orthognathic intervention evaluated for TMJ internal derangement pre and post-surgery	Vanderbilt University School of Medicine, Nashville, Tennessee, USA
Little *et al.*, 1986	Cohort	Retrospective	17 patients retrospectively evaluated for the effects of surgical orthodontic correction on the TMJ and related structures	University of Louisville School of Dentistry, Louisville, Kentucky, USA
Milosevic and Samuels, 2000	Case Control	(Prospective)	42 patients evaluated - the post orthodontic prevalence of TMD and functional occlusion contacts assessed in surgical and non surgical cases	Multi centre study. Department of Clinical Dental Sciences University of Liverpool, Liverpool, U.K
Motamedi, 1996	Case Study	Retrospective	13 patients evaluated and compared for the long-term outcome of bilateral and unilateral osteotomies of the mandible	Baqiyatallah Medical Centre Tehran, Iran

Author, Year	Study Design	Prospective/Retrospective*	Description	Site†
Nemeth *et al.*, 2000	RCT	Prospective	127 patients evaluated before and 2 years after surgery for signs and symptoms of TMD	Multi centre study. Private Clinic, Austin, Texas, USA University of Texas Health Science Center, San Antonio, Texas, USA
Nurminen *et al.*, 1999	Cohort	Retrospective	28 orthognathic patients questioned regarding motivation for starting treatment. Satisfaction with results evaluated on the basis of replies to a questionnaire and clinical exam	Institute of Dentistry Turku University, Turku, Finland
Onizawa *et al.*, 1995	Case Control	(Prospective)	30 patients investigated for alterations in TMJ function after orthognathic surgery. The study also compared the findings with those of healthy volunteers	Department of Oral and Maxillofacial Surgery, Medizinische Hochschule, Hannover, Germany
Pahkala and Heino, 2004	Cohort	(Prospective)	72 patients observed before and 2 years after surgical-orthodontic treatment for pre-operative and post-operative TMD	Kuopio University Hospital, Kuopio, Finland

Author, Year	Study Design	Prospective/Retrospective*	Description	Site†
Panula *et al.*, 2000	Case Control	Prospective	60 patients investigated in a controlled prospective 4 year follow-up study to examine the influence of orthognathic treatment on signs and symptoms of TMJ dysfunction	Multi center study. Vaasa Central Hospital, Seinajoki, Finland Central Hospital, University of Oulu, Finland
Raveh *et al.*, 1988	Cohort/Case Control ?	N/R	103 patients underwent sagittal split osteotomy and findings including dysfunction reported. New techniques for reproduction of condyle relation also evaluated.	University of Berne, Berne, Switzerland
Rodriguez-Garcia *et al.*, 1998	RCT	Prospective	124 patients with Cl II malocclusion examined, and the relationship between malocclusion and TMD before and after BSSO evaluated.	Multi center study University of Texas Health Science Center, San Antonio, Texas, USA
Schearlinck *et al.*, 1994	Cohort	Prospective	103 patients evaluated for skeletal stability, TMJ function, and inferior alveolar nerve function. The patients presented with mandibular hypoplasia and treated with BSSO	Department of Oral and Maxillofacial Surgery, Rijnstate Hospital, Arnhem, The Netherlands

Author, Year	Study Design	Prospective/Retrospective*	Description	Site†
Scott *et al.*, 1997	RCT	Prospective	58 patients studied to document the agreement between prospective clinical examinations and retrospective chart review in identifying signs and symptoms of TMD	Multi center study University of Texas Health Science Center, San Antonio, Texas, USA
Smith *et al.*, 1992	Cohort	Prospective	22 patients examined for signs and symptoms of TMD post-orthognathic surgery	University of Detroit, School of Dentistry, USA
Timmis *et al.*, 1986	Cohort	Prospective	28 BSSO patients evaluated - signs and symptoms of TMD and masticatory dysfunction investigated	University of Texas Health Science Center, San Antonio, Texas, USA
Ueki *et al.*, 2001	Cohort	(Prospective)	42 patients investigated for the relation between changes in condylar long axis and TMJ function after BSSO	Department of Oral and Maxillofacial Surgery, Kanazawa University, Kanazawa, Japan
Ueki *et al.*, 2002	Cohort	(Prospective)	42 patients studied to compare changes in TMJ morphology and clinical symptoms after BSSO	Department of Oral and Maxillofacial Surgery, Kanazawa University, Kanazawa, Japan
Upton *et al.*, 1984	Cohort	Retrospective	102 patients responded to a questionnaire exploring the relationship of surgical correction of skeletal disharmony with TMJ pain dysfunction	University of Michigan, Ann Arbor, Michigan, USA

Author, Year	Study Design	Prospective/Retrospective*	Description	Site†
Westermark *et al.*, 2001	Cohort	Retrospective	1,515 patients - paper reports TMD before and after orthognathic surgery based on patients own reports	Karolinska Hospital, Stockholm, Sweden
White and Dolwick, 1992	Cohort	Retrospective	75 patients studied retrospectively to assess the prevalence and variance of TMD in an orthognathic population	Department of Oral and Maxillofacial Surgery, University of Florida College of Dentistry, Gainesville, Florida, USA
Wolford *et al.*, 2003	Cohort	Retrospective	25 bimaxillary surgery patients treatment records evaluated for TMD signs and symptoms	Private practice Baylor College of Dentistry, Dallas, Texas, USA
Zhou *et al.*, 2001	Cohort	Retrospective	94 patients evaluated for the objective relationship between pre-operative psychological status and attitude and post-surgical experience of treatment	University of Hong Kong, Hong Kong, China

* Items placed in brackets are assumed to be either prospective or retrospective based on study information. N/R represents not reported and unable to assume from the study information.

† If the site is not reported, the country of first author was stated.

Table 2.9 Study Participants

Author, Year	Sample size	No. F	No. M	Age Range	Mean Age	Ethnicity	Inclusion /Exclusion criteria [$]	Skeletal Deformity / Malocclusion							
								SkI	SkII	SkIII	Deep[‡]	AOB[§]	Asymm	Unclear	N/R[**]
Aghabeigi *et al.*, 2001	83	Approx 2:1 ratio		15-60	25.8	N/R	All patients who responded to survey					✓			
Aoyama *et al.*, 2005	37	21	16	19-35	24	N/R	N/R								✓
Athanasiou and Melsen, 1992	36	25	11	17-23	N/R	N/R	CL, Sy, Cf, Edent, Hx of T			✓					
Athanasiou and Yücel-Eroğlu, 1994	82	N/R	N/R	17-39	N/R	N/R	CL, Sy, Cf, Edent, Hx of T								✓
Athanasiou *et al.*, 1996	43	N/R	N/R	17-39	N/R	N/R	CL, Sy, Cf, Edent, Hx of T					✓			
Azumi *et al.*, 2004	13	11	2	16-46	26[††] 30.7 35.7	N/R	N/R		✓						
Bailey *et al.*, 2001	2074	65%	35%	15 to>35	N/R	N/R	All patients records between 1984-1996 Patients not offered surgery								✓
Borstlap *et al.*, 2004a	222	169	53	14-53	25.2	N/R	Pre and post-op ortho Ps, Open bite, and Incomplete arches		✓						

Author, Year	Sample size	No. F	No. M	Age Range	Mean Age	Ethnicity	Inclusion /Exclusion criteria [$]	Skeletal Deformity / Malocclusion							
								SkI	SkII	SkIII	Deep[‡]	AOB[§]	Asymm	Unclear	N/R[**]
Borstlap *et al.*, 2004b	222	169	53	14-53	25.2	N/R	N/R		✓						
Cutbirth *et al.*, 1998	100	70	30	N/R	N/R	N/R	BSSO cases Maxillary surgery		✓						
Dahlberg *et al.*, 1995	53	33	20	17-53	28	N/R	N/R		✓	✓		✓	✓		
De Boever *et al.*,1996	102	75	27	15-48	29	N/R	BSSO cases, >14yrs, Ps, CA, Edent, Med, Pregnant		✓						
De Clercq *et al.*, 1995	196	150	46	14-24	35	N/R	Patients with normal/low angle (≤ 32º) and mand deficiency tx by adv, High angle (>32º) mandibular retrognathia Pts tx with bimax surgery CL, laterognathia and genioplasty only		✓		✓	✓			
De Clercq *et al.*, 1998	238	149	89	14-42	19.81	N/R	All patients Rx between Jan 1993- Aug 1994 CL, CA, Edent, Laterognathia and Genioplasty only								✓

Author, Year	Sample size	No. F	No. M	Age Range	Mean Age	Ethnicity	Inclusion /Exclusion criteria [$]	Skeletal Deformity / Malocclusion							
								SkI	SkII	SkIII	Deep[‡]	AOB[§]	Asymm	Unclear	N/R[**]
Dervis and Tuncer,2002	50	29	21	19-42	29.3	N/R	Ps, Le Fort II & III TMJ surgery, Deformity of condyle, Rigid fixation								✓
Egermark *et al.*, 2000	52	34	18	15-65	27	N/R	All orthognathic patients between 1988-1995								✓
Feinerman and Piecuch, 1995	66	42	24	N/R	36.5[§] 30.4	N/R	Pre-op TMJ exam in charts, Availability for follow up		✓	✓					
Flynn *et al.*, 1990	40	28	12	18-45	27.5	Caucasian	Age 18-45 yrs, Mand retrognathia, Ortho appliance removed by last evaluation Edent, Ps,		✓						
Forssell *et al.*, 1998	100	71	29	17-55	31	N/R	N/R		✓	✓	✓	✓	✓		
Gaggl *et al.*, 1999	25	20	5	19-32	23	N/R	N/R		✓						
Hackney *et al.*,1989	15	N/R	N/R	N/R	N/R	N/R	N/R		✓						

Author, Year	Sample size	No. F	No. M	Age Range	Mean Age	Ethnicity	Inclusion /Exclusion criteria [$]	Skeletal Deformity / Malocclusion							
								SkI	SkII	SkIII	Deep[‡]	AOB[§]	Asymm	Unclear	N/R[**]
Herbosa *et al.*,1990	29	19	10	16-33	20.2	N/R	N/R					✓			
Hoppenreijs *et al.*,1998	259	203	56	14-46	23.6	N/R	Mand retrognathia and AOB, Le Fort I, Complete clinical records CL, CA, T, amelogeneis imperfecta		✓			✓			
Hu *et al.*, 2000	50	32	18	18-35	N/R	Chinese	N/R			✓					
Hwang *et al.*, 2000	11	11	0	16-28	19	N/R	Post-op reduced condylar height, reduced OB, increased OJ CA, T, Facial asymmetry, Condylar resorption due to Med		✓	✓					
Hwang *et al.*, 2004	39	36	3	15-43	N/R	N/R	Post-op reduced condylar height, reduced OB, increased OJ CA, T, Facial asymmetry, Condylar resorption due to Med		✓			✓			
Kallela *et al.*, 2005	40	29	11	17-54	29	N/R	First 40 patients undergoing BSSO advancement		✓						

Author, Year	Sample size	No. F	No. M	Age Range	Mean Age	Ethnicity	Inclusion /Exclusion criteria [$]	Skeletal Deformity / Malocclusion							
								SkI	SkII	SkIII	Deep[‡]	AOB[§]	Asymm	Unclear	N/R[**]
Karabouta and Martis, 1985	280	N/R	N/R	N/R	N/R	N/R	N/R		✓	✓		✓	✓		
Kerstens *et al.*, 1989	480	N/R	N/R	N/R	N/R	N/R	N/R								✓
Lai *et al.*, 2002	23	15	8	17-32	20.9	N/R	CL, CA			✓		✓	✓		
Landes, 2004	30	17	13	16-44	25	N/R	N/R		✓	✓					
Link and Nickerson, 1992	39	33	6	17-47	29	Caucasian	All patients refered to one surgeon between 1986-1987 Class III malocclusions excluded		✓	✓		✓			
Little *et al.*, 1986	17	14	3	16-37	25.6	N/R	Hx of max impaction and availability to attend								✓
Milosevic and Samuels, 2000	42	N/R	N/R	N/R	22.6	N/R	Received fixed appliance, Rx to Class I CL	✓	✓	✓					
Motamedi, 1996	13	1	12	19-37	25.8	N/R	N/R						✓		

Author, Year	Sample size	No. F	No. M	Age Range	Mean Age	Ethnicity	Inclusion /Exclusion criteria [$]	Skeletal Deformity / Malocclusion							
								SkI	SkII	SkIII	Deep[‡]	AOB[§]	Asymm	Unclear	N/R[**]
Nemeth *et al.*, 2000	127	95	32	N/R	28.5[§] 30.4	N/R	Class II maloccoclusions, BSSO, >14 yrs, stable residence Med, Edent, Perio, Bimax cases, CA, Ps, Pregnancy		✓						
Nurminen *et al.*, 1999	28	19	9	18-46	31	Finnish	N/R		✓	✓		✓	✓		
Onizawa *et al.*, 1995	30	20	10	17-34	24	N/R	Deformity of condyle, TMJ surgery, Le Fort II and III	✓	✓	✓					
Pahkala and Heino, 2004	72	49	23	16-53	32	N/R	Sleep apnoea, Patients who moved away		✓	✓		✓	✓		
Panula *et al.*, 2000	60	49	11	16-56	33.2	N/R	N/R		✓	✓		✓			
Raveh *et al.*, 1988	103	N/R	N/R	N/R	N/R	N/R	N/R		✓	✓					
Rodrigues-Garcia *et al.*, 1998	124	92	32	15-57	30.2	N/R	Class II malocclusion, BSSO, >14 yrs Med, Edent, Perio,		✓						
Schearlinck *et al.*, 1994	103	71	32	14-43[§] 15-45	25.8[§] 23.7	N/R	Maxillary surgery, Genioplasty		✓						

Author, Year	Sample size	No. F	No. M	Age Range	Mean Age	Ethnicity	Inclusion /Exclusion criteria [$]	Skeletal Deformity / Malocclusion							
								SkI	SkII	SkIII	Deep[‡]	AOB[§]	Asymm	Unclear	N/R[**]
Scott *et al.*, 1997	58	44	14	14-57	30	N/R	Class II malocclusion, BSSO, >14 yrs Edent, Perio, CA, Ps, Bimax surgery		✓						
Smith *et al.*, 1992	22	14	8	15-53	26.3	Canadian	N/R		✓						
Timmis *et al.*, 1986	28	19	9	N/R	28.6[§] 27.1	N/R	N/R								✓
Ueki *et al.*, 2001	42	N/R	N/R	N/R	N/R	N/R	N/R			✓			✓		
Ueki *et al.*, 2002	42	N/R	N/R	15-37	23	Japanese	N/R			✓			✓		
Upton *et al.*, 1984	102	70	32	N/R	N/R	N/R	All orthognathic patients between 1978-1981		✓	✓		✓	✓		
Westermark *et al.*, 2001	1516	958	558	N/R	26	N/R	N/R		✓	✓		✓	✓		
White and Dolwick, 1992	75	55	20	N/R	24.6	N/R	N/R		✓	✓			✓		
Wolford *et al.*, 2003	25	23	2	14-49	N/R	N/R	Selected patients with confirmed TMJ disc derangement only, Min 12 month post-op r/v								✓

Author, Year	Sample size	No. F	No. M	Age Range	Mean Age	Ethnicity	Inclusion /Exclusion criteria [$]	Skeletal Deformity / Malocclusion							
								SkI	SkII	SkIII	Deep[‡]	AOB[§]	Asymm	Unclear	N/R[**]
Zhou *et al.*, 2001	94	54	40	N/R	N/R	Chinese	CL, CA			✓					

$ Key for inclusion exclusion criteria: CA= Craniofacial anomalies , CL = Clefts, Edent= edentulous patients, Med= Medical /mental conditions , Perio= Periodontal condition, Ps= Previous orthognathic surgery, Sy = Syndromes, T= trauma

[‡] Deep bite = includes low angle

[§] AOB = includes high angle

[**] N/R = Not reported

[††] Variable mean ages/ age range depending on the surgical group or gender

Table 2.10 Orthognathic Intervention

Author, Year	Orthognathic Interventions												
	Maxillary (solely)					Mandibular (solely)					Bimax Combination of procedures listed	Other Procedures	Comments
	Le Fort 1 Advancement	Le Fort 1 Inferior Reposition	Le Fort 1 Impaction	Le Fort 1 Unspecified	Surgical Expansion	BSSO Advancement	BSSO Setback	VRO Advancement	VRO Setback	Unspecified			
Aghabeigi *et al.*, 2001			✓								✓	Segmental procedures	
Aoyama *et al.*, 2005							✓						
Athanasiou and Melsen, 1992								✓					
Athanasiou and Yücel-Eroğlu, 1994				✓		✓			✓		✓		
Athanasiou *et al.*, 1996			✓						✓				
Azumi *et al.*, 2004												Distraction osteogenesis	
Bailey *et al.*, 2001													Intervention not reported
Borstlap *et al.*, 2004a						✓							

Author, Year	Orthognathic Interventions												
	Maxillary (solely)						Mandibular (solely)					Bimax Combination of procedures listed	Other Procedures	Comments
	Le Fort 1 Advancement	Le Fort 1 Inferior Reposition	Le Fort 1 Impaction	Le Fort 1 Unspecified	Surgical Expansion	BSSO Advancement	BSSO Setback	VRO Advancement	VRO Setback	Unspecified			
Borstlap *et al.*, 2004b						✓							
Cutbirth *et al.*, 1998						✓							
Dahlberg *et al.*, 1995	✓									✓		✓	Other procedures not reported
De Boever *et al.*, 1996						✓							
De Clercq *et al.*, 1995				✓						✓	✓		
De Clercq *et al.*, 1998				✓						✓	✓		
Dervis and Tuncer, 2002													Intervention not reported
Egermark *et al.*, 2000				✓						✓			
Feinerman and Piecuch, 1995				✓		✓	✓						
Flynn *et al.*, 1990						✓							
Forssell *et al.*, 1998				✓		✓	✓				✓	Genioplasty	
Gaggl *et al.*, 1999				✓		✓							

Author, Year	Orthognathic Interventions												
	Maxillary (solely)					Mandibular (solely)					Bimax Combination of procedures listed	Other Procedures	Comments
	Le Fort 1 Advancement	Le Fort 1 Inferior Reposition	Le Fort 1 Impaction	Le Fort 1 Unspecified	Surgical Expansion	BSSO Advancement	BSSO Setback	VRO Advancement	VRO Setback	Unspecified			
Hackney *et al.*, 1989						✓							
Herbosa *et al.*, 1990			✓										
Hoppenreijs *et al.*,1998				✓							✓	Genioplasty	
Hu *et al.*, 2000						✓			✓				
Hwang *et al.*, 2000										✓	✓		
Hwang *et al.*, 2004			✓			✓					✓		
Kallela *et al.*, 2005						✓							
Karabouta and Martis, 1985						✓	✓						
Kerstens *et al.*, 1989	✓					✓			✓		✓		
Lai *et al.*, 2002							✓		✓				
Landes, 2004						✓	✓						

Author, Year	Orthognathic Interventions												
	Maxillary (solely)					Mandibular (solely)					Bimax Combination of procedures listed	Other Procedures	Comments
	Le Fort 1 Advancement	Le Fort 1 Inferior Reposition	Le Fort 1 Impaction	Le Fort 1 Unspecified	Surgical Expansion	BSSO Advancement	BSSO Setback	VRO Advancement	VRO Setback	Unspecified			
Link and Nickerson, 1992			✓			✓		✓			✓		
Little *et al.*, 1986			✓										
Milosevic and Samuels, 2000													Intervention not reported
Motamedi, 1996										✓	✓		
Nemeth *et al.*, 2000						✓							
Nurminen *et al.*, 1999				✓						✓	✓		
Onizawa *et al.*, 1995				✓		✓	✓				✓		
Pahkala and Heino, 2004						✓	✓						
Panula *et al.*, 2000				✓		✓	✓				✓	Genioplasty	
Raveh *et al.*, 1988				✓		✓	✓				✓	Segmental procedure	
Rodrigues-Garcia *et al.*, 1998						✓							

Author, Year	Orthognathic Interventions												
	Maxillary (solely)						Mandibular (solely)					Bimax Combination of procedures listed	Other Procedures	Comments
	Le Fort 1 Advancement	Le Fort 1 Inferior Reposition	Le Fort 1 Impaction	Le Fort 1 Unspecified	Surgical Expansion	BSSO Advancement	BSSO Setback	VRO Advancement	VRO Setback	Unspecified			
Schearlinck *et al.*, 1994						✓							
Scott *et al.*, 1997						✓					✓	Genioplasty	
Smith *et al.*, 1992						✓							
Timmis *et al.*, 1986						✓	✓						
Ueki *et al.*, 2001							✓						
Ueki *et al.*, 2002							✓		✓		✓		
Upton *et al.*, 1984													Intervention not reported
Westermark *et al.*, 2001													Intervention not reported
White and Dolwick, 1992													Intervention not reported
Wolford *et al.*, 2003													Intervention not reported
Zhou *et al.*, 2001	✓									✓	✓	Genioplasty	

Table 2.11 Classification of TMD

Author, Year	How outcome was measured/assessed				Classification			
	Self report	Clinical examination	Radiographic	Other	Helkimo/ Modified Helkimo	EACD	CMI	No formal TMD classification presented
Aghabeigi *et al.*, 2001	✓	✓						✓
Aoyama *et al.*, 2005		✓						✓
Athanasiou and Melsen, 1992		✓			✓			
Athanasiou and Yücel-Eroğlu, 1994		✓			✓			
Athanasiou *et al.*, 1996		✓	✓		✓			
Azumi *et al.*, 2004		✓	✓					✓
Bailey *et al.*, 2001	Unclear							✓
Borstlap *et al.*, 2004a		✓						✓
Borstlap *et al.*, 2004b	✓	✓	✓‡‡					✓
Cutbirth *et al.*, 1998		✓						✓
Dahlberg *et al.*, 1995		✓		Arthrography				✓
De Boever *et al.*,1996		✓					✓	

Author, Year	How outcome was measured/assessed				Classification			
	Self report	Clinical examination	Radiographic	Other	Helkimo/ Modified Helkimo	EACD	CMI	No formal TMD classification presented
De Clercq *et al.*, 1995		✓						✓
De Clercq *et al.*, 1998	✓							✓
Dervis and Tuncer, 2002	✓	✓			✓			
Egermark *et al.*, 2000	✓	✓			✓			
Feinerman and Piecuch, 1995	✓	✓						✓
Flynn *et al.*, 1990	✓	✓						✓
Forssell *et al.*, 1998	✓§§							✓
Gaggl *et al.*, 1999		✓	✓					✓
Hackney *et al*, 1989	✓	✓						✓
Herbosa *et al.*, 1990		✓	✓*					✓
Hoppenreijs *et al.*, 1998		✓						✓
Hu *et al.*, 2000	✓	✓						✓
Hwang *et al.*, 2000			✓					✓
Hwang *et al.*, 2004			✓					✓

Author, Year	How outcome was measured/assessed				Classification			
	Self report	Clinical examination	Radiographic	Other	Helkimo/ Modified Helkimo	EACD	CMI	No formal TMD classification presented
Kallela *et al.*, 2005	✓	✓			✓			
Karabouta and Martis, 1985		✓						✓
Kerstens *et al.*, 1989	✓	✓						✓
Lai *et al.*, 2002		✓						✓
Landes, 2004		✓			✓			
Link and Nickerson, 1992		✓						✓
Little *et al.*, 1986	✓	✓			✓			
Milosevic & Samuels, 2000		✓			✓			
Motamedi, 1996		✓						✓
Nemeth *et al.*, 2000	✓	✓					✓	
Nurminen *et al.*, 1999	✓	✓						✓
Onizawa *et al.*, 1995	✓	✓						✓
Pahkala and Heino, 2004	✓	✓			✓			

Author, Year	How outcome was measured/assessed				Classification			
	Self report	Clinical examination	Radiographic	Other	Helkimo/ Modified Helkimo	EACD	CMI	No formal TMD classification presented
Panula *et al.*, 2000	✓	✓			✓			
Raveh *et al.*, 1988		✓						✓
Rodrigues-Garcia *et al.*, 1998	✓	✓					✓	
Schearlinck *et al.*, 1994		✓						✓
Scott *et al.*, 1997		✓					✓	
Smith *et al.*, 1992	✓	✓			✓			
Timmis *et al.*, 1986		✓						✓
Ueki *et al.*, 2001	✓†	✓						✓
Ueki *et al.*, 2002		✓	✓					✓
Upton *et al.*, 1984	✓							✓
Westermark *et al.*, 2001	✓							✓
White and Dolwick, 1992	✓							✓
Wolford *et al.*, 2003	✓†	✓						✓

Author, Year	How outcome was measured/assessed				Classification			
	Self report	Clinical examination	Radiographic	Other	Helkimo/ Modified Helkimo	EACD	CMI	No formal TMD classification presented
Zhou *et al*., 2001	✓							✓

‡‡ Condylar Morphology Scale (CMS), Pullinger Index used
§§ Included use of VAS/Likert scales

Table 2.12 Self-Reported TMD Symptoms[***]

Study, Year	Time interval	Joint Sounds			Pain								Jaw Movement			Other Symptoms		
		Click	Pop	Crepitus	TMJ	Jaw	Face	Muscles	Movement	Ear	Unspecified	Fatigue	Limited opening	Jaw Locking	Jaw deviation	Headache	Chewing Diff.	Parafunction
Aghabeigi *et al.*, 2001	Pre-Rx	38				45							3					
	Post-op	43				38							14					
De Clercq *et al.*, 1998	Pre-op	30				23 4.3±2.1[†††]							19	18			N/R	N/R
	1-2.5yrs Post-op	30				17 3.4±2.2[†]							21	18			57	13
Dervis and Tuncer, 2002	Pre-op															20		16
	2yrs Post-op															16		12
Egermark *et al.*, 2000	2-9.5yrs Post-op	50										18	25			83		69
Flynn *et al.*, 1990	1-5yrs Post-op	33		5		20						40		8			18	23
Forssell *et al.*, 1998	1 mnth Pre-op	3.5 ± 1.9[†]														3.6±2.1[†]		
	1 yr Post-op	1.9 ± 1.1[†]														1.7±1.3[†]		

Study, Year	Time interval	Joint Sounds			Pain								Jaw Movement			Other Symptoms		
		Click	Pop	Crepitus	TMJ	Jaw	Face	Muscles	Movement	Ear	Unspecified	Fatigue	Limited opening	Jaw Locking	Jaw deviation	Headache	Chewing Diff.	Parafunction
Hackney *et al.*,1989	Pre-op				17													
	6-12mnth Post-op				11													
Kallela *et al.*, 2005	Pre-op	28		3	28			15				20		3				
	1 yr Post-op	8		8	8			8				8		0				
	Longest follow up	3		3	13			5				5		0				
Nurminen *et al.*, 1999	Pre-op	32														32	68	
Pahkala and Heino, 2004	Pre-Rx													6		46		
	Mean 1.9yr Post-op													1		13		
Panula *et al.*, 2000	Pre-Rx															61		
	1 yr Post-op															18		
	Longest follow up															20		

Study, Year	Time interval	Joint Sounds			Pain								Jaw Movement			Other Symptoms		
		Click	Pop	Crepitus	TMJ	Jaw	Face	Muscles	Movement	Ear	Unspecified	Fatigue	Limited opening	Jaw Locking	Jaw deviation	Headache	Chewing Diff.	Parafunction
Rodrigues-Garcia *et al.*, 1998	Pre-op						46						2.06 ± 1.60[‡‡‡]					
	2 yr Post-op						32						1.61 ± 1.21[‡]					
Timmis *et al.*, 1986	Pre-op						39					0		4		7		
	6-36mnth Post-op						29					4		0		0		
Upton *et al.*, 1984	Pre-op	27	22		19		26						27					
Westermark *et al.*, 2001	Pre-op	24			11				9							10	9	5
	2 yr Post-op	20			6				4							3	4	2
White and Dolwick, 1992	Pre-op[§§§]	34	4	8	20			21					13			12		
Wolford *et al.*, 2003	Pre-op					3.7[†]							4.5[†]					
	Longest follow up					6.8[†]							4.8[†]					

Study, Year	Time interval	Joint Sounds			Pain								Jaw Movement			Other Symptoms		
		Click	Pop	Crepitus	TMJ	Jaw	Face	Muscles	Movement	Ear	Unspecified	Fatigue	Limited opening	Jaw Locking	Jaw deviation	Headache	Chewing Diff.	Parafunction
Zhou *et al.*, 2001	Post-op						83										71	

[***] Percentages have been rounded up
[†††] Visual Analoge Scale (VAS) rating
[‡‡‡] Oral Health Status Questionnaire 1=Mild, 7= Extreme
[§§§] Unclear whether finding reported are from clinical examination or patient questionnaire

Table 2.13 TMD Signs-Clinical Findings[****]

Author, Year	Time Interval (m= Month Y = year)	Joint Sounds			Pain						Range of jaw movement					Jaw Locking	Deviation
		Click (%)	Pop (%)	Crepitus (%)	TMJ (%)	Muscle (%)	Jaw (%)	Face (%)	Movement (%)	Ear (%)	MIO †††† (mm)	Lateral excursions (mm)			Limited opening (%)		
												Rt	Lt	N/S[#]			
Aoyama *et al.*, 2005	Pre-op	14			3	14									3		
	1y Post-op	11			11	19									8		
Athanasiou and Melsen, 1992	Pre-op	36[¥]			8	11					46.5	7.1	9		53		36[¥]
	6m Post-op	11[¥]			0	11					41.1	7.8	8.1		64		11[¥]
Athanasiou and Yücel-Eroğlu, 1994	Pre-op	32[¥]			10	16									32[¥]		
	6m Post-op	17[¥]			2	7									17[¥]		
Athanasiou *et al.*, 1996	Pre-op										Mn[‡‡‡‡] 46.2 Mx 45.5	Mn[‡] 8.2 Mx 9.1	Mn[‡] 8.3 Mx 9.1				
	6m Post-op										Mn[‡] 40.7 Mx 43.6	Mn[‡] 7.6 Mx 8.2	Mn[‡] 7.4 Mx 8.1				
Azumi *et al.*, 2004[§§§§]	Pre-op	27			4												
	Post distraction	0			8												
	After distraction removal	12			19												

Author, Year	Time Interval (m= Month Y = year)	Joint Sounds			Pain						Range of jaw movement					Jaw Locking	Deviation
		Click (%)	Pop (%)	Crepitus (%)	TMJ (%)	Muscle (%)	Jaw (%)	Face (%)	Movement (%)	Ear (%)	MIO †††† (mm)	Lateral excursions (mm)			Limited opening (%)		
												Rt	Lt	N/S#			
Borstlap *et al.*, 2004a	Pre-op	33			16						46.4			10.1			
	3m Post-op	22			17						37.6			6.6			
	6m Post-op	25			14						41.8			7.5			
	24m Post-op	28			10						45.6			8.3			
Borstlap *et al.*, 2004b	3m Post-op	25			24												
	6m Post-op	12			30												
	24m Post-op	17			26												
Cutbirth *et al.*, 1998	Pre-op	39			13												
	Post-op	18			5												
Dahlberg *et al.*, 1995	Pre-op	30		4	53												
De Boever *et al.*, 1996	Pre-op	36				8											
Dervis and Tuncer, 2002	Pre-op	38		24	20	70					49.5				10		28
	2y Post-op	28		30	14	40					48.3				10		14

Author, Year	Time Interval (m= Month Y = year)	Joint Sounds			Pain						Range of jaw movement					Jaw Locking	Deviation
		Click (%)	Pop (%)	Crepitus (%)	TMJ (%)	Muscle (%)	Jaw (%)	Face (%)	Movement (%)	Ear (%)	MIO †††† (mm)	Lateral excursions (mm)			Limited opening (%)		
												Rt	Lt	N/S#			
Egermark *et al.*, 2000	5y Post-op	25				23					52			8.4			17
Feinerman and Piecuch, 1995	Pre-op	52			20	33					IMF 48.6 ***** RF 49.7	Authors report that results are incomplete					
	2-9y Post-op	49			14	29					IMF** 48.6 RF 47.6	IMF** 8.2 RF 9.7	IMF** 8.6 RF 9.3				
Flynn *et al.*, 1990	1-5y Post-op	30		10	13	28					43.5						8
Gaggl *et al.*, 1999	Pre-op	88		36		28					47.5						88
	3m Post-op	52		16		12					35.5						96
Hackney *et al.*, 1989	Pre-op	22			17						> 40						0
	6-12m Post-op	17			11						> 40						0
Herbosa *et al.*, 1990	Pre-op	28	4	4		28								10.2 to 10.3			
	6-18m Post-op	17	0	4		7								9.4 to 9.8			

Author, Year	Time Interval (m= Month Y = year)	Joint Sounds			Pain						Range of jaw movement					Jaw Locking	Deviation
		Click (%)	Pop (%)	Crepitus (%)	TMJ (%)	Muscle (%)	Jaw (%)	Face (%)	Movement (%)	Ear (%)	MIO †††† (mm)	Lateral excursions (mm)			Limited opening (%)		
												Rt	Lt	N/S#			
Hoppenreijs *et al.*, 1998	Pre-Rx	RHS 38 LHS 40									N/A						
	Latest Follow up	RHS 31 LHS 32									45						
Hu *et al.*, 2000	Pre-op										46.2‡ 45.9						
	6m Post-op										42.1‡ 44.5						
Kallela *et al.*, 2005	Pre-op	25		23	13	13					44.7						
	1y Post-op	13		3	8	3					44.7						
	Latest Follow up	8		5	13	0					45.9						
Karabouta and Martis, 1985	Pre-op	41			29										4		30
	6m Post-op	6			4										3		5
Landes, 2004	3m Post-op										47% †††††			66%			
	6m Post-op										76%††			96%			
	1y Post-op										90%††			109 %			
Link and Nickerson, 1992	Pre-op										50						
	Post-op										44						

Author, Year	Time Interval (m= Month Y = year)	Joint Sounds			Pain						Range of jaw movement					Jaw Locking	Deviation
		Click (%)	Pop (%)	Crepitus (%)	TMJ (%)	Muscle (%)	Jaw (%)	Face (%)	Movement (%)	Ear (%)	MIO †††† (mm)	Lateral excursions (mm)			Limited opening (%)		
												Rt	Lt	N/S#			
Little *et al.*, 1986	Post-op	30				6									18		
Milosevic & Samuels, 2000	Post-op										42.0	4.8	4.6				
Nemeth *et al.*, 2000	Pre-op	47		4													
	1y Post-op	29		11													
Onizawa *et al.*, 1995	Pre-op	50			30						50.1	8.0	7.4				40
	3m‡‡‡‡‡										II 35.4 III 37.3	II 5.4 III 6.5	II 5.2 III 5.8				
	6m‡‡										II 40.6 III 41.3	II 6.7 III 6.9	II 6.5 III 6.5				
Pahkala and Heino, 2004	Pre-Rx	35		8	21	32											28
	~2y Post-op	13		12	10	22											26
Panula *et al.*, 2000	Pre-Rx	42		22	45	50									0		
	1y Post-op	42		20	12	20									13		
	Latest Follow up	48		10	18	18									10		

Author, Year	Time Interval (m= Month Y = year)	Joint Sounds			Pain						Range of jaw movement					Jaw Locking	Deviation
		Click (%)	Pop (%)	Crepitus (%)	TMJ (%)	Muscle (%)	Jaw (%)	Face (%)	Movement (%)	Ear (%)	MIO †††† (mm)	Lateral excursions (mm)			Limited opening (%)		
												Rt	Lt	N/S#			
Raveh *et al.*, 1988	Pre-op	6		3	6												
	1-4 y Post-op	4		2	1												
Rodrigues-Garcia *et al.*, 1998	Pre-op	49	14	5													
	2 y Post-op	24	8	15													
Schearlinck *et al.*, 1994	Pre-op										46.8						
	1 y Post-op	6				13					45.8					2	
Scott *et al.*, 1997§§§§§	8 weeks Post-op	R 3 CE 17		R 0 CE 2	R 9 CE 48										R N/R CE 90		
	6m Post-op	R 3 CE 43		R 0 CE 3	R 2 CE 48										R N/R CE 45		
	1y Post-op	R 3 CE 33		R 0 CE 12	R 2 CE 45										R 0 CE 33		
	2y Post-op	R 7 CE 50		R 2 CE 10	R 3 CE 29										R 3 CE 21		
Smith *et al.*, 1992	Pre-op	50		9							49.7	9.9	8.9				
	6-7m Post-op	64		9							44.8	8.6	8.5				

Author, Year	Time Interval (m= Month Y = year)	Joint Sounds			Pain						Range of jaw movement					Jaw Locking	Deviation
		Click (%)	Pop (%)	Crepitus (%)	TMJ (%)	Muscle (%)	Jaw (%)	Face (%)	Movement (%)	Ear (%)	MIO †††† (mm)	Lateral excursions (mm)			Limited opening (%)		
												Rt	Lt	N/S#			
Timmis *et al.*, 1986	Pre-op	54			4	18											25
	6-36m Post-op	36			4	14											18
Ueki *et al.*, 2001	Pre-op	62		7							SP ****** 44.4 BP 49.6						
	1y Post-op	19		7							SP*** 40.7 BP 45.8						
Westermark *et al.*, 2001	Pre-op	24													N/R		
	2y Post-op	N/R													10		
White and Dolwick, 1992	Pre-op	35	4	8	20	21									13		
Wolford *et al.*, 2003	Pre-op	64			16						48.6			8.3			
	Longest Follow up	16			24						40.7			6.7			

**** All percentages have been rounded up

¥ The results are for both clicks and deviations combined

†††† MIO= maximal incisal opening. All figures quoted are means unless a range is specified
# Not Specified
‡‡‡‡ Results are subdivided according to surgical groups e.g. (mandibular osteotomy and maxillary osteotomy)
§§§§ Study looked at number of joints affected not patients
***** Results are subdivided according to Inter maxillary fixation surgical group and rigid fixation group
††††† Range of motion on mouth opening was reduced to the following percentages
‡‡‡‡‡ Results are subdivided according to skeletal group
§§§§§ This study evaluated retrospective (records =R) and prospective (clinical exam=CE) evaluation of TMD after orthognathic surgery
****** Results are subdivided according to fixation method SP=straight plate BP=bent plate

Table 2.14 Percentage of patients presenting with confirmed TMD at the various time points[††††††]

Author, Year	Pre Ortho %	Pre Surgery %	< 6 mnths Post-op %	≥ 6 mnths Post-op %	≥ 1 yr Post-op %	≥ 2 yrs Post-op %
Aghabeigi *et al.*, 2001	40					45
Aoyama *et al.*, 2005		30				38
Athanasiou and Melsen 1992		67		67		
Athanasiou and Yücel-Eroğlu, 1994		66		62		
Athanasiou *et al.*,1996[‡‡‡‡‡‡]		Mn 62 Mx 88		Mn 77 Mx 71		
Borstlap *et al.*, 2004a		39		31		31
Cutbirth *et al.*, 1998		7				
Dahlberg *et al.*, 1995		53				
De Boever *et al.*, 1996		58				
De Clercq *et al.*, 1995		26		18		
Dervis and Tuncer, 2002		60				38
Herbosa *et al.*, 1990		38			21	

Author, Year	Pre Ortho %	Pre Surgery %	< 6 mnths Post-op %	≥ 6 mnths Post-op %	≥ 1 yr Post-op %	≥ 2 yrs Post-op %
Hu *et al.*, 2000		44				
Kallela *et al.*, 2005		73				48
Karabouta and Martis, 1985		41			11	
Kerstens *et al.*, 1989		16				
Lai *et al.*, 2002		26			4	
Landes, 2004§§§§§§		II 64 III 21			II 7 III 0	
Little *et al.*, 1986		47	59			
Milosevic and Samuels, 2000				43		
Motamedi, 1996		69				
Nurminen *et al.*, 1999	32					
Onizawa *et al.*, 1995		67				
Pahkala and Heino, 2004	78					
Panula *et al.*, 2000	73					60
Raveh *et al.*, 1988		28				

Author, Year	Pre Ortho %	Pre Surgery %	< 6 mnths Post-op %	≥ 6 mnths Post-op %	≥ 1 yr Post-op %	≥ 2 yrs Post-op %
Rodrigues-Garcia *et al.*, 1998		46				74
Schearlinck *et al.*, 1994		46				
Smith *et al.*, 1992[********]		A 73 C 82				
Ueki *et al.*, 2001		43				
Ueki *et al.*, 2002		74				
Upton *et al.*, 1984		53				
Westermark *et al.*, 2001		43				28
White and Dolwick, 1992		49				
Wolford *et al.*, 2003		36				84

[††††††] Percentages have been rounded up
[‡‡‡‡‡‡] The results have been divided into two groups depending on surgery type Mn= Mandibular osteotomy group and Mx = Maxillary osteotomy group
[§§§§§§] The results have been presented according to skeletal classification II = Skeletal II, III= Skeletal III
[********] A= TMD diagnosis based on Anamnestic evaluation C= TMD diagnosis based on Clinical evaluation

Table 2.15 Change in TMJ signs and symptoms

Author, Year	Sign/ symptom	Initial Time Point		Follow Up Time Point †††††††					
		Initial Time interval	% Affected	Follow up Time interval	% Affected	% Same	% Better	% Worse	% New symptoms/signs
Aghabeigi *et al.*, 2001	Pain	Pre-Rx	40	1 yr Post-op	45	30	N/R	8	N/R
	Dysfunction		N/R‡‡‡‡‡‡		43	32	N/R	11	N/R
Aoyama *et al.*, 2005	TMD Diagnosis	Pre-op	29	1 yr Post-op	38	60	16	24	
Athanasiou and Melsen, 1992	Muscular pain	Pre-op	11	6 mnth Post-op	11				
	Mandibular mobility		53		67				
	TMJ function		39		11				
	TMJ pain		8		0				
Athanasiou and Yücel-Eroğlu, 1994	TMD Diagnosis	Pre-op	66	6 mnth Post-op	62	n = 1	n = 11	n = 8	

Author, Year	Sign/ symptom	Initial Time Point		Follow Up Time Point †††††††					
		Initial Time interval	% Affected	Follow up Time interval	% Affected	% Same	% Better	% Worse	% New symptoms/signs
Athanasiou *et al.*, 1996	TMD in mandibular osteotomy group	Pre-op	62	6 mnth Post-op	77			15	
	TMD in maxillary osteotomy group	Pre-op	88	6 mnth Post-op	71		18		
Azumi *et al.*, 2004	TMJ symptoms	Pre-op	n= 6 N=13	Post-op	n=7	n=1	n=6	n=7	
Borstlap *et al.*, 2004a	TMD Diagnosis	Pre-op	39	24 mnth Post-op	30	44			22
Cutbirth *et al.*, 1998	Click	Pre-op	39	Post-op			21	10	
	Pain		13				8	10	
De Clercq *et al.*, 1995	TMD Diagnosis	Pre-op	27	6 mnth Post-op	18		n=34	n=17	

Author, Year	Sign/ symptom	Initial Time Point		Follow Up Time Point †††††††					
		Initial Time interval	% Affected	Follow up Time interval	% Affected	% Same	% Better	% Worse	% New symptoms/signs
De Clercq *et al.*, 1998				1 to 2.5 yrs Post-op		49	40	11	
Dervis and Tuncer, 2002	TMD Diagnosis	Pre-op	60	2 yr Post-op	38				10
Egermark *et al.*, 2000	TMD Diagnosis			2.2 to 9.5 yrs Post-op		37	51	12	
	Headache					33	67	-	
	Chewing ability					17	81	-	
Feinerman and Piecuch, 1995	Click	Pre-op	52	2.5 to 9 yrs Post-op	49	n=7	n=23	n=4	
	TMJ pain		20		14	n=2	n=10	n=1	
	Muscle pain		33		29	n=5	n=16	n=1	
Hackney *et al.*, 1989	Click	Pre-op	22	6 to 12 mnth Post-op	17	6	17	11	
	TMJ pain		17			11	6		

Author, Year	Sign/ symptom	Initial Time Point		Follow Up Time Point †††††††					
		Initial Time interval	% Affected	Follow up Time interval	% Affected	% Same	% Better	% Worse	% New symptoms/signs
Hu *et al.*, 2000	TMD Diagnosis	Pre-op	22	6 mnth Post-op		41	55	10	
Hwang *et al.*, 2004	TMJ sounds	Pre-op	59	2 yrs Post-op	46		26		26
	TMJ pain		21		28				
Kallela *et al.*, 2005	1 or more signs or symptoms of TMD	Pre-op	73	Latest Follow up 1 to 5 yrs Post-op	48		41	18	
Karabouta and Martis, 1985	1 or more signs or symptoms of TMD	Pre-op	41 n=114 N=280	Post-op	11.1 n=12 N=114				4 n=6 N=166
Kerstens *et al.*, 1989	TMJ pain & dysfunction	Pre-op	16	1.4 to 4.7 yrs Post-op			66	12	
Lai *et al.*, 2002	Clicking ± Pain	Pre-op	26 n=6 N=23	≥ 6 mnth Post-op	4	n=0	n=6		n=1

Author, Year	Sign/ symptom	Initial Time Point		Follow Up Time Point †††††††					
		Initial Time interval	% Affected	Follow up Time interval	% Affected	% Same	% Better	% Worse	% New symptoms/signs
Little *et al.*, 1986	TMD Diagnosis	Pre-op	47 n=8 N=17	1.4 to 4.7 yrs Post-op	59 n=10 N=17	6 n=1	35 n=6	41 n=7	35 n=6
Onizawa *et al.*, 1995	1 or more subjective findings	Pre-op	67	6 mnth Post-op		33	30	17	
Pahkala and Heino, 2004	TMD Diagnosis	Pre-Rx	78 n=56 N=72	1.9 yrs Post-op	67 n=48 N=72		51 n=37 N=72	14 n=10 N=72	
	TMJ pain					n=4	n=11		n=3
	Clicking					n=5	n=20		n=4
	Crepitation					n=5	n=1		n=4
	Locking					n=0	n=4		n=1
	Muscle pain					n=10	n=13		n=6
	Deviation					n=5	n=15		n=14
	Headache					n=6	n=27		n=3

Author, Year	Sign/ symptom	Initial Time Point		Follow Up Time Point †††††††					
		Initial Time interval	% Affected	Follow up Time interval	% Affected	% Same	% Better	% Worse	% New symptoms/signs
Panula *et al.*, 2000	1 or more signs or symptoms of TMD	Pre-Rx	73	29 mnth Post-op	60				7
Raveh *et al.*, 1988	TMD e.g. pain, subluxation and clicking	Pre-op	28	1 to 4yrs Post-op		26	64	7	
Rodriguez-Garcia *et al.*, 1998	Pain	Pre-op	46	2yrs Post-op	31	19	27	13	
Schearlinck *et al.*, 1994	TMD Diagnosis	Pre-op	46 n=47 N=103	Post-op		20	68	12	11 n=11 N=103
Scott *et al.*, 1997	N/R								

Author, Year	Sign/ symptom	Initial Time Point		Follow Up Time Point †††††††					
		Initial Time interval	% Affected	Follow up Time interval	% Affected	% Same	% Better	% Worse	% New symptoms/signs
Smith *et al.*, 1992	TMD Anamnestic evaluation	Pre-op	73	6 to 7 mnths Post-op		50	32	18	
	TMD Clinical evaluation		82			64	18	18	
	Clicks					67	13	20	
Ueki *et al.*, 2001	TMD Diagnosis	Pre-op	67 n=28 N=42	1 yr Post-op			64 n=18 N=28		
Ueki *et al.*, 2002	TMD-based on radiographic examination	Pre-op	74 n=32 N=43	6 mnth Post-op			n=21		
Upton *et al.*, 1984	TMJ pain & dysfunction symptoms	Pre-op	53	Post-op		16	78	5	8.5

Author, Year	Sign/ symptom	Initial Time Point		Follow Up Time Point †††††††					
		Initial Time interval	% Affected	Follow up Time interval	% Affected	% Same	% Better	% Worse	% New symptoms/signs
Westermark, 2001	1 or more signs or symptoms of TMD	Pre-op	43	2 yrs Post-op	28				21
White and Dolwick, 1992	TMD Diagnosis	Pre-op	49	Post-op		3	89	8	8
Zhou *et al.*, 2001	Pain	Pre-op	54	Post-op			51		
	Clicking		55				67		

††††††† Where possible percentages are reported, otherwise n= denotes the number of patients affected and N= total number of patients in the group
‡‡‡‡‡‡‡ N/R = Not reported

Table 2.16 TMD findings in studies using the Helkimo Index

Study, Year	Dysfunction Severity	Initial Time Interval		Follow Up Time Interval				
		Initial time interval	% Affected	Follow up time interval	% Affected	% Same	% Better	% Worse
Athanasiou and Melsen, 1992		**Pre-op**		**6 months post-op**				
	Di0§§§§§§§	33		33				
	Di1	58		58				
	D2	8		8				
Athanasiou and Yücel-Eroğlu, 1994		**Pre-op**		**6 months post-op**				
	Di0	34		38				
	Di1	49		51				
	Di2	17		11				
Athanasiou *et al.*, 1996		**Pre-op**		**6 months post-op**				
	Di0	28		26				
	Di1+Di2	72		74				
Dervis and Tuncer, 2002	No break down reported							
Egermark *et al.*, 2000		**Pre-op**		**2.2 to 9.5 years post-op**				
	Di0	N/R		35				
	Di1	N/R		50				
	Di2	N/R		13				
	Di3	N/R		2				

Study, Year	Dysfunction Severity	Initial Time Interval		Follow Up Time Interval				
		Initial time interval	**% Affected**	**Follow up time interval**	**% Affected**	**% Same**	**% Better**	**% Worse**
Kallela *et al.*, 2005		**Pre-op**		**1 to 5 years post-op**				
	Ai0	50		80				
	Ai1	18		10				
	Ai2	32		10				
	Di0	43		58				
	Di1	50		38				
	Di2	7		5				
	Di3	0		0				
Landes, 2004	No break down reported							
Little *et al.*, 1986		**Pre-op**		**1 to 4.7 years post-op**				
	Ai0********	53		41				
	Ai1	24		47				
	Ai2	24		13				
	Di0	N/R		35				
	Di1	N/R		53				
	Di2	N/R		12				
	Di3	N/R		0				

Study, Year	Dysfunction Severity	Initial Time Interval		Follow Up Time Interval				
		Initial time interval	**% Affected**	**Follow up time interval**	**% Affected**	**% Same**	**% Better**	**% Worse**
Milosevic and Samuels, 2000		**Pre-op**		**At least 6 months post-debond**				
	Di0	N/R		57				
	Di1	N/R		43				
	Di2	N/R		0				
	Mi0††††††††	N/R		10				
	Mi1	N/R		50				
	Mi2	N/R		40				
Pahkala and Heino, 2004		**Pre-op**		**Mean of 1.9 years post-op**				
	Di0	22		33				
	Di1	36		58				
	Di2	31		8				
	Di3	11		0				
Panula *et al.*, 2000‡‡‡‡‡‡‡		**Pre-op**		**Mean of 2.5 years post-op**				
	Ai0	~12		~50				
	Ai1	~68		~48				
	Ai2	~20		~2				
	Di0	~4		~8				
	Di1	~13		~38				
	Di2	~75		~54				
	Di3	~8		~0				

Study, Year	Dysfunction Severity	Initial Time Interval		Follow Up Time Interval				
		Initial time interval	**% Affected**	**Follow up time interval**	**% Affected**	**% Same**	**% Better**	**% Worse**
Smith *et al.*, 1992		**Pre-op**		**6-7 months post-op**				
	Ai0	27		23		50	32	18
	Ai1	46		73				
	Ai2	27		4				
	Di0	18		9		64	18	18
	Di1	46		68				
	Di2	36		23				
	Di3	0		0				

§§§§§§§ Helkimo's Dysfunction Index
Di0 = No dysfunction
Di1= Mild dysfunction
Di2= Moderate dysfunction
Di3= Severe dysfunction

******** Helkimo's Anamnestic Index
Ai0= Symptom free
Ai1= Mild symptoms
Ai2= Severe symptoms

†††††††† Helkimo's Mandibular Mobility Index
Mi0= Normal mobility
Mi1= Mild impairment
Mi2= Severely impaired

‡‡‡‡‡‡‡ Percentages reported in this study are approximate only and have been taken from the graph in the published article.

Table 2.17 Findings in studies using the Cranio Mandibular Index (CMI)§§§§§§§§

Study, Year	Initial Time Point				Follow Up Time Point			
	Initial time Interval	**CMI**	**M*i***	**D*i***	**Follow up time Interval**	**CMI**	**M*i***	**D*i***
De Boever *et al.*, 1996	Pre-ortho	0.18	0.18	0.17	Pre-op	0.17	0.20	0.15
Nemeth *et al.*, ********* 2000	Pre-op	N/R	N/R	N/R	2y Post-op	WF 0.05††††††††† RF 0.04‡	WF 0.08‡ RF 0.08‡	WF 0.02‡ RF 0.01‡
Rodrigues-Garcia *et al.*, 1998	Pre-op	0.14	0.15	0.13	2y Post-op	0.10	0.08	0.12
Scott *et al.*, 1997	Values not reported							

§§§§§§§§ The CMI consists of two sub-indices: The Dysfunction Index (D*i*) and the Muscle Index (M*i*). All three indices range from 0 to 1, with 1 indicating the highest level of clinical dysfunction

********* Results for this study were divided according to patient group. WF= wire fixation, RF= rigid fixation

††††††††† The values indicate the change between pre-op and post-op scores (not actual CMI, M*i* and D*i* scores)

Table 2.18 Quality Assessment‡‡‡‡‡‡‡‡‡

Author, Year	Selection SA	Selection SJC	Performance SA	Performance SJC	Measurement SA	Measurement SJC	Attrition SA	Attrition SJC	Overall Bias
Aghabeigi *et al.*, 2001	High	High	Low	Low	High	High	Low	Low	**High**
Aoyama *et al.*, 2005	High	High	High	High	High	High	Low	Low	**High**
Athanasiou and Melsen, 1992	High	High	High	High	High	High	Low	Low	**High**
Athanasiou and Yücel-Eroğlu,1994	Low	Low	Low	Low	High	High	Low	Low	**High**
Athanasiou *et al.*, 1996	High	High	High	High	High	High	High	High	**High**
Azumi *et al.*, 2004	High	High	Low	Low	High	High	Low	Low	**High**
Bailey *et al.*, 2001	High	High	High	High	High	High	Low	Low	**High**
Borstlap *et al.*, 2004a	High	High	Low	Low	High	High	Low	Low	**High**
Borstlap *et al.*, 2004b	High	High	Low	Low	Low	High	Low	Low	**High**
Cutbirth *et al.*, 1998	High	High	High	High	High	High	Low	Low	**High**
Dahlberg *et al.*, 1995	High	High	High	High	High	High	Low	Low	**High**
De Boever *et al.*, 1996	High	High	Low	Low	Low	Low	Low	Low	**High**

Author, Year	Selection SA	Selection SJC	Performance SA	Performance SJC	Measurement SA	Measurement SJC	Attrition SA	Attrition SJC	Overall Bias
De Clercq *et al.*, 1995	High	High	High	High	High	High	Low	High	**High**
De Clercq *et al.*, 1998	High	High	High	High	High	High	Low	Low	**High**
Dervis and Tuncer, 2002	High	High	High	High	High	High	Low	Low	**High**
Egermark *et al.*, 2000	High	High	Low	Low	High	High	Low	Low	**High**
Feinerman and Piecuch, 1995	High	Low	High	High	High	High	Low	Low	**High**
Flynn *et al.*, 1990	High	High	High	High	High	High	Low	Low	**High**
Forssell *et al.*, 1998	High	High	High	High	High	High	Low	Low	**High**
Gaggl *et al.*,1999	High	High	High	High	High	High	High	High	**High**
Hackney *et al.*, 1989	High	High	High	High	High	High	High	High	**High**
Herbosa *et al.*, 1990	High	High	High	High	High	High	Low	Low	**High**
Hoppenreijs *et al.*, 1998	High	High	High	High	High	High	Low	Low	**High**
Hu *et al.*, 2000	High	High	Low	Low	High	High	Low	Low	**High**
Hwang *et al.*, 2000	High	High	High	Low	High	High	Low	Low	**High**

Author, Year	Selection SA	Selection SJC	Performance SA	Performance SJC	Measurement SA	Measurement SJC	Attrition SA	Attrition SJC	Overall Bias
Hwang *et al.*, 2004	High	High	High	High	High	High	Low	Low	**High**
Kallela *et al.*, 2005	High	High	High	High	High	High	Low	Low	**High**
Karabouta and Martis, 1985	High	High	Low	Low	High	Low	High	Low	**High**
Kerstens *et al.*, 1989	High	High	High	High	High	High	Low	Low	**High**
Lai *et al.*, 2002	High	High	Low	High	High	High	Low	Low	**High**
Landes, 2004	High	High	High	High	High	High	High	High	**High**
Link and Nickerson, 1992	High	High	Low	High	High	Low	High	High	**High**
Little *et al.*, 1986	High	Low	Low	Low	High	High	High	High	**High**
Milosevic and Samuels, 2000	High	High	High	High	High	High	Low	Low	**High**
Motamedi, 1996	High	High	High	High	Low	Low	High	High	**High**
Nemeth *et al.*, 2000	High	High	High	High	High	High	Low	Low	**High**
Nurminen *et al.*, 1999	High	High	Low	Low	Low	Low	Low	Low	**High**
Onizawa *et al.*, 1995	High	High	High	High	High	High	Low	Low	**High**

Author, Year	Selection SA	Selection SJC	Performance SA	Performance SJC	Measurement SA	Measurement SJC	Attrition SA	Attrition SJC	Overall Bias
Pahkala and Heino, 2004	High	High	High	High	High	High	Low	Low	**High**
Panula *et al.*, 2000	High	Low	High	High	High	High	Low	Low	**High**
Raveh *et al.*, 1988	High	High	High	High	High	High	Low	Low	**High**
Rodriguez-Garcia *et al.*, 1998	High	High	Low	Low	Low	Low	Low	Low	**High**
Schearlinck *et al.*, 1994	High	High	High	Low	Low	Low	High	High	**High**
Scott *et al.*, 1997	High	Low	Low	Low	High	High	Low	Low	**High**
Smith *et al.*, 1992	High	High	Low	Low	High	High	Low	Low	**High**
Timmis *et al.*, 1986	High	High	High	High	High	High	Low	Low	**High**
Ueki *et al.*, 2001	High	High	High	High	High	High	High	High	**High**
Ueki *et al.*, 2002	High	High	Low	Low	High	High	Low	Low	**High**
Upton *et al.*, 1984	High	High	High	High	High	High	Low	Low	**High**
Westermark *et al.*, 2001	High	High	High	High	High	High	Low	Low	**High**
White and Dolwick, 1992	High	High	High	High	High	High	Low	Low	**High**

Author, Year	Selection SA	Selection SJC	Performance SA	Performance SJC	Measurement SA	Measurement SJC	Attrition SA	Attrition SJC	Overall Bias
Wolford *et al.*, 2003	High	High	High	High	High	High	Low	Low	**High**
Zhou *et al.*, 2001	High	High	High	High	High	High	Low	High	**High**

‡‡‡‡‡‡‡‡ This table indicates the level of bias assigned to each of the sections (selection, performance, measurement and attrition) of the quality assessment forms by both reviewers (SA and SJC) as well as the overall bias assigned to each study. If a study scored high bias in any section it was automatically given an overall high bias.

2.3.1 Evidence Tables

Study characteristics (Table 2.8)

A total of 53 articles were analysed for the review. The majority of studies (n=41) were of a cohort design, 8 were case-control studies, whilst 3 were part of larger randomised controlled trials. Almost half of the studies (n=20) were not explicit about whether the study was retrospective or prospective, although with the majority of these it could be assumed based on the details provided in the study. Based on these assumptions there were 21 retrospective and 28 prospective studies (Table 2.8); the remaining 4 articles (Karabouta and Martis, 1985; Raveh *et al.,* 1988; Kerstens *et al.,* 1989; Flynn *et al.,* 1990) were not sufficiently clear to determine whether they were prospective or retrospective.

Forty-one studies followed patients longitudinally, with patients clinically examined before and after surgery. Signs and symptoms of TMD prior to surgery were compared with those post-surgery, although the post-surgical time interval varied from 6 months to 4 years. In seven studies, records of the patients were examined and surveys or questionnaires were sent to patients thus providing self-reported assessments of TMD. In eight studies radiological changes or other imaging modalities (such as MRI or arthrography) were used as diagnostic tests for TMD.

The papers which made up this systematic review spanned from the North America to Europe and Asia. The sites ranged from private practices to university hospitals and multi centre trials were also included.

Study participants (Table 2.9)

The sample size for the studies ranged from 11 to over 2000 patients. In the majority of these, the ratio of females to males was over 2:1. The mean age of the participants ranged from 19 to 36.5 years. Whilst not all studies reported a mean age, the majority (n=39) provided an age range.

A small number of studies specified the ethnicity of patients, in fact only seven studies reported this information (Link and Nickerson, 1992; Smith *et al.*, 1992; Flynn *et al.,*

1990; Nurminen *et al.,* 1999; Hu *et al.,* 2000; Zhou *et al.,* 2001; Ueki *et al.,* 2002). Not all studies reported their inclusion/ exclusion criteria; having this information is essential for determination of the extent of bias when assessing the study.

The types of skeletal deformities investigated in the studies were extensive. Thirty-three articles looked at patients with skeletal II deformities, either in isolation (15 articles) or in combination with other deformities such as anterior open bites (18 articles). Twenty-two studies looked at patients with skeletal III deformities, whilst 16 assessed patients with anterior open bites. Ten studies did not specify the malocclusion type or skeletal deformity of their subjects.

Orthognathic Interventions (Table 2.10)

As skeletal II deformities were the most common amongst the study participants, mandibular advancement was the most common orthognathic intervention (n=28 studies). The majority of the advancements were sagittal split osteotomies (BSSO) (n=27), although in two of the studies vertical ramus osteotomies (VRO) were carried out for mandibular advancement (Athanasiou and Melsen, 1992; Link and Nickerson, 1992). Thirteen studies favoured BSSO setback as the intervention of choice for correction of skeletal III deformities, whilst VRO setback was performed in six studies.

Le Fort I osteotomies were the most common maxillary interventions. However, in the majority of studies the direction of movement of the maxillary surgery was not specified. Six of the articles clearly stated that they had looked at Le Fort I impaction, whilst three looked at advancement osteotomies. This was in contrast with the mandibular surgeries, where only three studies failed to report on the type of mandibular intervention.

In eighteen of the studies, bimaxillary surgery was reported, with the surgery being a combination of the various mandibular and maxillary procedures. Forty studies had a subset of participants who had undergone only mandibular surgery, whilst twenty had a subset who had solely undergone maxillary Le Fort I procedures.

Other surgical interventions also reported, but with less frequency, included segmental procedures, distraction osteogenesis and genioplasty. Of the 53 studies included, only

seven failed to include any information on the types of orthognathic surgical interventions performed.

Classification of TMD (Table 2.11)

Signs and symptoms of TMD were evaluated by patient self report, clinical examination and/or radiographic findings. In the majority of the studies (n=44), clinical examinations were conducted, whilst patients' self report was utilised in twenty-six studies. Clinical examination and self report were combined in twenty studies. In only four of the studies did the patients' self report solely provide information regarding TMJ status. Radiographic findings contributed to the diagnosis of TMD or TMJ findings in eight studies.

The majority of the studies did not report a formal classification for the TMD diagnosis. Of the 53 studies included in this systematic review, 37 studies did not appear to classify TMD according to any published criteria. This implies that there is potential for great variability in the diagnosis of TMD. Only sixteen studies diagnosed TMD using a validated scale; twelve of these studies used the Helkimo/Modified Helkimo Index (Helkimo, 1974), whilst four studies used the Cranio Mandibular Index (Fricton and Schiffman, 1986). None of the studies classified TMD according to the RDC/TMD criteria which is the classification system now recommended in research (Wahlund *et al.*, 1998). It is, however, important to note that the RDC/TMD was first described in 1992 and only forty of the included studies were published after this time and could potentially have used the RDC/TMD criteria.

Self reported TMD symptoms (Table 2.12)

Of the 53 included studies, only 18 presented information regarding the symptoms reported by patients (some studies stated that they looked at this but did not report on the findings).

<u>Joint sounds</u>

With regards to joint sounds reported by the subjects, the pre-surgical prevalence ranged from 27 % to 38 % and post-surgical prevalence ranged from 3% to 50%. In the studies that followed subjects longitudinally, the percentage of subjects experiencing joint sounds decreased post-surgically in two studies: clicking reduced from 28% to 3%

(Kallela *et al.,* 2005) and joint sounds from 24% to 20% (Westermark *et al.,* 2001). The prevalence of joint sounds remained the same in one study at 30% (De Clercq *et al.,* 1998) and clicking increased in one study from 38% to 43% (Aghabeigi *et al.,* 2001). The most commonly reported joint sounds were clicks (6 studies), whilst crepitus was reported in 3 studies (Flynn *et al.,* 1990; White and Dolwick, 1992; Kallela *et al.,* 2005).

Pain

Painful symptoms reported by patients included TMJ pain, jaw, face and muscle pain, pain on movement and ear pain. The percentage of patients reporting TMJ pain ranged from 11 % to 28 % prior to surgery and from 6% to 19% after surgery. In all studies that reported both pre-surgical and post-surgical results, the percentage of patients affected by TMJ pain decreased post-surgically (Hackney *et al.,* 1989; Westermark *et al.,* 2001; Kallela *et al.,* 2005). A similar trend was seen with jaw pain, where decreases from 45% to 38% (Aghabeigi *et al.,* 2001) and from 23% to 17% (De Clercq *et al.,* 1998) were observed. Facial pain, muscle pain and pain on movement were also found to have a similar tendency to decrease post-surgery. A small number of studies (n=3) used a Visual Analogue Scale (VAS) to determine changes in patients' perceptions to pain; with the exception of one study (Wolford *et al.,* 2003), the results showed a reduction in VAS scores post-operatively.

Movement

With regards to jaw movements, the percentage of patients affected by a limitation in mouth opening increased post-surgically from: 19% to 21% and from 3% to 14% (De Clercq *et al.,* 1998; Aghabeigi *et al.,* 2001). This was also seen in a study using a VAS scale where the average overall score increased from 4.5 to 4.8 (Wolford *et al.,* 2003). The percentage of patients affected by jaw locking either remained the same (De Clercq *et al.,* 1998) or decreased following surgery (Timmis *et al.,* 1986; Pahkala and Heino, 2004; Kallela *et al.,* 2005).

Other

The percentage of patients experiencing headaches reduced post-surgery in all studies that provided this information (n=6). This reduction also applied to chewing difficulties

and parafunction, although fewer studies recorded these parameters especially with regards to pre and post-surgical results (n=1 and n=3 respectively).

Clinical TMD signs (Table 2.13)

A range of TMD signs were reported. For the purpose of this review, these were categorised according to:

- Joint sounds
- Pain
- Range of jaw movement
- Jaw locking
- Deviation

Joint sounds

Clicking was the most commonly reported joint sound and the percentage of patients affected prior to surgery ranged from 6% (Raveh *et al.,* 1988) to 88% (Gaggl *et al.,* 1999). Post-surgically the percentage of patients affected by clicking ranged from 4% (Raveh *et al.,* 1988) to 64% (Smith *et al.,* 1992). The percentage of crepitus reported was between 3% (Raveh *et al.,* 1988) and 36% (Gaggl *et al.,* 1999) pre-surgically and between 2% (Raveh *et al.,* 1988) and 30% (Dervis and Tuncer, 2002) post-surgically. In the majority of studies that presented both pre-surgical and post-surgical data, there was a tendency for the percentage of patients affected by joint clicking to decrease post-surgically (22 studies out of 24). Only two studies (Scott *et al.,* 1997; Panula *et al.,* 2000) found that clicking increased following surgery.

With regards to crepitus, the findings were varied. Some studies reported a decrease in crepitus post-surgery (Gaggl *et al.,* 1999; Panula *et al.,* 2000; Dervis and Tuncer, 2002; Kallela *et al.,* 2005), whilst others reported that it either remained the same (Herbosa *et al.,* 1990; Smith *et al.,* 1992; Ueki *et al.,* 200) or increased (Rodrigues-Garcia *et al.,* 1998; Nemeth *at al.,* 2000; Pahkala and Heino, 2004).

Pain

Pre-surgical TMJ pain varied from 3% (Aoyama *et al.,* 2005) to 45% (Panula *et al.,* 2000) and post surgically, it ranged from 0 (Athanasiou and Melsen, 1992) to 29%

(Scott *et al.*, 1997). In the majority of studies, the proportion of patients affected by TMJ pain decreased post-surgically (14 studies out of 18). It was, however, seen to increase in three studies (Azumi *et al.*, 2004; Borstlap *et al.*, 2004b; Aoyama *et al.*, 2005) and remained the same in one (Timmis *et al.*, 1996).

Muscle pain was also a commonly reported TMD sign and the proportion of symptomatic individuals ranged from 8% (De Boever *et al.*, 1996) to 70% (Dervis and Tuncer, 2002) prior to surgery. Following surgery, the percentage of affected patients ranged from 0% (Kallela *et al.*, 2005) to 40% (Dervis and Tuncer, 2002). When comparing the pre and post-surgical findings, the majority of studies (9 out of 11) showed a decrease in the percentage of patients affected by muscle pain post-surgery. Only one study (Aoyama *et al.*, 2005) reported an increase in symptoms, whilst one study found that it remained the same (Athanasiou and Melsen, 1992).

Movement

The range of jaw movements involved observation of the results for maximal incisal opening, right and left lateral excursions and the percentage of patients affected by limited mouth opening. The values recorded for maximal incisal opening (MIO) ranged from 44.4mm to 50.1mm prior to surgery and between 40.7mm and 52mm following surgery. MIO decreased post-surgery in the majority of the studies, however the longer the follow-up period reported the greater the tendency for this to improve. Gaggl *et al.* (1999) reported a MIO value of 47.5mm prior to surgery and 35.5mm three months post-surgery, but studies that had a longer follow-up such as Borstlap *et al.* (2004a) showed a reduction from 46.4mm prior to surgery to 45.6mm two years post-surgically (which at 1mm is unlikely to be clinically relevant).

The values recorded for lateral excursions were within the expected range, at approximately 7mm to 10.3mm prior to surgery and slightly reduced at 6.5mm to 9.8mm following surgery.

A small number of studies (n=9) reported the percentage of patients affected by limited mouth opening. Of these, the percentages ranged from 0 (Panula *et al.*, 2000) to 53% (Athanasiou and Melsen, 1992) prior to surgery and 3% (Karabouta and Martis, 1985) to 64% (Athanasiou and Melsen, 1992) post-surgery. In most cases there was an

increase in the percentage of patients affected by limited opening post-surgery (3 studies out of 5).

Jaw locking and deviations

Jaw locking and deviations on jaw opening were rarely reported in the clinical findings. Only one study (Schearlinck *et al.,* 1994) reported the incidence of jaw locking and this was seen in 2% of post-surgery subjects. There were no pre-surgical results available for this study. With regards to deviations, the prevalence ranged between 25% (Timmis *et al.,* 1996) and 88% (Gaggl *et al.,* 1999) pre-surgically and between 5% (Karabouta and Martis, 1985) and 96% (Gaggl *et al.,* 1999) post-surgery. It was not possible to identify any trends in these results as there were too few studies which provided this information.

Percentages of patients presenting with confirmed TMD at the various time parts (Table 2.14)

For the majority (n=31) of the studies that reported the overall prevalence of TMD amongst their participants, the initial time point was prior to surgery. Very few studies (Nurminen *et al.,* 1999; Panula *et al.,* 2000; Aghabiegi *et al.,* 2001; Pakhala and Heino, 2004) looked at patients at the start of treatment before any pre-surgical orthodontics. Eighteen studies also reported post-surgery follow-up, this ranged from 6 months post-surgery to studies that followed the patients more than 2 years post-surgery. Thus there was great variation in the follow-up periods.

TMD was reported to affect between 7% (Cutbirth *et al.,* 1998) and 78% (Pahkala and Heino, 2004) of the participants prior to surgery. In the eighteen longitudinal studies with follow up data, the post-operative prevalence of TMD varied. The percentage of patients affected by TMD was found to decrease in the majority (n=10, N=18) of the studies. This decrease in TMD was marked in some studies from 43% to 28% and from 73% to 48% (Westermark *et al.,* 2001; Kallela *et al.,* 2005) and less in others e.g. 66% to 62% (Athanasiou and Yücel-Eroğlu, 1994). TMD prevalence remained the same in one study (Athanasiou and Melsen, 1992) and actually increased in five studies (Little *et al.,* 1986; Rodrigues-Garcia *et al.,* 1998; Aghabiegi *et al.,* 2001; Wolford *et al.,* 2003; Aoyama *et al.,* 2005). This increase was marked in the Wolford *et al.* (2003) study,

where the percentage of participants affected by TMD increased from 36% to 84% following surgery.

Athanasiou *et al.* (1996) reported TMD in patients who had either mandibular or maxillary osteotomies. The results indicated that the percentage of patients affected by TMD increased in the mandibular osteotomy group and decreased in the maxillary group. Whilst Landes (2004) reported the prevalence of TMD in Skeletal II and Skeletal III groups pre and post-orthognathic surgery and found that the percentage of patients affected by TMD decreased in both skeletal groups.

Change in TMJ signs and symptoms (Table 2.15)

Thirty five studies reported changes in TMD / TMJ signs and symptoms and these included:

- Pain (general)
- Muscle pain
- TMJ pain
- Dysfunction
- Mandibular mobility
- TMJ function
- Click
- Headache
- Chewing ability
- TMJ sounds
- Crepitation
- Locking
- Deviation
- One or more subjective signs or symptoms

There was great variability in the signs and symptoms investigated amongst the studies. The initial time point for most studies was prior to surgery, although in two studies (Panula *et al.,* 2000; Zhou *et al.,* 2001) the initial time point was prior to any pre-surgical orthodontic treatment. Subsequent follow-up time intervals ranged from 6 months to 9 years (Egermark *et al.,* 2000).

There was little consistency in the results for changes in TMJ signs and symptoms during follow-up. Only thirteen studies reported whether patients who were asymptomatic prior to surgery developed new signs and symptoms post-surgery and this ranged from 4% (Karabouta and Martis, 1985) to 35% (Little *et al.*, 1986).

When considering whether signs or symptoms improved, the percentage ranged from 6% improvement in TMJ pain (Hackney *et al.*, 1989) to 89% improvement in TMD diagnosis (White and Dolwick, 1992). Between 5% (Upton *et al.*, 1984) and 41% (Little *et al.*, 1986) showed worsening of TMJ signs and/or symptoms. In the majority of studies which reported whether symptoms got better, worse or remained the same, the percentage of patients whose symptoms improved (18 studies out of 23), outweighed those whose symptoms worsened (4 studies out of 23).

In patients who had TMJ signs and symptoms at the initial time point, the proportion whose symptoms remained the same ranged from 3% (White and Dolwick, 1992) to 67% (Smith *et al.*, 1992), depending on which sign or symptom was being studied.

TMD findings in studies using the Helkimo Index (Table 2.16)

Twelve studies classified TMD according to the Helkimo, or modified Helkimo, Index. Of these, two studies (Dervis and Tuncer, 2002; Landes, 2004) did not report a breakdown of the results into the Dysfunction and Anamnestic Indices. In the remainder of the studies, the results were reported according to either the Dysfunction Index (where Di0 indicates no dysfunction, Di1 mild dysfunction, Di2 moderate dysfunction and Di3 severe dysfunction) and/or the Anamnestic Index (Ai0 indicates symptom free, Ai1 mild symptoms, Ai2 moderate symptoms and Ai3 severe symptoms).

Three studies (Little *et al.*, 1986; Egermark *et al.*, 2000; Milosevic and Samuels, 2000) had incomplete results for the initial time point. In the remaining studies, both the pre and post-surgical percentage of patients with TMD was reported. The percentage of patients with no dysfunction (Di0) pre-operatively ranged from 4% (Panula *et al.*, 2000) to 43% (Kallela *et al.*, 2005). Post-surgery this changed to between 8% (Panula *et al.*, 2000) and 58% (Kallela *et al.*, 2005). In four of the studies where a comparison was possible, the proportion of Di0 patients increased post-surgery, it remained the same in

one study (Athanasiou and Melsen, 1992) and decreased in two studies (Smith *et al.*, 1992; Athanasiou *et al.*, 1996).

When mild dysfunction is considered (Di1), the proportion of patients affected ranged from 13% (Panula *et al.*, 2000) to 58% (Athanasiou and Melsen, 1992) prior to surgery, and between 38% (Panula *et al.*, 2000; Kallela *et al.*, 2005) and 68% post-surgery (Smith *et al.*, 1992). The proportion of moderate dysfunction (Di2) ranged from 7% (Kallela *et al.*, 2005) to 75% (Panula *et al.*, 2000) prior to surgery and between 5% (Kallela *et al.*, 2005) and 54% (Panula *et al.*, 2000) post-surgery. Very few studies reported patients with severe dysfunction (Di3) (n=3). In four of the studies the proportion of Di1 patients increased post-surgery, whilst the proportion of Di2 and Di3 patients showed a tendency to decrease post-surgery (n=5).

Only four studies also recorded the Anamnestic Index (Little *et al.*, 1986; Smith *et al.*, 1992; Panula *et al.*, 2000; Kallela *et al.*, 2005) and the results varied between studies. In two studies the proportion of patients who were symptom free (Ai0) increased post-surgery (Panula *et al.*, 2000; Kallela *et al.*, 2005). In the remaining two studies the proportion of Ai0 patients decreased post-surgery (Little *et al.*, 1986, Smith *et al.*, 1992). Similar results were also seen with mild symptoms (Ai1). However the percentage of patients with severe symptoms (Ai2) decreased following surgery in all cases (Little *et al.*, 1986; Smith *et al.*, 1992; Panula *et al.*, 2000; Kallela *et al.*, 2005).

One study (Milosevic and Samuels, 2000) reported results for the mandibular mobility index, however only post-surgical results were given and, as such, pre/post- surgery comparisons were not possible.

TMD findings in studies using the CMI index (Table 2.17)

Of the 53 eligible articles, only four studies used the Cranio Mandibular Index (CMI) for the classification of TMD (De Boever *et al.*, 1996; Scott *et al.*, 1997; Rodrigues-Garcia *et al.*, 1998; Nemeth *et al.*, 2000). Of these four studies, Scott *et al.* (1997) did not report any values, whilst Nemeth *et al.* (2000) reported the change between pre and post-surgery scores for wire fixation and rigid fixation groups (Table 2.17).

Prior to surgery the CMI values were between 0.14 (Rodrigues-Garcia *et al.,* 1998) and 0.18 (De Boever *et al.,* 1996). When comparing the Dysfunction Index scores, Rodrigues-Garcia *et al.* (1998) reported a value of 0.13, whilst De Boever *et al.* (1996) reported a value of 0.17. The Muscle Index scores on the other hand were 0.18 (De Boever *et al.,* 1996) and 0.15 (Rodrigues-Garcia *et al.,* 1998) respectively.

Quality Assessment (Table 2.18)

The results of the quality assessment are presented in Table 2.18. Both investigators (SA and SJC) scored the articles independently, according to the four quality assessment categories (selection, performance, measurement and attrition). If one, or more, of the categories was recorded as a high risk of bias, then this classification applied to the article as a whole. This assessment meant that all 53 eligible articles were judged to be at high risk of bias.

Quality of Life

There were no studies identified which matched the inclusion criteria for this review and which looked at how TMD affected quality of life in orthognathic patients. As such no conclusions could be drawn with regards to this outcome measure.

2.3.2 Meta-analyses

Twelve studies used the Helkimo Index (Helkimo, 1974) to classify TMD in pre and/or post-surgery patients (Table 2.16). Although the patients represented in these studies had differing combinations of skeletal deformities, malocclusions, and had undergone a range of orthognathic interventions, there was sufficient homogeneity to carry out a meta-analysis on the proportion of patients affected by TMD prior to surgery. However it was not appropriate to carry out a meta-analysis on the post-surgical proportions as the patients in these studies had undergone different interventions and this was considered to be a source of marked clinical heterogeneity. A meta-analysis was carried out based on data from the five studies that had complete pre-operative results (Smith *et al.,* 1992; Athanasiou and Yücel-Eroğlu, 1994; Panula *et al.,* 2000; Pahkala and Heino, 2004; Kallela *et al.,* 2005). Although 12 studies were identified for potential inclusion,

7 were eliminated on the basis of incomplete or duplicated results; this will be discussed in further detail at a later stage.

Two further subgroups were identified in this review which were sufficiently homogenous to enable meta-analyses to be carried out regarding the effect of surgery on TMD prevalence.

1. Patients with Skeletal II deformity undergoing BSSO advancement procedures
2. Patients with vertical maxillary excess undergoing Le Fort 1 maxillary impaction procedures.

In both of these subgroups only those studies where TMD was classified according to Helkimo's Index were included, as this reduces potential measurement bias. In addition as the patients within each subgroup had undergone the same intervention, differences in performance bias were less likely to be a major source of heterogeneity. It should be noted, however, that the vertical relationships of the patients in these subgroups were not specified.

A further factor which was taken into account prior to conducting the meta-analyses was whether there was the potential for the patients to have been included in more than one study. There was a high chance of this occurring in the Athanasiou longitudinal studies between 1992 and 1996. Personal communication with Professor Athanasiou revealed that the data reported from the three longitudinal studies (Athanasiou and Melsen, 1992; Athanasiou and Yücel-Eroğlu, 1994; Athanasiou *et al.*, 1996) were derived from the same pool of patients. As such it was necessary to eliminate two of these studies from the meta-analysis to avoid the risk of duplication of data.

Proportion of orthognathic patients with TMD prior to surgery

Statistical tests of heterogeneity were carried out on the five studies eligible for meta-analysis (Table 2.19), to assess whether the individual study results were likely to reflect a single underlying effect, as opposed to a distribution of effects. The P value of <0.001 signified that the null hypothesis of homogeneity should be rejected, which indicates variations between the studies which are in excess of sampling variation, therefore a random effects model was chosen.

Study/ Method	Study Estimate / Pooled Estimate	95% Confidence Interval	
		Lower	Upper
Athanasiou and Yucel-Eroglu (1994)	0.66	0.56	0.76
Kallela *et al.*, (2005)	0.57	0.42	0.73
Smith *et al.*, (1992)	0.82	0.66	0.98
Pahkala and Heino, (2004)	0.67	0.57	0.77
Panula *et al.*, (2000)	0.97	0.92	1.01
Pooled (Fixed)	*0.86*	*0.82*	*0.89*
Pooled (Random)	*0.74*	*0.57*	*0.92*

Test for heterogeneity: Q= 65.384 on 4 degrees of freedom (P<0.001)

Table 2.19 Heterogeneity test and Meta-analysis for the overall proportion of patients with TMD prior to surgery (using the Helkimo Index)

The random effects pooled estimate of TMD prevalence prior to surgery for all studies was 74% (CI 57% to 92%) (Table 2.19, Figure 2.6). There was significant between-study variation (Figure 2.6) and the individual study estimates (66%, 57%, 82%, 67% and 97%) varied greatly (Table 2.19).

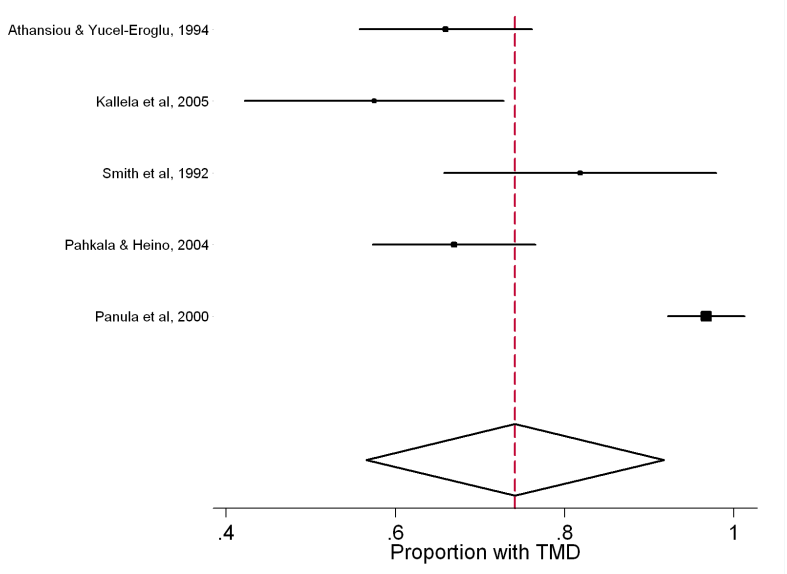


Figure 2.6 Forest plot of the overall proportion of patients with TMD pre-operatively (using the Helkimo Index)

Patients with Skeletal II deformity undergoing BSSO advancement procedures

Statistical tests of heterogeneity were carried out and Tables 2.20a to 2.20c report the findings of these tests. P-values of P=0.005, P<0.001 and P=0.0041 all indicate significant heterogeneity between the results of the included studies (rejection of the null hypothesis of homogeneity), and variations between the studies in excess of sampling variation. As discussed previously a random effects model was therefore utilised. The meta-analysis of the studies using fixed and random models is shown in Tables 2.20a to 2.20c

Study/ Method	Study Estimate / Pooled Estimate	95% Confidence Interval	
		Lower	Upper
Athanasiou and Yucel-Eroglu (1994)	0.33	0.07	0.60
Kallela *et al.* (2005)	0.57	0.42	0.73
Smith *et al.*, (1992)	0.82	0.66	0.98
Pooled (Fixed)	*0.64*	*0.54*	*0.74*
Pooled (Random)	*0.59*	*0.35*	*0.84*

Test for heterogeneity: Q= 10.500 on 2 degrees of freedom (P= 0.005)

Table 2.20a Heterogeneity test and Meta-analysis for the proportion of skeletal II patients with TMD prior to surgery (using the Helkimo Index)

Study/ Method	Study Estimate / Pooled Estimate	95% Confidence Interval	
		Lower	Upper
Athanasiou and Yucel-Eroglu (1994)	0.83	0.62	1.04
Kallela *et al.* (2005)	0.43	0.27	0.58
Smith *et al.* (1992)	0.91	0.79	1.03
Pooled (Fixed)	*0.74*	*0.66*	*0.83*
Pooled (Random)	*0.72*	*0.40*	*1.04*

Test for heterogeneity: Q= 24.721 on 2 degrees of freedom (P<0.001)

Table 2.20b Heterogeneity test and Meta-analysis for proportion of skeletal II patients with TMD following surgery (assessed using the Helkimo Index)

Study/ Method	Study Estimate / Pooled Estimate	95% Confidence Interval		P value
		Lower	Upper	
Athanasiou and Yucel-Eroglu (1994)	0.50	0.16	0.84	N/A
Kallela *et al.*(2005)	-0.01	-0.23	0.20	N/A
Smith *et al.* (1992)	0.09	-0.11	0.29	N/A
Pooled (Fixed)	*0.12*	*-0.02*	*0.25*	*0.10*
Pooled (Random)	*0.16*	*-0.09*	*0.41*	*0.22*

Test for heterogeneity: Q= 6.378 on 2 degrees of freedom (P= 0.041)
NB: a negative sign indicates that the proportion of patients with TMD decreased

Table 2.20c Heterogeneity test and Meta-analysis of the change in proportion of TMD pre and post-surgery in skeletal II patients undergoing BSSO advancement surgery (assessed using the Helkimo Index)

There was significant between-study variation in the proportion of patients affected by TMD pre-operatively (Smith *et al.*, 1992; Athanasiou & Yucel-Eroglu, 1994; Kallela *et al.*, 2005). This significant between-study variation was also found for the proportion of TMD post-surgery and the overall change following surgery.

Due to these variations, random models were used to present the results graphically. The Forest plots of the proportion of patients with TMD pre and post-surgery are shown in Figures 2.7a and 2.7b and the change in the proportion of patients affected by TMD following surgery is shown in Figure 2.7c.

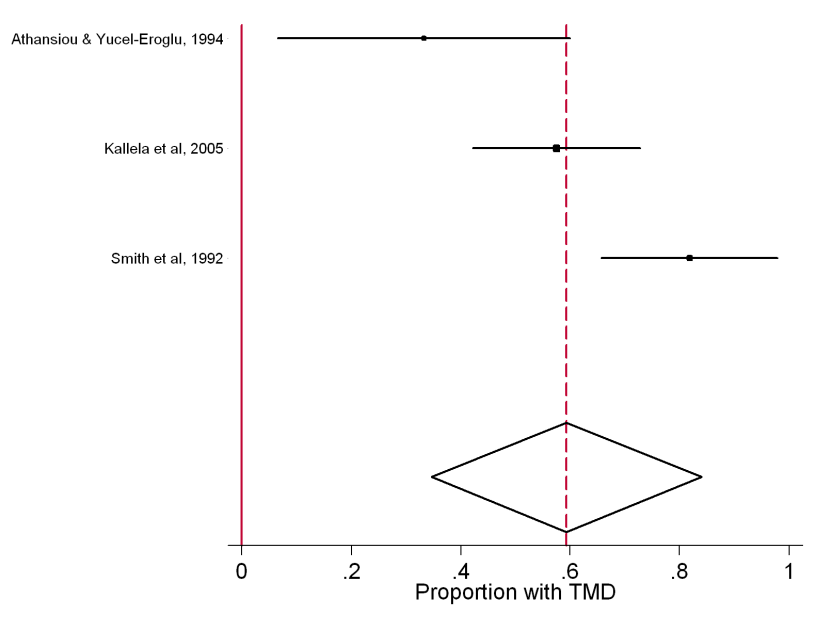


Figure 2.7a Forest Plot showing the proportion of pre-surgery skeletal II patients who were diagnosed as having TMD (BSSO advancement surgery).

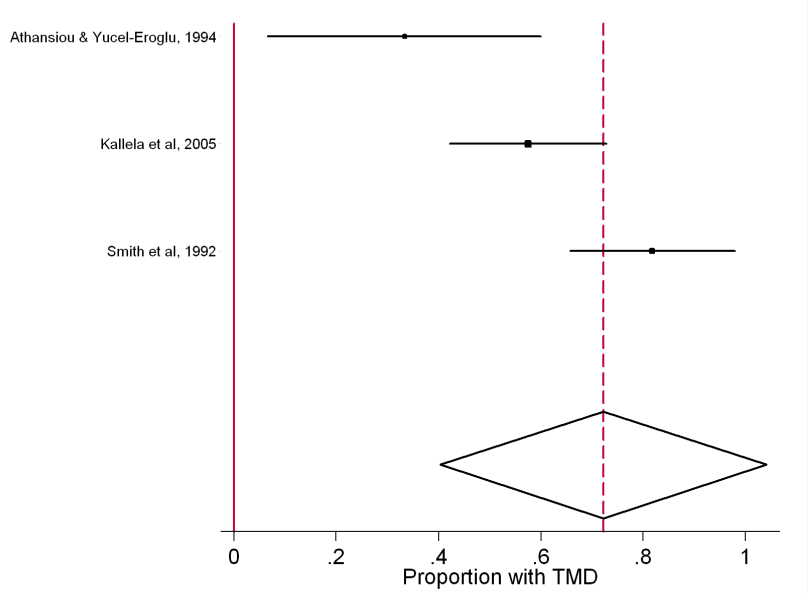
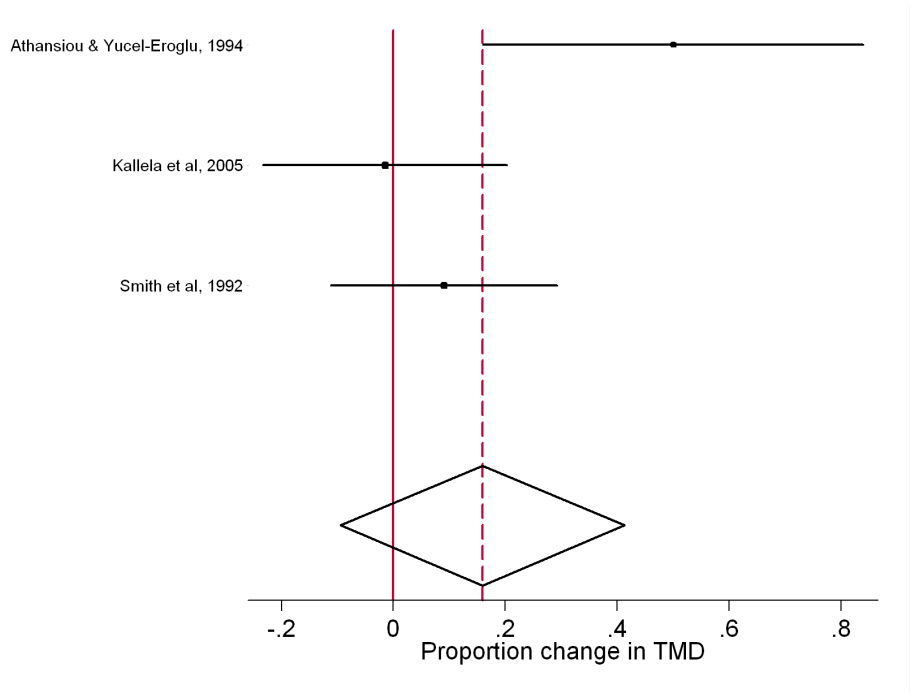


Figure 2.7b Forest Plot showing the proportion of post-surgery skeletal II patients who were diagnosed as having TMD (BSSO advancement surgery).

Figure 2.7a shows that the pooled meta-analysis effect of pre-operative patients suffering from TMD was 59% (95% CI 35% to 84%) but the individual study estimates varied greatly (33%, 57% and 82%). The pooled post-surgery percentage of patients suffering from TMD was 72% (95% CI 40% to 100%), whilst the individual study estimates were 83%, 43% and 91%, respectively (Figure 2.7b).



N.B: A positive change indicates a worsening in the proportion of people affected.

Figure 2.7c Forest Plot showing the change in proportion of skeletal II patients affected by TMD when comparing pre- and post-surgery

Figure 2.7c shows a pooled change in the percentage of patients affected by TMD of 16% (95% CI -9% to 41%), which suggests an increase in patients affected by TMD following surgery to correct a Class II malocclusion. However, the confidence interval crosses zero and the P-value of 0.22 indicates no evidence of a significant overall change. As with the previous results, the individual study estimates varied greatly (50 % increase in TMD, 1 % decrease and 9 % increase respectively).

Patients with VME undergoing Le Fort 1 maxillary impaction procedures (post-surgery data)

It was not possible to carry out a meta-analysis on the pre-operative data, or to obtain an estimate of the change following treatment as the pre-operative results for Little *et al.* (1986) were not reported. Only two studies were identified for inclusion in this meta-analysis. The test for heterogeneity indicated no evidence of between study heterogeneity (P=0.713) (Table 2.21). The meta-analysis for the post-surgical data is

shown in Table 2.21 and the pooled estimate for the studies was 68% (95% CI 52% to 84%) for both the fixed and random effects models.

Study/ Method	Study Estimate / Pooled Estimate	95% Confidence Interval	
		Lower	Upper
Athanasiou *et al.*(1996)	0.71	0.49	0.92
Little *et al.*(1986)	0.65	0.42	0.87
Pooled (Fixed)	*0.68*	*0.52*	*0.84*
Pooled (Random)	*0.68*	*0.52*	*0.84*

Test for heterogeneity: Q= 0.135 on 1 degrees of freedom (P= 0.713)

Table 2.21 Heterogeneity test and Meta-analysis for VME patients undergoing Le Fort I impaction (post-surgery data)

The Forest plot (Figure 2.8) shows that the study estimates of both studies (71% and 65%) do not vary greatly from the pooled meta-analysis estimate of 68% (95% CI 52% to 84%). It must however be noted that only two studies have contributed to these results.

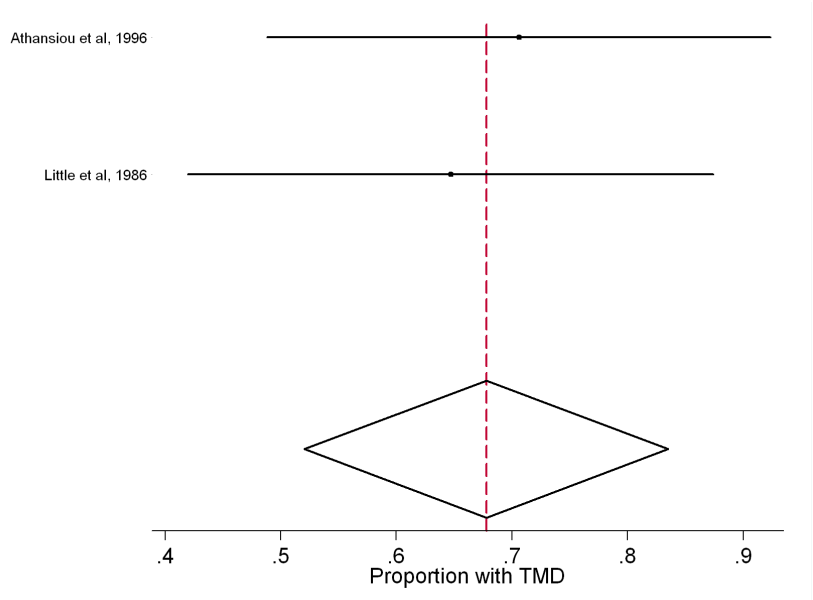


Figure 2.8 Forest plot of the proportion of VME patients undergoing Le Fort 1 maxillary impaction affected by TMD (post-operative data)

2.4 Discussion

2.4.1 Heterogeneity

From the results of this review, it is clear that there is great variation in studies where TMD and orthognathic treatment are investigated. This variability encompasses how TMD is classified, the signs and symptoms recorded, and the time intervals reported, amongst other factors.

Patients

When looking at the patients represented in these studies it immediately becomes apparent that there is great heterogeneity with respect to the included participants. The age range and mean ages of the participants varied from study to study, although they were within the range set by the inclusion criteria. The relevance that age may have on the proportion of orthognathic patients affected by TMD is unclear but Rutkiewcz *et al.* (2006) reported a higher prevalence of TMD signs in older patients. In addition age may be a contributory factor in diminishing the normal functional remodelling capacity of the condyle, thus resulting in idiopathic condylar resorption (Arnett *et al.*, 1996).

Ethnicity of the participants was also a possible source of heterogeneity amongst the studies, with many authors not specifying this information. The studies which did report this information had patients who were Caucasian, Japanese, Chinese, Canadian and Finnish and it is unclear whether certain ethnic groups may have a higher predisposition to TMD than others.

Perhaps most importantly, however, was the great variation in the skeletal groups included in the studies. Whilst some studies included patients with one specific skeletal discrepancy, others included a range of skeletal deformities, and as such comparisons were not always possible, and when carried out could be a source of heterogeneity. Most of the studies that reported positive effects on TMD after orthognathic surgery reported this association in skeletal Class II patients. A decrease in signs and symptoms of TMD by more than 50% post-surgery compared with the pre-surgery state was reported in some studies (Karabouta and Martis, 1985; Kerstens *et al.*, 1989; White and Dolwick 1992), while subjects with skeletal Class III patterns or patients with a high

mandibular plane angle (> 32°) seemed to benefit considerably less from surgery (Kerstens *et al.*, 1989; White & Dolwick, 1992; De Clercq *et al.*, 1995). As such the participants' skeletal deformity may have a direct impact on TMD, especially following surgery.

Intervention

Due to the variety of skeletal groups represented in the studies, it is inevitable that a variety of interventions or surgical procedures were carried out. Whether a particular type of surgery has a greater predisposition to causing (or curing) TMD is not known. As stated previously, patients with certain skeletal deformities (e.g. high angle patients) did not appear to benefit as much from their surgeries. This may be a direct effect of the skeletal deformity itself, the type of surgery carried out or may be a reflection on how the data was collected.

Outcome

Perhaps, the greatest source of heterogeneity in this review was the different outcome measures used to report TMD. In addition, many studies did not classify TMD according to a validated scale. Although the shortcomings of the lack of a universal scale or outcome measure in reporting TMD has not previously been explored in relation to orthognathic populations, it has been identified in other epidemiological studies (Luther, 1998a).

Epidemiological research has found that signs and symptoms of TMD are not uncommon in the general population. In US studies, clicking sounds have been reported in 8% to 41% of adults (Fricton and Schiffman, 1995), whilst the prevalence of TMD related pain was reported at 12% (Dworkin *et al.*, 1990). In Scandinavia, estimates ranged from 16% to 59% for reported symptoms, and from 33% to 86% for clinical signs (Carlsson, 1984). However, this discrepancy between US and European studies may not reflect true differences between these populations, but instead may be due to the fact that the set of diagnostic criteria used differed between the studies. Some studies may rely on self-reports of pain and dysfunction, whereas others may include diverse clinical assessment procedures (Carlsson and LeResche, 1995).

2.4.2 Narrative Findings

Study Characteristics (Table 2.8)

The study characteristics of the included articles were standard, the majority were cohort studies, which in terms of the hierarchy of evidence is approximately halfway up the pyramid (Figure 2.1). The areas of potential bias in these studies include: i) selection bias arising from the way that patients were included and ii) measurement bias arising from the unmasked (unblinded) assessment of subjective outcomes. Although a RCT would provide greater protection from bias, this type of study design would not have been feasible for patients undergoing orthognathic interventions in the majority of cases. Ethical considerations would be breached if patients were randomised into groups having surgery and groups not having surgery, for example.

Study Participants (Table 2.9)

The majority of the included studies had a reasonable number of study participants as case series were not included in this review. With regards to gender, more women than men were recruited, and this may be related to the greater proportion of women seeking orthognathic treatment in general (Samman *et al.,* 1996; Yu *et al.,* 2000). A Class II malocclusion is one of the most common malocclusions (Proffit *et al.,* 1998) and this may explain why the majority of the deformities reported in the studies were skeletal II deformities. This may also explain why procedures to correct skeletal II deformities (i.e. mandibular advancements) were the most commonly reported interventions amongst the studies. Many other surgical interventions were also reported and this, in addition to the various skeletal deformities, was a source of great heterogeneity for this review.

Classification of TMD (Table 2.11)

It was encouraging to note that the majority of studies identified TMD by clinical examination and a number of the studies supplemented this with either patients' self report or, less frequently, radiographic imaging. However, despite a clinical examination being conducted, the majority of these studies did not classify TMD according to any validated scale. These studies appear to have used their own methods of classifying TMD, according to non-standardised criteria which made it virtually impossible for comparisons to be made between the studies. The exceptions to this were the twelve studies that used the Helkimo Index.

Patients' self reported symptoms (Table 2.12)

I. Joint sounds and Pain

There was great variability in the proportion of joint sounds post-surgery. However, the patients' perception was that pain tended to improve after surgery. For almost all types of pain reported (TMJ, jaw, muscles, face) there was a tendency for the percentage of patients with reported pain to decrease following surgery. It is unclear whether this was a genuine effect due to changes within the joint caused by surgery, or a placebo effect due to the patients altered outlook. Although placebo effects in patients undergoing orthognathic intervention have not been explored, they have been researched widely in medicine. Turner *et al.* (1994) reviewed the literature to estimate the importance and implications of placebo effects in pain treatment. They found that placebo response rates varied greatly and were frequently much higher than the often-cited "one third" and, as with medication, surgery can produce substantial placebo effects. They concluded that placebo effects influence patient outcomes after any treatment, including surgery, which the clinician and patient believe is effective.

II. Movement

Limitations in mouth opening increased post-surgery in almost all studies, but this is likely to be due to inflammation and scar tissue formed as a direct result of the surgery itself. It is not uncommon for patients to have a reduction in mouth opening immediately after surgery, and in many cases the limitation of opening continues to improve up to 24 months post-surgery (Zimmer *et al.*, 1991).

Clinical signs (Table 2.13)

I. Pain

The clinical findings were similar to the patients' self reported findings. All types of pain showed a tendency to decrease following surgery, and a reduction in mouth opening was observed in the majority of cases.

II. Joint sounds

With regards to joint sounds, however, the clinical findings seemed to show a reduction in clicking post-surgery, the results for crepitus on the other hand were more varied, with some studies reporting an increase and others, a decrease post-surgery. In the

majority of studies that reported post-surgery TMD results, the overall proportion of TMD decreased post-surgically, this was however subjectively observed as a trend in the data.

III. Movement

A shortcoming of a large number of the studies was the failure to record maximum inter-incisal opening and the lateral excursions. These are very simple recordings to take and are essential to establish the range of jaw movements.

Quality assessment (Table 2.18)

Quality assessment of individual studies is an essential feature of systematic reviews (Moher *et al.,* 1999) and is necessary to account for bias, gain insight into potential comparisons, and guide interpretation of the findings. In the past decade, research has focused on two main issues: (i) which components of the quality assessment are predictive of valid results and (ii) which tools (scales or checklists) produce the best quality assessments (Moja *et al.,* 2005). Egger *et al.* (2003) found that the quality of allocation concealment and evidence of double blinding were strongly related to the reported treatment effect sizes. Whilst a number of quality scales and checklists have been proposed over the years (Moher *et al.,* 1995; Jüni *et al.,* 1999), the answer to question (ii) remains unclear, and many doubt that a generic quality assessment tool which would prove valid for all research can ever be found (Moja *et al.*, 2005).

For the current review, a quality assessment tool was developed which was more appropriate for the research in question than previously devised generic tools proved to be. The development of this tool, along with establishing the criteria for assigning the risk of bias presented major challenges for the review. The quality assessment forms and flowcharts that were developed proved to be reliable and reproducible, and can be recommended for assessing the quality of non-randomised TMD studies in the future.

2.4.3 Meta-analysis findings

Percentage of Orthognathic patients with TMD

Attempts to determine the exact percentage of patients with TMD in an orthognathic population was difficult. There was great variability amongst the studies with regards to the percentages reported (7% to 78%). This variability could be explained by the different criteria used for assessing and classifying TMD and it may also be dependent on the characteristics of the study participants themselves (i.e. skeletal deformity, age etc.).

As previously stated, it was appropriate to conduct a meta-analysis for only a few specifically chosen studies. The meta-analysis pooled estimate for the percentage of pre-operative orthognathic patients with TMD was 74% (95% CI 57% to 92%). The wide confidence intervals (95% CI 57% to 92%) highlight the lack of precision of this estimate. This estimate was towards the higher end of the range reported in all of the studies and was influenced by the large weight given to the Panula *et al.* (2000) study (Figure 2.6). Panula *et al.* (2000) discussed the high prevalence reported and reiterated that other studies have also found a high prevalence of TMD in orthognathic patients (Schneider and Witt, 1991; Link and Nickerson, 1992). They attributed the high prevalence reported in their study, when compared with other studies, to:

- The criteria used for the self-reported symptoms
- The patient sample itself and
- Varying patterns of referrals

The first two points have been discussed previously but not the third issue. Patterns of referrals may vary in different countries and cultures and this could impact on the prevalence of TMD in orthognathic populations. Thus studies which have found that the majority of orthognathic patients have normal TMJ function (Laskin *et al.*,1986) may be associated with cosmetic motives for seeking treatment. In contrast, certain countries or cultures may only advocate orthognathic surgery for patients who have impairment in function and, as such, these studies are likely to report a greater proportion of patients affected by TMD.

On the whole, given the clinical and statistical heterogeneity associated with TMD in orthognathic populations, one must question whether obtaining a single estimate for the proportion of TMD is appropriate. It may be that there are several different estimates based on the differing patient characteristics (such as skeletal relationship) or differing interventions (such as the type of surgery).

Class II patients

Prior to surgery the percentage of skeletal II patients with TMD was estimated at 59% (95% CI 35% to 84%), whilst the post-surgery estimate was 72% (95% CI 40% to 100%). The wide confidence intervals associated with the values again indicate lack of precision. The change in percentage of patients with TMD when comparing pre and post-surgery data suggests a 16% increase in TMD following surgery (95% CI -9% to 41%). The P-value of 0.216 indicates no evidence of a statistically significant change in the percentage of patients affected and the wide confidence intervals show lack of precision. Thus in the pre-treatment informed consent process, this information may be used when discussing potential TMD changes with patients. Patients should be advised that some studies have shown a reduction in TMD, whilst others have shown an increased prevalence, although overall there does not appear to be a significant change. Patients must also be advised of the great individual variation.

Patients presenting with VME

The final meta-analysis looked at the percentage of vertical maxillary excess patients affected by TMD post-surgery (Table 2.21). Unfortunately the lack of pre-surgery data prevented an estimation of the pre-surgical prevalence and consequently also prevented an estimation of the pre to post-surgery change. The pooled estimate of TMD post-surgery was 68% (95% CI 52% to 84%), which is clearly a high percentage. It is difficult to draw conclusions from this analysis without any pre-treatment data, however, this is an important area to consider in future research. The limitations of only including two studies in a meta-analysis should not be overlooked and any conclusions have to be treated with caution.

The findings from all of the meta-analyses in this review were subject to considerable variation amongst the results. As such it was not possible to draw strong inferences relating to the percentage of orthognathic patients with TMD with any degree of

certainty. It is important to explain sources of heterogeneity in these results and, in most cases, the study design (cohort studies) was likely to be a source of selection bias. Additionally one can hypothesise when carrying out studies involving TMD that if a larger number of patients are identified with TMD, this may be because clinicians are specifically attempting to identify this group of individuals and this is a potential source of measurement bias. Other sources of heterogeneity involving patient characteristics, intervention and outcomes have been discussed previously.

Summary

Although determining a precise percentage of orthognathic patients affected by TMD was not possible narratively or with a meta-analysis, the appropriateness and the clinical relevance of attempting to do this is debatable given the clinical diversity of patients and their interventions. This became clear during the systematic review as the study data were analysed in detail.

Whilst remaining mindful of the heterogeneity, certain trends in the signs and symptoms of TMD were tentatively observed in this study. Pain tended to decrease following surgery and this was true both clinically and for self reported symptoms. Limitation in jaw movements was also often experienced. With respect to joint sounds, the post-surgery results were more varied. The percentage of patients with clicking tended to decrease post-surgically, but any improvements in crepitus were questionable.

A large number of patients experienced an improvement in TMD symptoms after orthognathic surgery but conversely, some subjects who were asymptomatic prior to surgery developed TMD following surgery. There are, however, limitations to most of the studies; few had non-treatment control groups for comparison, the sample sizes were small in some studies, follow-ups were often short and many studies were retrospective. For the majority of parameters, the heterogeneity of the studies prevented the results from being analysed statistically. This heterogeneity might originate, in part, from lack of a universal diagnostic system and the variability of TMD; as such definitive conclusions could often not be drawn. In a recent review by Abrahamsson *el al.* (2007), investigating the changes in TMD before and after orthognathic surgery, no clear conclusions could be drawn. This study was limited by the number of articles included

in the review (three) and the authors also cited heterogeneity in study design and ambiguous results as explanatory factors.

2.5 Conclusions

The conclusions which can be drawn from this systematic review have clinical implications which may be useful for orthodontic practitioners and surgeons when advising their patients and obtaining informed consent.

Although orthognathic surgery should not be advocated solely for treating TMD, according to this systematic review patients who are undergoing orthognathic treatment for the correction of dentofacial deformity and who are also suffering from TMD appear to be more likely to see an improvement in their signs and symptoms than a deterioration. The majority of the studies included in the review showed that the various signs and symptoms of TMD tended to improve post-surgery, and fewer studies showed signs and symptoms which became worse. This trend can form part of the information given to prospective patients, but it should be stressed that absolutely no guarantees can be made.

With specific regards to pain; TMJ pain, muscle pain and headaches experienced by patients pre-surgically appeared more likely to improve than to worsen post-surgery. This trend was observed in those studies which undertook post-surgical examinations.

Clicking sounds also appeared more likely to improve post-surgery than to deteriorate, but the results were less consistent than those observed for pain. In contrast, crepitus did not appear to be affected by surgery and, as such, is unlikely to either improve or deteriorate. However, fewer studies reported on crepitus so these findings should be treated with some caution. Crepitus is closely associated with pathology/ resorption of the condylar head as a result of advanced TMJ damage and degenerative changes. It is usually due to a tear in the disc or the posterior attachment which then produces bone to bone contact, wear and flattening of the condylar head. Thus the exact influence that surgery may have on this remains unclear.

The majority of patients experienced restriction in mouth opening and lateral excursions post-surgery. This, however, continued to improve and the majority of patients appeared to regain the full mandibular range of motion two years after surgery.

Recommendations

The major limitation in conducting this review was the great source of heterogeneity associated with this topic. Many researchers have noted this shortcoming and as such the following recommendations can be made:

1. Standardised criteria should be used for diagnosing and classifying TMD. These should be valid and reproducible, as well as simple to carry out.
2. Future research in TMD should adhere to an internationally recognised set of criteria and a universal scale.
3. There is a need for more prospective longitudinal studies which implement strict quality assurance protocols to minimise bias, thus increasing their standing in the evidence based hierarchy.
4. Research should focus on categorising participants homogenously to reduce the effects of confounding factors and enable adequate comparisons to be made between studies.

By following the above recommendations it should be possible to conduct good quality studies that are adequately homogenous and allow comparisons to be made, enabling statistical analyses to be carried out and further strengthen conclusions in the area of TMD and orthognathic surgery.

Chapter III: Temporomandibular Joint Disorders in Orthognathic Patients and a Control group with no Skeletal Discrepancies

Introduction, Aims and Objectives

The following two chapters in this PhD report on the recruitment of orthognathic patients with skeletal discrepancies. These individuals were examined to establish the percentage of patients affected by TMD, as well as the range of signs and symptoms present. In addition the orthognathic patients were followed longitudinally throughout treatment to establish whether TMD signs and symptoms alter during the course of orthognathic intervention. The results of this part of the investigation are discussed in Chapter IV.

This chapter reports the findings for pre-treatment orthognathic patients compared with control subjects who presented with no antero-posterior, vertical or transverse skeletal discrepancies. Control subjects are an essential part of most research designs, allowing researchers to reduce confounding variables and bias and to attribute observed changes to the effect of an intervention rather than to other factors. Normal biological variation, researcher bias and environmental variations are all factors that can affect outcomes, thus control groups act as a standard for comparison purposes. The main objectives of this study were:

1. To determine the percentage of orthognathic patients with TMD.
2. To determine the percentage of control subjects with TMD.
3. To compare the percentage of subjects with TMD in the two cohorts.
4. To investigate the signs and symptoms and the range of jaw movements in those individuals affected by TMD.
5. To investigate how the presence of TMD affects quality of life.
6. To investigate whether TMD signs and symptoms in those subjects with no skeletal discrepancy differ from those in orthognathic patients.

3.1 Introduction

TMD has an uncertain aetiology, although some studies have found that certain malocclusions (Class III, deep bites and anterior open bites) may be linked with symptoms of TMD (Mohlin *et al.*, 1980; Mohlin and Thilander, 1984). Thus an important consideration is whether skeletal discrepancies have an impact on the development of TMD. As with the general population, it is difficult to determine the true prevalence of TMD among orthognathic patients. The systematic review in Chapter II showed great variability between studies with regards to the percentage of patients affected, with figures from 7% to 78% reported (Pahkala and Heino, 2004; Cutbirth *et al.*, 1998). This may be explained by the different criteria used when assessing and classifying TMD. Thus it is unclear whether patients who have skeletal discrepancies have a higher prevalence of TMD than subjects with no skeletal discrepancies, or whether skeletal discrepancies are indeed an aetiological factor for TMD.

A number of studies have investigated and compared the signs and symptoms of TMD in orthognathic and control subjects. Dervis and Tuncer (2002) used Helkimo's Anamnestic and Dysfunction Indices to evaluate the signs and symptoms of TMD in orthognathic patients immediately before surgery, 1 week after removal of intermaxillary fixation, and 1 and 2 years after surgery. Fifty patients and fifty subjects without skeletal discrepancies were recruited into the study and a statistically significant reduction in the prevalence of TMD signs and symptoms was noted 2 years after surgery compared with before surgery. At initial examination, orthognathic patients did not report significantly more TMD signs and symptoms than the healthy subjects, however, at the final examination, greater improvements in TMD symptoms were noted in the orthognathic patients when compared with the healthy controls. The results of the study suggested that the functional status of the temporomandibular joint may be improved following orthognathic surgery, but no clear association could be shown between TMD symptoms and the type of dentofacial deformity. The small sample sizes involved when grouping patients according to their skeletal deformity could result in a lack of study power and the inability to show any clear association between TMD and the type of skeletal deformity.

A study by Onizawa *et al.* (1995) investigated TMD symptoms in 30 pre-operative patients compared with those of 30 volunteers with no skeletal discrepancy and changes in symptoms were evaluated at 3 and 6 months post-surgery. They found no significant difference in the prevalence of joint sounds, deviation on opening, or tenderness of the TMJ and masticatory muscles between the patients and the healthy volunteers. Patients did not report signs and symptoms of TMD significantly more than the volunteers with no skeletal discrepancies. However, this study had a relatively small sample size and assessing patients 3 and 6 months post-surgery is may not allow sufficient time for healing or for inflammation to subside post-surgery, thus results from this study should be interpreted with some caution.

Panula *et al.* (2000) undertook a prospective follow-up study to examine the influence of orthognathic treatment on signs and symptoms of TMD. Sixty consecutive patients were diagnosed and classified according to the Helkimo Index and 20 patients with similar skeletal discrepancies who declined treatment served as controls. They found that the majority (73.3%) of patients had TMD at the initial assessment but at the final assessment this prevalence had significantly reduced to 60%. In the control group, the results were almost identical, with 75% having some signs or symptoms of TMD at the first assessment, but in contrast with the patient group this increased to 85% at follow-up. The results from this study could not be directly compared with the previous studies due to the differing types of controls recruited; the control subjects had skeletal discrepancies thus they were included to determine whether surgery had an effect on their TMD status, but also taking time into account and removing it as a potential confounding factor.

A more recent study by Abrahamsson *et al.* (2009) investigated 121 consecutively referred orthognathic patients. These patients were interviewed and examined for signs and symptoms of TMD and headaches. A group recruited for comparison included 56 individuals with no skeletal discrepancies matched for gender and average age with the patients. The advantage of this study was that all TMD diagnoses were carried out according to the RDC/TMD criteria by one of two calibrated examiners. As demonstrated by the systematic review in Chapter II, previous research in this field has been difficult to synthesise due to the heterogeneity of the study designs and diagnostic criteria used. The use of the RDC/TMD criteria in the study by Abrahamsson *et al.*

(2009) ensured standardisation of the results obtained and gave a high reliability to the TMD diagnosis (John *et al.*, 2005). In contrast with previous findings (Onizawa *et al.* 1995; Dervis and Tuncer, 2002), Abrahamsson *et al.* (2009) found a significant difference in the prevalence of TMD between patients and subjects with no skeletal discrepancies, with the patient group suffering more signs and symptoms. Forty two percent of the patients were diagnosed with at least one form of TMD in comparison with 32% of the non-patients, and this difference was statistically significant.

It has been reported that the most common motivating factors for a patient to seek orthognathic treatment are the desire for enhanced aesthetics and the relief of functional problems (Cunningham *et al.*, 1995). Nurminen *et al*. (1999) found that, of the 28 orthognathic patients examined in their study, the most common reason for seeking professional help was to alleviate problems with biting and chewing (68%). A number of patients also complained of temporomandibular joint symptoms (32%) and headache (32%). Similar trends were noted by Espeland *et al.* (2008), where the most frequent motives for treatment were to improve dental appearance and also chewing ability (83 and 81% of patients, respectively). With increasing numbers of patients seeking orthognathic treatment, it appears more patients are resorting to surgical intervention for functional problems. In a cohort of pre-surgery patients, Forrsell *et al.* (1998) found that problems relating to function were most frequently reported, followed by aesthetic concerns and, to a lesser extent, social interaction problems. In addition, the patients' motives for seeking treatment were primarily related to functional issues (Forrsell *et al.*, 1998). The fact that functional issues were of greater concern than aesthetics differs from findings in previous studies. This could be explained partly by sociocultural differences, alternatively patients may think they are more likely to get treatment if they report functional rather than aesthetic problems, or this may truly reflect a change in motivation for seeking orthognathic treatment.

As the demand for orthognathic treatment is rising, it is important to understand the motivational factors behind a patient seeking treatment, and whether functional considerations such as TMD genuinely play a role. If TMD is equally prevalent amongst individuals with skeletal deformities and the general population and the signs and symptoms experienced in these two groups are the same, then providing

orthognathic treatment solely on the basis of these functional issues is clearly not justified.

By investigating the prevalence of TMD in an orthognathic cohort using reliable diagnostic tools and comparing the findings with those from subjects with no skeletal discrepancies, the impact of the condition can be fully understood and patients' motivations to seek treatment may be corroborated.

3.2 Materials and Methods

3.2.1 Pilot Study and Ethical Approval

The pilot study was conducted by Miss RA Muwahid (2006) as part of her MSc thesis and this established the most appropriate methodology to be used in this study. The success and the findings of this pilot study also encouraged the continuation of the study on a longitudinal basis.

Ethical approval for the initial pilot study was obtained from the University College London Hospitals Ethics Committee in February 2005 (Appendix 3). A notice of major amendment detailing the change in the investigator and requesting that this study be extended was approved in March 2006. A second notice of substantial amendment was submitted to include a comparison group of subjects with no skeletal discrepancies into this study and approval for this was obtained in April 2006 (Appendix 4).

3.2.2 Calibration

The importance of a valid and reproducible examination is essential to reduce misclassification errors in research. In order to achieve this it was important to be calibrated in undertaking a thorough TMJ examination and diagnosis according to the RDC/TMD criteria. Manchester University Dental Hospital runs a clinic which specialises in temporomandibular disorders and this is one of the few TMD specialist clinics in the country. Mr Stephen Davies (SD) is the lead clinician in the Temporomandibular Disorder Clinic and has published numerous articles in this field; he is regarded by many as a leading UK expert in diagnosing and managing TMD.

SD was contacted to arrange attendance at the clinic in order to calibrate the researcher (SA) against an expert in TMJ examinations. This request was granted and four full day sessions at the University of Manchester were attended in February and March of 2006.

During the first session a two hour tutorial was given on TMJ anatomy, disorders affecting the TMJ and diagnosing and classifying TMD. The RDC/TMD classification was adopted by Manchester University Dental Hospital in 2005 and this classification was followed for the remainder of the sessions. The second half of the first day involved clinical examination of new patients attending the TMD clinic and diagnosing them according to the RDC/TMD classification. Initially SD undertook the supervision of the clinical examination, to ensure this was done correctly and the first three clinical examinations on new patients were supervised.

In subsequent sessions, when each patient had been examined, a diagnosis was submitted by the researcher (SA) and SD then also examined the patient and submitted his diagnosis independently. The results were compared to determine agreement.

Over the four sessions, forty-four new patients were examined and by the final session there was excellent agreement in the diagnosis and classification of TMD between the two examiners. The results of the agreement are shown in Table 3.2.

3.2.3 Recruitment of participants

Recruitment of orthognathic patients

All patients for this study were recruited from the Joint Orthodontic/Orthognathic clinic at the Eastman Dental Hospital, UCLH Foundation Trust from April 2006 to January 2009. New patients attending the clinic were invited to participate, an information leaflet was given to each patient and the research procedures were explained in detail. The patients were allowed to read the information leaflet (Appendix 5) and consider their decision for as long as required. If there were any questions the researcher was available to offer assistance. If a patient agreed to take part in the study, they were asked to sign a consent form (Appendix 6) and a copy of this was given to the patient, another was placed in the hospital records and a final copy kept in the study file.

Inclusion criteria for the patients were:

1. Over 16 years of age

2. Awaiting orthodontic and orthognathic surgical treatment at the Eastman Dental Hospital
3. Seen prior to starting any orthodontic treatment

Exclusion criteria for patients were:

1. A history of previous orthognathic surgery
2. If they had already commenced pre-surgical orthodontics
3. No requirement for pre-surgical orthodontic treatment
4. Cleft lip and/or palate or other craniofacial syndromes
5. Previous history of facial trauma

A sample size calculation was conducted based on patient reported signs and symptoms in a study of 22 patients by Smith *et al.* (1992). A discordant proportion of 32% was obtained; as such it was estimated that a sample size of 57 subjects would be required to have an 80% power to detect a difference in proportions of 0.20.

Recruitment of control subjects with no skeletal discrepancies.

This cohort consisted of non-clinical members of staff at the Eastman Dental Institute and Hospital who volunteered to take part. E-mails and flyers were generated inviting subjects to be involved in this study and those who were interested were requested to contact the researcher. A suitable appointment was arranged and the volunteer attended for a short examination to establish their skeletal pattern. Provided the subjects had no skeletal discrepancy, they were included in the study and asked to read the information leaflet and complete a consent form (Appendix 7). The subjects recruited were gender matched to patients in the orthognathic group as previous research has suggested that gender may influence the prevalence of TMD.

Although age matching would have also been ideal, the difficulties in recruiting to the study meant this was not possible. However it was ensured that all of the subjects with no skeletal discrepancies were within the 16 to 40 years age range, to coincide with that of patients presenting for orthognathic treatment.

To ensure accuracy in skeletal pattern determination, the researcher (SA) initially assessed patients who were attending the Orthodontic Department for routine

orthodontic care and the classification of both antero-posterior (I, II or III) and vertical (normal, reduced or increased) skeletal relationships was compared with the cephalometric findings. The researcher examined 20 patients in total with 100% accuracy in determining the skeletal patterns.

3.2.4 Data collection for the study

One researcher (SA) carried out all of the data collection for this study, including the clinical examinations for both groups.

There were three main components to the assessments:

1. Questionnaire to determine self-reported symptoms and quality of life
2. Clinical examination to determine the clinical signs present and therefore the presence or absence of TMD
3. Kinesiography to investigate the range of jaw movements

Questionnaire assessing patient self reported TMD symptoms and QoL (Appendix 8)

Each subject completed a questionnaire which was divided into three sections and took approximately 10 minutes to complete.

1. The first section comprised demographic details (e.g. age, gender, ethnicity and occupation).
2. The second section included 12 questions relating to the frequency of TMJ symptoms experienced by the patient in the previous three months, including headaches, facial pain, jaw clicking, and limited mouth opening. These questions were collated from questionnaires used in previous TMD studies and were based on the most common TMD symptoms.
3. The third section was the 14 questions which form the Oral Health Impact Profile (OHIP-14), a validated questionnaire widely used in dentistry (Slade, 1997). The OHIP-14 is an instrument which measures the subject's perception of the social impact of oral disorders on their well being and quality of life. If any symptoms were present, the frequency was indicated. As such it was aimed to determine how often facial and dental problems affected the subject's day to day life.

Clinical examination (RDC/TMD) (Further details of this examination procedure can be watched on the DVD included as Appendix 9)

This was a non invasive examination, following which each subject was classified according to the RDC/TMD classification. The researcher completed a TMJ examination form (Appendix 10) for each subject. There were three main components to the examination.

1. TMJ examination
    - This included palpation of the TMJ (both intra-auricular and at the lateral poles) for any pain or tenderness. The patient was asked to open and close their mouth several times to enable the researcher to listen for joint sounds. A double barrelled stethoscope was used to amplify any sounds heard and these were then recorded as necessary.
    - The range of jaw movements was recorded, including the maximal and comfortable opening, as well as the right and left lateral excursions. All measurements were taken with the patient in an upright and comfortable position and a millimetre ruler was used to record the measurements.
    - Finally, any deviations in the mandibular path of opening were recorded.

2. Muscle examination

The muscles of mastication were palpated bilaterally for any signs of tenderness/ discomfort.

- The masseter was palpated bimanually at the origin and insertion by placing one finger intra-orally and the other on the cheek.
- The temporalis was examined at both the origin and insertion by asking the patient to clench the teeth together whilst palpating extra-orally.
- The lateral pterygoids were examined by recording the response to resisted movements. The operator's hand was placed under the chin and the patient was asked to open against resistance. In addition, intra-oral palpation behind each maxillary tuberosity was carried out to ascertain pain in the lateral pterygoid region.

- Pain or tenderness from the medial pterygoid muscles was recorded with caution in this study as the muscle is not accessible to comfortable palpation and the results of medial pterygoid palpation are unreliable. This was however recorded as a best estimate for completeness.

It is recommended that the pressure generated for palpation with the middle and index fingers should be 900grams for the extra-oral muscles and 450grams for the joints and intra-oral muscles (Dworkin and LeResche, 1992). A domestic weighing scale was used to calibrate the examiner in generating these forces. Consistency in applying the correct force was checked at 6 monthly intervals throughout the duration of the study. The domestic scale was placed in such a way that the dial was not visible to the examiner and finger pressure was applied to the scale. A colleague recorded the forces generated, ensuring the examiner applied forces in the range of both 400-500grams and 850-950grams respectively. This process was repeated if recalibration was required.

3. Occlusion
   - The skeletal base and type of malocclusion, including the British Standard Institution Incisor Classification (British Standard Institution 1983) were recorded.
   - The dentition was also studied in centric occlusion and lateral excursions for premature contacts and non-working side interferences. Any signs of excessive tooth wear were noted.

<u>RDC/TMD Classification:</u>

This was originally published by Dworkin and LeResche (1992) and was approved by the European Academy of Craniomandibular Disorders (EACD) in 2002. The classification is divided into:

Axis 1 - a physical diagnosis based on pathophysiology

Axis 2 - an assessment of TMD pain and related parafunctional behaviours in relation to psychological distress and psychosocial dysfunction

As part of the joint orthodontic/orthognathic surgical team, a liaison psychiatrist is present to assess the patients' behaviour and expectations. If a patient was perceived to be psychologically distressed as a result of their condition, further assessment of behavioural, psychological and psychosocial factors was available to establish Axis 2 diagnoses. The subdivisions of Axis 1 are as follows (Further details and the classification table are available in Appendix 11):

Axis 1 Group	Subdivision
Group 1 Muscle disorders	**(1a)** Myofacial pain **(1b)** Myofacial pain with limited opening
Group 2 Disc displacements	**(2a)** Disc displacement with reduction **(2b)** Disc displacement without reduction and limited opening (lock) **(2c)** Disc displacement without reduction, without limited opening.
Group 3 Arthralgia, arthritis and arthrosis	**(3a)** Arthralgia **(3b)** Arthritis **(3c)** Arthrosis

Table 3.1 RDC/TMD Axis 1 diagnoses

Radiographic Assessments

Radiographic assessments were required to determine the patient's skeletal pattern and this was also confirmed by clinical examination. As part of the routine procedure for patients attending orthognathic consultations at the Eastman Dental Hospital, lateral cephalograms are taken to assess the severity of skeletal discrepancies and for treatment planning purposes, thus all orthognathic patients recruited in this study had radiographs available. All pre-treatment lateral cephalograms were scanned and saved using Dolphin Imaging™ software, and the researcher digitised each cephalogram to obtain the ANB

and MMPA angles. The patients were then categorised into Class I, II, or III skeletal patterns based on the ANB value and into average, high or low angle according to their MMP angle. The classifications were based on known mean values and standard deviations for the patient's ethnic group.

Due to ethical considerations, it was not possible to obtain lateral cephalograms for the control subjects and the absence of any significant skeletal discrepancies was therefore determined solely on the basis of the clinical assessment as previously indicated.

Kinesiography

The kinesiograph K6-I evaluation system (Myotornics-Noromed Inc., Seattle, USA) is an integrated computerised machine that consists of a head frame connected to a computer system. The machine tracks mandibular movement in three dimensions: anterior/posterior, vertical and lateral (Figure 3.1).

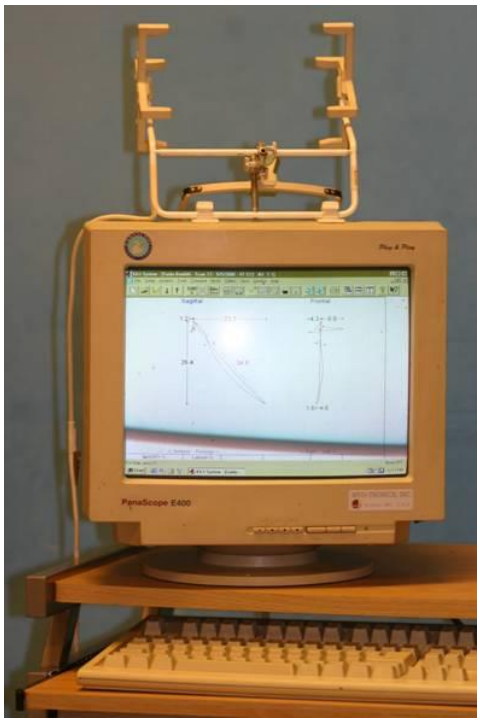


Figure 3.1 Kinesiograph K6-I evaluation system and head frame

The head frame was secured on the subject's head such that the horizontal bars on the head frame were parallel to the subject's interpupillary line and the left and right sensory arrays were equidistant from the subject's mandible (Figure 3.2). A magnet was attached

to the patient's labial vestibule in the lower midline, just below the mandibular incisors using Stomahesive® adhesive tape (Convatec, E.R. Squibb and Sons, L.L.C., New Jersey, USA) to secure the magnet in place. Mandibular movements were then tracked from the incisor point by a sensory array in the head frame that is sensitive to alterations in the magnetic field.

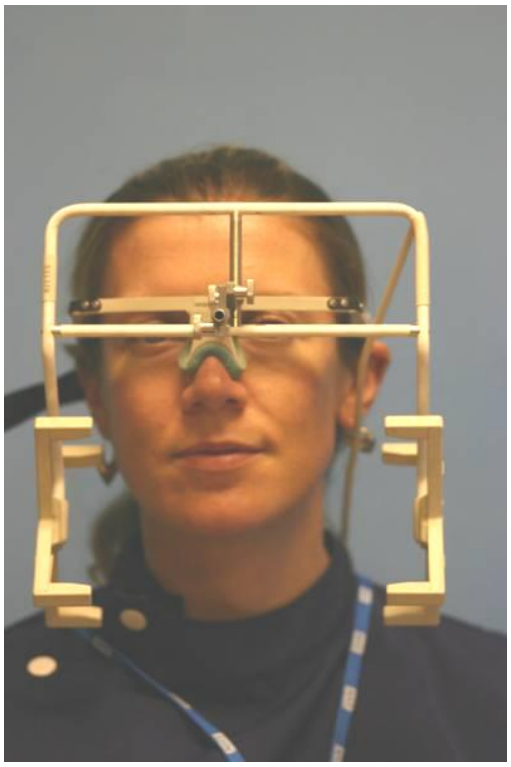


Figure 3.2 Kinesiograph: head frame secured on subject's head

Two scans (described below) were undertaken for each subject and each was repeated at least three times. The data were obtained by registering the range of jaw movements as a scan on screen, in addition to numerical values. The results were then saved as a series of graphs (Figure 3.3).

Scan 1: The subject was asked to open and close their mouth comfortably and simultaneous sagittal and frontal tracings were recorded. This scan illustrates normal opening and whether opening/closing of the mandible can be achieved without deviation.

Scan 2: The subject was asked to open his/her mouth to their maximum opening without straining the muscles, then slide the mandible as far to the left as possible and then to

the right as far as possible. Finally the subject was asked to protrude the mandible as far forward as possible and return to the centric occlusion. Hence the range of motion was recorded, including maximum vertical opening, maximum lateral excursions and maximum protrusive movements.

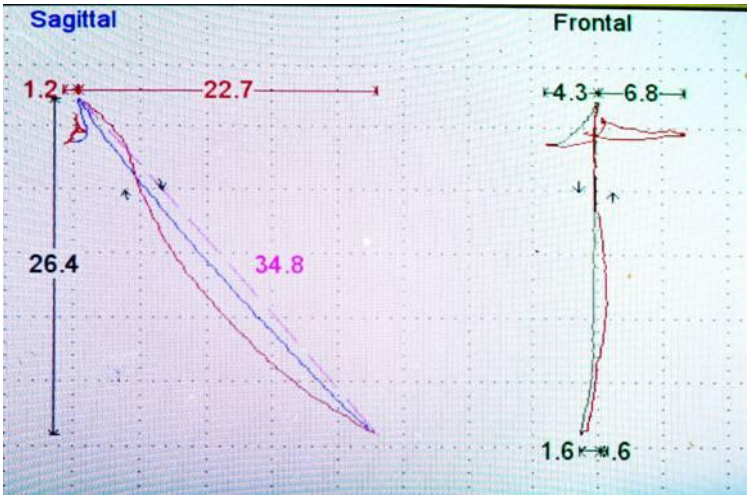


Figure 3.3 Graphs obtained from the kinesiograph for scan 2

3.2.5 Statistical Analyses

Statistical tests were undertaken using SPSS version 14 (SPSS UK Ltd, Guildford Surrey, UK).

Demographics

Descriptive statistics were used to provide summaries of the data; these consisted of percentages, means, medians and standard deviations.

Questionnaire findings

The Mann Whitney U test was used to compare the orthognathic and control subjects for the various self-reported symptoms. The Mann-Whitney U test is a non-parametric test that can be used to test for differences in medians for independent variables (Petrie and Watson, 2006). A two-way ANOVA was carried out to test the effect of presence/absence of TMD and the subject group on the OHIP-14 scores and assess whether any interaction existed between these variables.

Clinical findings and TMD diagnosis

Two-by-two contingency tables were constructed for all binary variables and Chi squared analyses were undertaken to test for statistical significance between groups. In instances, when expected frequencies were less than or equal to 5, a Fishers Exact Test was used (Petrie and Watson, 2006).

For continuous variables (e.g. opening and lateral excursions) the data set was assessed for normality using histograms and box and whisker plots and, as the data were found to follow normal distributions, independent sample *t*-tests were used to test for differences in means between the two groups (Petrie and Watson, 2006).

TMD in relation to aetiological factors

Three-by-two contingency tables were constructed for some of the analyses (TMD and skeletal base, TMD and MMPA) and Chi squared analyses were undertaken to test for significance (Petrie and Watson, 2006). Additionally logistic regression analyses were used to investigate possible associations between TMD (as the outcome variable) and gender, group and age.

3.3 Results

3.3.1 RDC/TMD: Calibration of TMD diagnosis

	Number of patients examined by both clinicians	Agreement
Week 1	10	6 (**60.0%**)
Week 2	12	10 (**83.3%**)
Week 3	11	11 (**100%**)
Week 4	11	11 (**100%**)
Total no of Patients	44	38 (**86.4%**)

Table 3.2 Agreement between the researcher (SA) and expert (SD) for calibration of TMD diagnosis

Reasonable agreement was observed between the two clinicians in the first week, but by the third and fourth week agreement was perfect (100%).

3.3.2 Demographics of subjects in the main study

Gender distribution

	Male	Female	Total N
Control	36 (50.0%)	36 (50.0%)	72 (100%)
Orthognathic	34 (50.0%)	34 (50.0%)	68 (100%)

Table 3.3 Gender distribution of control and orthognathic subjects.

A total of 72 control group subjects and 68 orthognathic patients were recruited. This was in keeping with the estimated sample size required for 80% power. There was an equal distribution of males and females in the control and orthognathic groups.

Ethnicity

	White	South Asian	Oriental	African/Afro Caribbean	Other	Total
Control	28 (38.9%)	20 (27.8%)	4 (5.6%)	4 (5.6%)	16 (22.3%)	72 (100%)
Orthognathic	31 (45.6%)	9 (13.2%)	5 (7.4%)	10 (14.5%)	13 (19.1%)	68 (100%)

Table 3.4 Ethnicity of control and orthognathic subjects

The majority of subjects recruited into this study were white (38.9% of controls and 45.6% of orthognathic patients). The next most prevalent ethnicity in both groups was South Asians, who represented 27.8% and 13.2% of the control and orthognathic subjects respectively.

Age

	Mean (years)	Standard Deviation (years)	Median (years)
Control	30.13	6.48	29.00
Orthognathic	24.26	7.71	21.50

Table 3.5 Age of control and orthognathic subjects

The mean age of the control group subjects was 30.13 years, whilst that of the orthognathic group was 24.26 years.

3.3.3 Orthognathic patients: Skeletal classification

Antero-posterior relationship

Antero-posterior Skeletal Base			Total
Class I	**Class II**	**Class III**	
10 (14.5%)	29 (42.6%)	29 (42.6%)	68 (100%)

Table 3.6 Antero-posterior skeletal relationships for the orthognathic cohort

An equal proportion of the orthognathic patients had Class II and Class III skeletal patterns (42.6%), whilst only 14.5% of the patients had a Class I pattern and these were patients with anterior open bites, facial asymmetries or both.

Vertical relationship

Vertical skeletal pattern (MMPA)			Total
Average	**Low**	**High**	
26 (38.2%)	10 (14.7%)	32 (47.1%)	68 (100%)

Table 3.7 Vertical relationships for the orthognathic cohort

With respect to the vertical relationship of the orthognathic patients, the majority presented with a high MMPA (47.1%), followed by an average angle (38.2%) and fewer patients presented with a low MMPA (14.7%).

3.3.4 Questionnaire findings

Self reported symptoms

Table 3.8 presents the self reported symptoms of both the orthognathic and control subjects based on the questionnaire findings. The following symptoms were asked about and the frequency of the symptoms recorded: headaches, earaches, general facial pain, and painful neck, jaw pain on opening/closing, jaw pain on biting/chewing, sore muscles around the jaw, clicking, jaw locking, limited mouth opening, clenching and grinding.

The Mann-Whitney U test showed a statistically significant difference between the two groups for a number of the symptoms, with the orthognathic patients suffering greater symptoms than the control group. These were earaches, general facial pain, jaw pain on opening and closing, jaw pain on biting or chewing, sore muscles around the jaw, clicking, jaw locks and limited mouth opening. With regards to headaches and painful neck symptoms however, no statistically significant differences were found between the two groups.

When considering parafunctional habits, no statistically significant difference was found between the two groups for grinding, however the control subjects group were found to exhibit significantly more clenching than the patient group (P=0.031).

Condition	Group	Frequency				Total N	P Value
		No	Occasionally	Frequently	All the time		
Headaches	Control	41 (56.9%)	26 (36.1%)	5 (6.9%)	0 (0%)	72 (100%)	0.593
	Orthognathic	36 (52.9%)	26 (38.2%)	5 (7.4%)	1 (1.5%)	68 (100%)	
Earaches	Control	70 (97.2%)	2 (2.8%)	0 (0%)	0 (0%)	72 (100%)	**0.003**
	Orthognathic	56 (82.4%)	7 (10.3%)	5 (7.4%)	0	68 (100%)	
General Facial Pain	Control	68 (94.4%)	4 (5.6%)	0 (0%)	0 (0%)	72 (100%)	**0.001**
	Orthognathic	51 (75.0%)	12 (17.6%)	4 (5.9%)	1 (1.5%)	68 (100%)	
Painful Neck	Control	52 (72.2%)	13 (18.1%)	6 (8.3%)	1 (1.4%)	72 (100%)	0.532
	Orthognathic	52 (76.5%)	12 (17.6%)	2 (2.9%)	2 (2.9%)	68 (100%)	
Jaw pain on opening/closing	Control	67 (93.1%)	3 (4.2%)	1 (1.4%)	1 (1.4%)	72 (100%)	**≤0.001**
	Orthognathic	44 (64.7%)	15 (22.1%)	7 (10.3%)	2 (2.9%)	68 (100%)	
Jaw pain on biting/ chewing	Control	65 (90.3%)	6 (8.3%)	1 (1.4%)	0 (0%)	72 (100%)	**≤0.001**
	Orthognathic	41 (60.3%)	20 (29.4%)	7 (10.3%)	0 (0%)	68 (100%)	
Sore muscles around the jaw	Control	62 (86.1%)	9 (12.5%)	0 (0%)	1 (1.4%)	72 (100%)	**0.048**
	Orthognathic	50 (73.5%)	11 (16.2%)	6 (8.8%)	1 (1.5%)	68 (100%)	
Clicking	Control	56 (77.8%)	12 (16.7%)	3 (4.2%)	1 (1.4%)	72 (100%)	**0.001**
	Orthognathic	37 (54.4%)	13 (19.1%)	10 (14.7%)	8 (11.8%)	68 (100%)	
Jaw Locks	Control	71 (98.6%)	1 (1.4%)	0 (0%)	0 (0%)	72 (100%)	**≤0.001**
	Orthognathic	54 (79.4%)	10 (14.7%)	1 (1.5%)	3 (4.4%)	68 (100%)	
Limited mouth opening	Control	71 (98.6%)	1 (1.4%)	0 (0%)	0 (0%)	72 (100%)	**0.002**
	Orthognathic	57 (83.8%)	5 (7.4%)	4 (5.9%)	2 (2.9%)	68 (100%)	
Clenching	Control	42 (58.3%)	21 (29.2%)	7 (9.7%)	2 (2.8%)	72 (100%)	**0.031**
	Orthognathic	52 (76.5%)	10 (14.7%)	5 (7.4%)	1 (1.5%)	68 (100%)	
Grinding	Control	51 (70.8%)	17 (23.6%)	3 (4.2%)	1 (1.4%)	72 (100%)	0.196
	Orthognathic	55 (80.9%)	9 (13.2%)	4 (5.9%)	0 (0%)	68 (100%)	

Table 3.8 Frequency of self reported symptoms for orthognathic and control subjects

Oral Health Impact Profile: OHIP-14

A two way ANOVA was carried out to determine whether a subject's TMD status and the group they belonged to (orthognathic or control) had an effect on the OHIP score. In addition whether any interaction existed between the OHIP-14 score, a subject's TMD status and the group they belonged to.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	6340.396[a]	3	2113.465	40.881	<0.001
Intercept	10530.708	1	10530.708	203.694	<0.001
Group	5134.730	1	5134.730	99.321	<0.001
TMD status	390.389	1	390.389	7.551	0.007
Group * TMD status	137.431	1	137.431	2.658	0.105
Error	7031.004	136	51.699		
Total	23968.000	140			
Corrected Total	13371.400	139			

Table 3.9 Two way ANOVA for the OHIP score as the dependent variable

The main effects (TMD status and group) were both statistically significant predictors of mean OHIP-14 score; however there was no interaction between the two variables and the OHIP-14 score.

	Mean	Median	Minimum	Maximum
Control	2.46	0	0	17
Orthognathic	15.31	14	0	39

Table 3.10 Overall OHIP Score for the control and orthognathic subjects

Group had a significant effect on the OHIP-14 score (P<0.001), with the orthognathic patients experiencing poorer quality of life on average (Table 3.10).

	Mean	Median	Minimum	Maximum
No TMD	6.60	3	0	39
TMD	12.48	13.0	0	35

Table 3.11 OHIP scores according to TMD status

The TMD status of the subjects also had an effect on the mean OHIP-14 score, with a statistically significant difference between the presence/absence of TMD and the relevant score (Table 3.11). Subjects with TMD had a statistically significantly higher OHIP-14 score, and therefore a significantly poorer quality of life on average, than those who were not affected.

No interaction existed between the TMD status and group with respect to the OHIP score (P=0.105), hence there was no evidence that the combined effect of TMD status and group is significantly different to their additive independent effects. Thus the presence of TMD, in combination with being an orthognathic patient, does not significantly alter the OHIP-14 score beyond what would be found from a combination of both factors independently.

OHIP Domain Scores

The OHIP-14 questions can be subdivided into seven domains and the descriptive results for the two groups according to these domains are shown in Table 3.12. The individual domains were not analysed statistically to avoid issues relating to multiple testing and "data dredging".

For all seven domains, the orthognathic group had higher mean OHIP-14 scores when compared with the control subjects group in this sample.

Domains	Group	Median	Mean	Minimum	Maximum
1. Functional Limitation	**Control**	0	0.10	0	2
	Orthognathic	1	1.18	0	8
2. Physical pain	**Control**	0	0.71	0	4
	Orthognathic	3	2.44	0	6
3.Physiological Discomfort	**Control**	0	0.69	0	5
	Orthognathic	5	4.35	0	8
4. Physical disability	**Control**	0	0.25	0	4
	Orthognathic	0	0.74	0	4
5. Psychological disability	**Control**	0	0.36	0	4
	Orthognathic	3	3.25	0	8
6. Social disability	**Control**	0	0.14	0	3
	Orthognathic	1	1.59	0	8
7. Handicap	**Control**	0	0.21	0	3
	Orthognathic	2	1.76	0	6

Table 3.12 Descriptive results for the seven OHIP domains for both control and orthognathic groups.

3.3.5 Clinical Findings

Temporomandibular Joint Clinical Findings

Both the orthognathic and control subjects were assessed for pain and tenderness associated with the lateral poles of the TMJ and intra-auricularly. In addition, any joint sounds were recorded. The results of the TMJ examinations are reported in Table 3.13 and show that 8.3% of the controls and 11.8% of the orthognathic patients had pain affecting either one or both TMJs, whilst 4.2% of the control group and 7.4% of the orthognathic patients had pain intra-auricularly. The Chi-squared test (or Fisher's exact test where necessary) for both variables were non-significant (P=0.499, P=0.485).

Similar results were observed for joint sounds, none of the controls and only 2 orthognathic patients suffered from crepitus and this difference in prevalence was not statistically significant (P=0.498), but the small number of observations must be borne in mind. The percentage of controls and orthognathic patients with clicks were 22.2% and 27.9% respectively and the difference between the groups was not statistically significant.

Sign/ Observation	Controls (N= 72)	Orthognathic Patient (N=68)	P Values
TMJ pain (lateral poles)	6 (8.3%)	8 (11.8%)	0.499
Intra-auricular pain	3 (4.2%)	5 (7.4%)	0.485 #
Clicks	16 (22.2%)	19 (27.9%)	0.435
Crepitus	0	2 (2.9%)	0.234 #

The table indicates the number of patients with signs not the number of sides
Fishers Exact test where cells have expected frequency of less than 5

Table 3.13 TMJ signs in the control and orthognathic subjects

Observations Relating to Clicks

The following table relates to the symptomatic joints only and classifies the type of clicks experienced by both groups.

	Control		Orthognathic	
	Right Joints N= 12	**Left Joints N=8**	**Right Joints N=11**	**Left Joints N=12**
Consistent	10 (83.3%)	6 (75.0%)	7 (63.6%)	9 (75.0%)
Intermittent	2 (16.7%)	2 (25.0%)	4 (36.4%)	3 (25.0%)
Opening	9 (75.0%)	6 (75.0%)	8 (72.7%)	11 (91.7%)
Closing	2 (16.7%)	2 (25.0%)	1 (9.1%)	1 (8.3%)
Both (opening + closing)	1 (11.1%)	0 (0%)	2 (20.0%)	0 (0%)
Painful	0 (0%)	0 (0%)	1 (9.1%)	0 (0%)
Single	12 (100%)	8 (100%)	11 (100%)	11 (91.7%)
Multiple	0 (0%)	0 (0%)	0 (0%)	1 (8.3%)

Table 3.14 Observations relating to TMJ clicks for both control and orthognathic subjects

The majority of the clicks heard in both groups were consistent and in the opening cycle. Only one of the clicks recorded was painful and only one multiple click was observed; both of these findings occurred in the orthognathic group but were experienced by different patients.

Muscle Pain

The muscles of mastication were assessed for pain or tenderness on palpation and those muscles that elicited a positive response were recorded. Although each of the muscle groups was assessed separately as per the RDC/TMD guidelines, the results of both the right and left muscle groups were combined (reflecting the number of subjects affected by the condition) for ease of comparison.

Muscle group	Control N= 72	Orthognathic N=68	P Values
Masseter	4 (5.6%)	13 (19.1%)	**0.014**
Temporalis	4 (5.6%)	8 (11.8%)	0.190
Lateral Pterygoid	6 (8.3%)	23 (33.8%)	**<0.001**

NB: This table show the number of patients suffering from pain or tenderness of the muscles NOT the number of sides affected

Table 3.15 The percentage of control and orthognathic subjects suffering from tenderness of the muscles of mastication

The orthognathic patients had a higher susceptibility to masseteric and lateral pterygoid pain (P=0.014 and P<0.001 respectively) although no statistically significant differences were found for temporalis pain or tenderness.

Range of Jaw movement

Deviations

	Control N=72	Orthognathic N=68	P Value
Lasting Deviations	0	8 (11.8%)	**0.002#**
Transient Deviations	8 (11.1%)	10 (14.7%)	0.525

Fisher's exact test

Table 3.16 The percentage of control and orthognathic subjects with deviation of the mandible on opening

None of the controls, compared with 11.8% of the orthognathic patients, had lasting deviations affecting their mandibular pathway of opening and this difference was statistically significant (P=0.002). In both the orthognathic patients and the control subjects, transient deviations were observed but, at 11.1. % and 14.7% respectively, the difference was not statistically significant (P=0.525).

Opening and lateral excursions

	Group	Mean	Std Dev	95 % CI Lower	95% CI Upper	Med	Min	Max	P value
Comfortable Opening (mm)	Control	44.11	9.60	41.85	46.37	45	20	65	0.113
	Orthognathic	41.76	7.76	39.88	43.64	42	23	58	
Maximum Assisted Opening (mm)	Control	49.07	8.86	46.99	51.15	50	25	67	0.634
	Orthognathic	48.40	7.70	46.53	50.26	48	25	65	
Right Lateral Excursion (mm)	Control	9.22	2.38	8.66	9.78	10	1	15	0.325
	Orthognathic	8.79	2.74	8.13	9.46	9.0	0	15	
Left Lateral Excursion (mm)	Control	9.81	2.31	9.26	10.35	10	0	15	**0.030**
	Orthognathic	8.87	2.73	8.21	9.53	9	0	16	

Table 3.17 Mean opening and lateral excursion values for both control and orthognathic subjects

The results for comfortable opening, maximum assisted opening and right and left lateral excursions all followed a normal distribution and as such it was appropriate to use parametric statistical tests. No significant differences were found for mean comfortable opening, maximum assisted opening and right lateral excursions, however, a statistically significant difference was found for left lateral excursions (P=0.030) with the orthognathic group having a reduced mean value compared with the control group.

3.3.6 TMD Diagnosis and Classification

	Diagnosis		Total N	P Value
	No TMD	TMD		
Control	52 (72.2%)	20 (27.8%)	72	**0.044**
Orthognathic	38 (55.9%)	30 (44.1%)	68	

Table 3.18 Presence of TMD in controls and orthognathic subjects from the RDC/TMD diagnosis

When comparing the prevalence of TMD in the control and orthognathic groups, 27.8% of the controls were classified as having TMD compared with 44.1% of the orthognathic patients. This difference was statistically significant (P=0.044).

The following table shows the distribution of TMD according to the RDC/TMD classification.

Diagnosis		Group	
		Control	Orthognathic
(1a) Myofacial pain	N	5	11
(1b) Myofacial pain with limited opening	N	0	3
(2a) Disc Displacement with reduction	N	15	16
(2b) Disc Displacement without reduction and with limited opening	N	2	4
(3c) Arthrosis	N	0	2
Total		22	36

NB: Subjects may have more than one diagnosis

Table 3.19 Distribution of TMD according to the RDC/TMD classification

Orthognathic patients most commonly suffered from disc displacement with reduction (2a), followed by myofacial pain (1a). However there were patients who also suffered from myofacial pain with limited opening (1b), disc displacement without reduction (2b) and arthrosis (3c). A similar pattern was seen for the controls who also suffered mainly from disc displacement with reduction (2a), followed by myofacial pain (1a). None of the controls were classified as suffering from myofacial pain with limited opening (1b) or arthrosis (3c)

3.3.7 TMD in relation to aetiological factors

This section explores the relationship between TMD and potential aetiological factors such as age, gender, skeletal pattern and occlusal features. Ethnicity was not included due to the small numbers in some of the groups.

TMD and Skeletal base (Orthognathic Group only)

	No TMD	TMD	P Value
Class I	6 (60.0%)	4 (40.0%)	0.360
Class II	15 (51.7%)	14 (48.4%)	
Class III	17 (58.6%)	12 (41.4%)	

Table 3.20 TMD in orthognathic patients according to A-P skeletal pattern.

There was no statistically significant relationship between the A-P skeletal base and the presence or absence of TMD (P=0.360).

TMD and MMPA (Orthognathic group only)

	No TMD	TMD	P Value
Average	14 (53.8%)	12 (46.2%)	0.342
Low	5 (50.0%)	5 (50.0%)	
High	19 (59.4%)	13 (40.6%)	

Table 3.21 Presence or absence of TMD according to vertical skeletal pattern

The results of the Chi squared test indicated no evidence of an association between the vertical relationship and the presence or absence of TMD (P=0.342).

TMD and Occlusal features (Control and Orthognathic Groups)

	Canine Guidance or Group function			P Value
	CG	**GF**	**Mixed (CG and GF)**	
No TMD	31 (64.6%)	47 (61.8%)	10 (83.3%)	0.351
TMD	17 (35.4%)	29 (38.2)	2 (16.7%)	

N.B It was not possible to record the excursions in 4 subjects due to open bite or extracted canine

Table 3.22 Presence or absence of TMD in relation to lateral excursions in control and orthognathic subjects

	Centric Occlusion/Centric relation		P Value
	Centric occlusion= Centric relation	**Centric occlusion ≠ Centric Relation**	
No TMD	70 (77.8%)	35 (70.0%)	0.309
TMD	20 (22.2%)	15 (30.0%)	

Table 3.23 Presence or absence of TMD in relation to centric occlusion/ centric relation in control and orthognathic subjects

No statistically significant association was found between the type of lateral excursion (canine guidance, group function or a combination of the two) and the presence or absence of TMD. In addition there was no statistically significant association observed for the presence of TMD and those who had centric occlusion coincident with centric relation and those who did not.

Presence or absence of TMD and relationship with gender, group and age

Logistic regression analyses were applied to the outcome of interest (the presence or absence of TMD) to investigate any associations with gender, group and age. The results of the univariate logistic regressions are shown in Table 3.24.

Factor		Odds Ratio	95% CI	P value
Gender	**Male** **Female**	1 1.455	(0.726, 2.915)	0.291
Group	**Control** **Orthognathic**	1 2.053	(1.016, 4.148)	**0.045**
Age (per year)		0.996	(0.952, 1.043)	0.877

Table 3.24: Univariate logistic regression investigating presence or absence of TMD, and association with gender, group and age

Females were 1.455 times more likely to have TMD than males, this was not however found to be statistically significant (P=0.291). When comparing the groups, orthognathic patients were twice (2.053) as likely to have TMD as the control subjects and this was significant (P=0.045). With regards to age, for every one unit of change (i.e. for every additional year) the odds of having TMD were reduced by 0.04% but this finding was not statistically significant.

Due to the fact that only one factor (group) was statistically significantly associated with the odds of having TMD and the remaining factors had no significant difference, it was not appropriate to undertake a multivariable analysis.

3.3.8 Kinesiograph Findings

The range of jaw movement was also established using the kinesiograph and the following parameters were recorded: comfortable opening, maximum opening, right and left lateral excursions, along with the maximum anterior jaw movement.

	Grp	Mean	N	Std Dev	Lower 95% CI	Upper 95% CI	Median	Min	Max	P Value
Comfortable Opening (mm)	Crl	33.8	60	11.4	30.85	36.74	37.35	5.2	50.5	**<0.001**
	OG	25.84	56	9.8	23.23	28.46	26.05	5.0	44.3	
Maximum Opening (mm)	Crl	37.5	60	7.3	35.61	39.40	38.40	20.3	50.8	**0.006**
	OG	34.3	56	6.5	32.52	36.03	34.60	19.7	46.3	
Right Lateral Excursion (mm)	Crl	7.03	60	2.6	6.36	7.70	6.80	0.9	13.2	0.420
	OG	6.6	56	2.0	6.10	7.17	6.60	3.1	11.9	
Left Lateral Excursion (mm)	Crl	7.1	60	2.6	6.44	7.79	7.25	1.7	12.7	0.305
	OG	7.4	56	2.7	6.65	8.11	7.20	1.4	14.4	
Maximum Anterior Movement (mm)	Crl	6.4	60	3.5	5.53	7.34	6.65	0.7	13.1	0.059
	OG	5.35	56	2.6	4.65	6.04	5.5	1.0	12.8	

Table 3.25 Kinesiograph findings for control (Crl) and orthognathic (OG) subjects

The orthognathic patients were found to have a statistically significantly reduced average comfortable opening compared with the control group ($P<0.001$), the findings were similar for average maximum opening, with the orthognathic group having a statistically

significantly reduced maximum opening (P=0.006) when compared with the control group. For the remainder of the kinesiograph results (i.e. lateral excursions and protrusions) no statistically significant differences were found between the groups.

3.4 Discussion

3.4.1 Demographics (Tables 3.3 to 3.7)

Previous authors have reported a higher proportion of females seeking orthognathic treatment with ratios of 3:2 (Mayo *et al.,* 1991) and approximately 2:1 quoted (Bailey *et al.,* 2001; Cunningham and Moles, 2009). This was not found to be the case for this study, as is reflected by the equal numbers of male and female orthognathic patients recruited during the study period. In view of the fact that it has previously been suggested that there may be a gender predilection for TMD, a similar distribution of control subjects was recruited.

The most common ethnic group in this study was white, which is not surprising given the results of the Government Census in 2001 when white individuals were noted to form the largest ethnic group in Britain (92.1%) (Office for National Statistics, 2008). With specific regard to the orthognathic patients, the findings of this study are similar to those reported by Bailey *et al.* (2001). They carried out a review to determine who seeks orthognathic treatment in the US and concluded that the vast majority of patients were white, although other ethnic minorities such as Hispanics were increasingly seeking treatment.

The mean age of the subjects in the control group was 30.13 years, which is in keeping with the inclusion criteria of 16-40 years of age. A mean age of 24.26 years was observed in the orthognathic group and this was similar to that reported in previous studies of UK orthognathic patients (Smith and Cunningham, 2004; Cunningham and Moles, 2009).

With regards to the skeletal pattern of the orthognathic patients, the majority of those recruited had a Class II or III antero-posterior skeletal pattern (42.6% in both instances) and there were fewer Class I cases (14.5%). When the vertical pattern was considered, a high angle was the most prevalent discrepancy (47.1%). Espeland *et al*. (2008) found that Class III patients constituted 55% of their sample, followed by 30% and 15% for skeletal Class II and I respectively. Although Class II malocclusions are the most prevalent in the Caucasian population (Proffit *et al.*, 1998), it appears that Class III and long-face individuals are more likely to seek orthognathic treatment than those with Class II problems. However, of those individuals offered orthognathic treatment, relatively more of the Class II groups were found to accept it (Bailey *et al.*, 2001).

3.4.2 Questionnaire findings: Patient self reported symptoms (Table 3.8)

Eight of the twelve parameters recorded from the self completion questionnaire were statistically significantly more problematic for the orthognathic patients than the control subjects. Headaches, neck pain and grinding showed equal prevalence in the two groups, but the patient group suffered from significantly more earaches, general facial pain, and jaw pain on opening/closing, jaw pain on biting/chewing, sore muscles around the jaw; clicking, jaw locking and limited mouth opening. In contrast, clenching was significantly more frequent amongst the controls.

Some of the findings in this current study are in agreement with previous findings and others conflict. Dervis and Tuncer (2002) found no significant difference for headaches or grinding between orthognathic patients and a control group who did not have skeletal discrepancies. However, in contrast with the current study, they found no statistically significant differences for any of the other subjective TMD symptoms reported by the control and patient groups. These conflicting results could be explained by the different time points used for conducting the examination in the two studies. Dervis and Tuncer (2002) examined orthognathic patients immediately prior to surgery, whilst in the current study patients were examined before any orthodontic treatment and this may have

influenced the results. In addition, fewer subjects were recruited in their study than in the current study which may have also affected the findings.

In a more recent study by Abrahamsson *et al.* (2009), orthognathic patients were also examined pre-treatment and compared with a group of subjects with no skeletal discrepancies. There were no reported differences between the groups with regards to the prevalence of headaches and grinding (P=0.373 and 0.080 respectively). However they did find that the patient group reported significantly more subjective TMD discomfort than the control group, and pain affecting the TMJ and masticatory muscles, jaw tiredness and clicking were also reported significantly more often in the orthognathic group.

3.4.3 Quality of Life (QoL) (Tables 3.9 to 3.12)

As the motivation to seek orthognathic treatment appears to be related to the desire to improve both function and aesthetics, one may expect orthognathic patients to have a poorer QoL. The OHIP-14 scores reflected this, with orthognathic patients having significantly higher overall average OHIP-14 scores, and therefore poorer QoL, compared with the controls (P<0.001). Similar findings were reported in other studies (Lee *et al.*, 2008).

A statistically significant difference was also found in the OHIP-14 scores between those subjects suffering from TMD and those who did not (P=0.007), with individuals suffering from TMD having a poorer QoL. A recent study assessing the impact of orofacial pain on the quality of life of patients with temporomandibular disorder also found a significant correlation between impact on quality of life and severity of TMD (Barros *et al.*, 2009).

When looking at the 7 domains separately (Functional limitation, Physical pain, Physiological discomfort, Physical disability, Psychological disability, Social disability and Handicap), the scores for the control group were relatively constant across all 7 domains, with mean scores ranging from 0.10 to 0.71. In the orthognathic group the mean scores ranged from 1.18 to 4.35, suggesting that the patients had a poorer quality of life in the

individual domains. These findings were not assessed statistically as the overall OHIP-14 was more relevant and showed a highly significant result. In addition as 7 domains would have been analysed there was a greater probability of obtaining a spurious significant result due to multiple testing and chance. However, the trends in the data would suggest that patients with skeletal discrepancies do have a poorer quality of life. The reasons behind this finding are clearly complex but were not the main focus of the current study.

3.4.4 Clinical findings

Joint related symptoms (Tables 3.13 to 3.14)

Some authors have reported equal proportions of orthognathic patients and controls suffering from TMJ pain on palpation (Dervis and Tuncer, 2002). When looking at pain on palpation of the TMJ (lateral poles) and intra-auricular pain in the current study, more subjects suffered from these symptoms in the orthognathic group than in the control group (11.8% *vs* 7.4% and 8.3% *vs* 4.2%). However, these differences were not statistically significant. Abrahamsson *et al.* (2009) found that orthognathic patients were four times more likely to have pain on TMJ lateral palpation than control subjects and this difference was statistically significant. The number of orthognathic patients recruited by Abrahamsson *et al.* (2009) was 121 compared with 68 in the present study, thus it is possible that the present study was underpowered and this may have affected the findings.

When comparing joint sounds between the two groups, no statistically significant differences were found for the prevalence of clicks or crepitus. These findings mirror those reported by Dervis and Tuncer (2002), but are in contrast with Abrahamsson *et al.* (2009) who found that orthognathic patients were twice as likely to have clicking on opening/closing than control subjects.

The majority of clicks observed in both the control and orthognathic groups were consistent, painless, and occurred on opening. It is not easy to draw conclusions regarding the clinical implications of these findings and this should be looked at in future studies. An opening click often reflects the condyle moving beneath the posterior band of the disc until

it returns to its normal relationship on the concave under surface of the disc. The opening click can occur at various points on the opening cycle: early, middle or late. Early clicks are often indicative of damage to the articular surfaces, whilst middle clicks are often caused by separation of the joint surfaces or by the snapping of the temporomandibular ligament over the lateral pole of the condyle. Clicks that occur late in the opening cycle may be the result of the condyle translating onto the anterior band of the meniscus and the closing click reflects reversal of this process (reciprocal clicking). The condyle moves under the posterior band of the disc until it snaps off the disc and onto the posterior attachment. Closing clicks usually occur in the final third of the cycle but must not be confused with the sounds generated by the premature contact of the teeth (Watt, 1980). The protrusive and retrusive condylar paths do not coincide because on mouth opening the disc is displaced and the distance between the osseous components is impaired, compared with when the disc is in a normal position between the bony joint components during mouth closure (Isberg, 2001).

Muscle Pain (Table 3.15)

A statistically significant difference was found when comparing prevalence of tenderness/pain on palpation of the masseter and lateral pterygoid muscles between the control and orthognathic groups, with the orthognathic group suffering from muscle tenderness more often. However, there were no statistically significant differences, between the two groups when considering pain on palpation of the temporalis. Again, previous studies have shown conflicting results. Dervis and Tuncer (2002) looked at overall muscle tenderness on palpation and found no significant differences between orthognathic patients and controls, although other researchers have found a statistically significant difference in prevalence (Abrahamsson *et al.*, 2009).

Range of Jaw movement (Tables 3.16 and 3.17)

Orthognathic patients had a greater prevalence of lasting deviations on opening when compared with controls, 11.8% of the orthognathic group and none of the controls had lasting deviations and this difference was statistically significant (P=0.002). The orthognathic group also had a higher percentage of transient deviations than the control

group (14.7% and 11.1% respectively), although this difference was not statistically significant. A significant difference was also reported by Abrahamsson *et al.* (2009) who found that orthognathic patients were more likely to have deviations on opening or closing of the mandible, although the types of deviation observed were not specified.

The aetiological factors associated with lasting deviations include condylar hyperplasia, coronoid hyperplasia, unilateral fibrous ankylosis, condyle osteoarthritis, unilateral disc displacement without reduction, adhesions within the joint (anchored disc phenomenon), unilateral mandibular dislocation, and occasionally primary or metastatic tumours of the condyle (Lima *et al.,* 2009). Disc displacement without reduction is caused by laxity of the lateral disc attachment which allows migration of the disc to an anterior and medial position, resulting in a mechanical barrier to the movement of the condyle. The anchored disc phenomenon occurs when the disc is pressed against the fossa in the absence of sufficient lubrication (Lima *et al.,* 2009). As lasting deviations are frequently caused by adhesions within the joint or disc displacement without reduction (Campos *et al.,* 2008; Lima *et al.,* 2009), this would imply that the orthognathic patients may be more likely to experience these conditions. Two individuals in the control group were classified as being RDC/TMD 2b (disc displacement without reduction and with limited opening) compared with 4 orthognathic patients (Table 3.19), although these numbers are too small to draw conclusions regarding the predilection of orthognathic patients to these conditions. Further comprehensive investigations with MRI imaging techniques would be required to confirm this with certainty.

There was no statistically significant difference for average comfortable and maximum assisted opening between the patients and controls, nor was there a difference with respect to right lateral excursions. A significant difference (P=0.030) was observed with respect to left lateral excursions, with the orthognathic group having a reduced mean value. Limitations in lateral excursions are sometimes also an indication of disc displacement without reduction (if this is less than 7mm) or adhesions within the joint (Lima *et al.,* 2009), this may therefore indicate that orthognathic patients have a greater susceptibility to these conditions. However, this finding could also be incidental due to multiple testing,

which would be supported by the fact that there was no significant difference for right lateral excursions. In addition, the magnitude of the differences found is unlikely to be clinically relevant (9.81mm compared with 8.87mm).

The findings contrast with those of Abrahamsson *et al.* (2009), who found a significant difference between the mean maximum opening and lateral excursion values for their orthognathic and control groups. It is also interesting that the mean maximum opening and lateral excursion values were higher for both groups in the Abrahamsson *et al.* (2009) study than were recorded in this study, thus the differing findings may be explained by the difference in sample frames (Sweden *vs.* UK). It is possible that anthropological differences exist between the two populations particularly with regards to jaw and muscular structure. It may also be possible that the culture for seeking treatment is different between the two populations, with the Scandinavian patients being referred or seeking treatment more commonly because of functional (rather than aesthetic) problems. As such, they may present with a greater degree of dysfunction, thus explaining the significant differences observed when comparing them with the control group.

3.4.5 TMD diagnosis and classification (Tables 3.18 and 3.19)

In this study, the presence or absence of TMD was diagnosed according to the RDC/TMD criteria (Dworkin and LeResche, 1992). The RDC/TMD demonstrates high reliability for the most common TMD diagnoses, thus supporting its use in clinical research (John *et al.*, 2005). Based on this classification 27.8% of the controls were diagnosed as having TMD compared with 44.1% of the orthognathic patients and this difference was statistically significant (P=0.044). This suggests that orthognathic patients are more likely to suffer from TMD than their skeletal Class I counterparts and clinicians should consider this when dealing with orthognathic patients. Abrahamsson *et al.* (2009) also used the RDC/TMD and their findings were in agreement with this study, 42.1% of the orthognathic group and 32.1% of the controls were diagnosed with TMD and this difference in prevalence was also statistically significant (P<0.001). Dervis and Tuncer (2002) found no statistically significant difference between orthognathic patients and control subjects, however they

used the Helkimo Index to diagnose TMD and this may explain the different results obtained.

The most commonly presenting classification based on the RDC/TMD was disc displacement with reduction (2a), which accounted for approximately half of the diagnoses observed in both the orthognathic and control groups. The next most prevalent diagnosis was myofacial pain (1a). These diagnoses were also amongst the most commonly observed in the Abrahamsson *et al.* (2009) study.

The higher prevalence of TMD reiterates the need for a thorough TMD examination prior to undertaking orthognathic intervention in order to obtain accurate baseline records and to allow a full discussion of the fact that it is not possible to guarantee any improvement in the signs and symptoms of TMD post-surgery. The findings may also have implications when managing adolescents with skeletal discrepancies and this should be looked at in future research.

3.4.6 TMD in relation to aetiological factors

A-P skeletal pattern (Table 3.20)

There was no evidence to suggest that the prevalence of TMD differed amongst the different A-P skeletal groups in this study, although the relatively small number of subjects in each of the sub-groups must be borne in mind and further studies with larger sample sizes are recommended. Other researchers have also reported a lack of association between TMD signs/symptoms and the skeletal classification (Laskin *et al.,* 1986; Onizawa *et al.,* 1995; Panula *et al.,* 2000; Dervis and Tuncer, 2002; Farella *et al.,* 2007). In contrast, White and Dolwick (1992) reported that TMD was more common amongst Class II patients and this finding was consistent with that of other studies (Upton *et al.,* 1984; Sonnesen *et al.,* 1998).

Forty percent of the patients with Class I skeletal pattern discrepancies had TMD, compared with 48.4% of Class II patients and 41.4% of Class III which suggests a trend

towards Class II patients having an increased TMD prevalence, although this was not statistically significant (P=0.360).

Vertical Pattern (Table 3.21)

There was no evidence of an association between the MMPA and the presence or absence of TMD. Forty six percent of the average angle patients had TMD compared with 50% of those low angle and 40.6% of those with high angles. Again, the actual numbers involved were small and although the findings were not statistically significant, the trend was for average and low angle patients to have a greater prevalence of TMD than the high angle patients. This finding was consistent with other studies (Kerstens *et al.,* 1989; White and Dolwick, 1992). Again the small sample size in the subgroups may have been a limiting factor.

Occlusal features (Tables 3.22 and 3.23)

The association between TMD and occlusal features has been explored in the orthodontic literature (Solberg *et al.,* 1979; Ingervall *et al.,* 1980; Pullinger *et al.,* 1988; Clark and Evans, 2001). Some studies found an association between occlusal discrepancies in the CR-CO and temporomandibular disorders (Solberg *et al.,* 1979; Ingervall *et al.,* 1980; Pullinger *et al.,* 1988). The findings from the current study are in agreement with more recent studies reporting no significant association between occlusal relationships and TMD (Clark and Evans, 2001). In their review articles, Reynders (1990) and Seligman and Pullinger (1991) concluded that no scientific evidence existed for a causal relationship between occlusion and TMD. Hence, orthognathic treatment cannot be recommended purely on occlusal grounds (such as occlusal slides).

Presence or absence of TMD and the influence of gender, group and age (Table 3.24)

Although both males and females suffer from TMD, studies have reported a higher prevalence among women, usually in the ratio of 2:1 (Dworkin *et al.,* 1990; Lipton *et al.,* 1993; LeResche 1997). When comparing results from previous studies, it is therefore important to consider the potential effect of the gender distribution of subjects in the patient and control groups. In this study the gender distribution in both the orthognathic and

control groups was 1:1, but in studies where a greater proportion of females are recruited this could have an effect on the overall prevalence of TMD within that group.

The results found in the current study were not significant for gender, however, the odds ratio of approximately 1.5 indicates that women are 1.5 times more likely to experience TMD than males and therefore seems to reiterate the trend reported in previous research. It must be borne in mind that the studies mentioned above are representative of the general population, whereas the results for the current study apply to a combined orthognathic patient/ control group population. Dervis and Tuncer (2002) did not find any significant difference between the females and males in their study of orthognathic patients, although they attributed this to the small sample size (21 males and 29 females).

Although the association between TMD and age has been explored in the general population, it is rarely reported in orthognathic cohorts. This study found no significant association between TMD and age. This suggests that there is no need to preclude older patients from having surgery because of concerns regarding development of TMD or worsening of existing signs/symptoms. However, it must be acknowledged that the age range of those recruited in the study was specific (16 to 40 years) and it would be unwise to attempt to extrapolate the results to patients outside this age range.

3.4.7 Kinesiography Findings (Table 3.25)

A significant difference was observed for comfortable opening and maximum opening between the control and orthognathic groups. In both cases the orthognathic group had a reduced mean opening (mean difference of 8mm for comfortable opening and 3mm for maximum opening). A difference of 8mm would be considered clinically relevant, however, a 3mm difference for the maximum opening is less likely to be of clinical importance. Of more importance is that both groups would be considered to have an adequate comfortable and maximum opening. No significant difference was observed for the remaining kinesiography findings (lateral excursions and protrusion).

The findings for comfortable and maximum recorded opening contradicted the findings observed from the clinical examination where there were no significant differences between the two groups with regards to opening. While some authors have indicated that moderate agreement can be expected between the measurements obtained from kinesiograph readings and conventional measurement methods (Rivera-Morales *et al.*, 1996), others have reported that jaw tracking devices have a low additional diagnostic value because of the biological variation in the function of the stomatognathic system, fluctuations over time and because of the inherent mechanical factors involved in the clinical use of such instruments. Although more recent tracking devices have higher reliability, the clinical usefulness is sometimes doubtful (De Boever *et al.*, 2008). Assembling the kinesiograph and attuning it to the patient is time consuming and although it may be useful for tracking jaw movements diagrammatically, it does not substitute for clinical measurements and, as such, the conclusions of this study would be that the kinesiography adds little diagnostic value to TMD studies. Similar trends in the data were observed when comparing the results with the clinical measurements however.

3.5 Conclusions

The prevalence of TMD reported in this orthognathic population was 44.1% which is lower than that reported by some authors (Schneider *et al*., 1991; Link and Nickerson, 1992; Panula *et al.*, 2000). It is, however, similar to that reported by Abrahamsson *et al.* (2009) and this may be explained by the use of the RDC/TMD criteria in both studies. This ability to compare findings highlights the benefits of standardising TMJ examination protocols and this is a recommendation for future research.

This study found a significant difference in TMD prevalence between the controls (27.8%) and patients (44.1%), with the patient cohort being more susceptible to TMD. However, although orthognathic patients appear more likely to suffer from TMD, whether treatment

will improve their TMD is highly questionable. This is an important issue to be highlighted in any informed consent process.

Orthognathic patients reported more TMD symptoms (such as general facial pain, jaw pain on opening/closing, clicking and limited mouth opening) than their control group counterparts. When comparing the clinical findings of the two groups, there was a greater prevalence of orthognathic patients presenting with signs such as pain on palpation of the TMJ and clicking, but these results were not significant. There was a significantly higher prevalence of orthognathic patients presenting with pain on palpation of the masseter and the lateral pterygoid than in the control group.

This chapter examined and discussed relevant variables concerning TMD and the presenting signs and symptoms in orthognathic patients, when compared with subjects with no skeletal discrepancies. The overall findings from this study support other researchers who have found that orthognathic patients are more likely to suffer from TMD (Abrahamsson *et al.,* 2009). However, no relationship could be established with regards to TMD and the various skeletal patterns due to the relatively small subgroups. Future studies involving larger sample sizes and classification according to the RDC/TMD criteria will hopefully address this issue.

Chapter IV: A Longitudinal Study of Temporomandibular Joint Disorders in Orthognathic patients

Introduction, Aims and Objectives

This chapter reports on a longitudinal study of orthognathic patients with skeletal discrepancies undertaking orthognathic intervention. The study followed this cohort of patients longitudinally throughout treatment with the aim of establishing whether any TMD symptoms altered during the course of treatment.

The objectives were as follows:

1. To determine patient reported symptoms and clinical signs during the course of treatment.
2. To investigate whether there were any changes in TMD signs and symptoms during the course of treatment.
3. To assess TMD signs and symptoms at the pre-surgery time point (which has often been used at the "baseline" measure in previous studies) and determine how this compares with the pre-treatment status.

4.1 Introduction

Viewpoints expressed regarding TMD and the impact of orthognathic treatment is often conflicting. There is little high quality research on the association between major skeletal disharmonies and the effects on TMD and few longitudinal, controlled long-term follow-up studies investigating TMD and function post-surgically. There appears to be wide variation in the prevalence of signs and symptoms of TMD in the orthognathic population prior to treatment, but several studies report significant proportions of orthognathic patients with TMD who experienced improvements in their symptoms after surgery (White and Dolwick,

1992; De Clercq *et al.,* 1995; Gaggl *et al.,* 1999). In contrast, other subjects who were asymptomatic pre-operatively developed TMD post-operatively (Scheerlinck *et al.,* 1994; Wolford *et al.,* 2003).

A longitudinal follow-up of 52 orthognathic patients undertaken by Egermark *et al.* (2000) showed that fifty-one percent reported improvement in their TMD signs and symptoms post-surgery, while 37% reported no change. Therefore, the results of this study supported the theory that orthognathic treatment may have a beneficial effect on TMJ status.

However, other studies report minimal or no change in TMD after orthognathic surgery. Sostmann *et al*. (1991) evaluated 86 orthognathic patients using Helkimo´s Anamnestic and Dysfunction Indices and found no relationship between TMD and the type of malocclusion or the surgical approach, but concluded that possible beneficial effects were achieved for certain symptoms, such as TMJ pain and sounds. A modification of Helkimo´s Index was also used in a prospective study of 22 Class II patients who underwent BSSO procedures (Smith *et al.,* 1992). Subjectively, there was a reduction in muscular pain, headache, joint sounds and parafunctional habits, but clinical signs remained largely unchanged.

Although a number of prospective longitudinal studies have investigated the signs and symptoms of TMD in orthognathic patients (for further details see the systematic review of the literature in Chapter II), very few of these studies (n=3) examined patients pre-treatment rather than pre-surgery as the initial time point (Rodrigues-Garcia *et al.,* 1998; Panula *et al.,* 2000; Pahkala and Heino, 2004) and none diagnosed patients according to the RDC/TMD criteria which is currently recommended for research in this area.

The prospective multicentre study undertaken by Rodrigues-Garcia *et al.* (1998) explored the relationship between Class II malocclusions and TMD pre-treatment and 2 years after BSSO using the Craniomandibular Index (CMI). The results showed significant improvements in CMI scores and muscle pain, reduction in subjective pain and discomfort and a reduction in clicking upon opening. However, crepitus in the TMJ increased. The magnitude of the change in muscular pain did not appear to be related to the severity of the

pre-treatment malocclusion and the authors concluded that the results did not support the theory that TMD is related to the presence of a severe Class II malocclusion.

Pahkala and Heino (2004) investigated the effect of the sagittal split ramus osteotomy on TMD in 72 (49 females and 29 males) patients before, and 2 years after, orthognathic treatment using the modified Helkimo Index. The patients were classified into subgroups: myogenous, arthrogenous, or both components of TMD. They found that clicking and headaches decreased significantly following treatment, whilst crepitus increased. In general, the severity of the dysfunction was reduced and multiple regression analysis showed that patients with the largest overjets and previous occlusal splint therapy benefited most from orthognathic treatment. In addition, patients with signs of mainly myogenous origin experienced greater improvement than patients with mainly arthrogenous components of TMD. The results suggested that, in patients with severe maxillomandibular discrepancies, orthognathic treatment may reduce myogenous TMD pain and discomfort.

There are, however, weaknesses in many of these studies as there are no non-treatment control groups; patient samples are often small; follow-up duration is short and many of the studies are retrospective.

4.2 Materials and Methods

4.2.1 Recruitment of orthognathic patients

All patients for this section of the study were recruited from the Joint Orthodontic/ Orthognathic clinic at the Eastman Dental Hospital, UCLH Foundation Trust during the period April 2006 to January 2009, and this cohort of patients is already described in Chapter III. Not all patients recruited for Chapter III had completed treatment and could be included in this chapter.

4.2.2 Ethical approval

A notice of substantial amendment was submitted to University College London Hospitals Ethics Committee to allow inclusion of a skeletal control group into this study and approval for this was obtained (Appendix 12).

4.2.3 Control group comprising subjects with skeletal discrepancies

It was initially intended to use a control group of patients with skeletal discrepancies in this study. A cohort of orthognathic patients were identified, who had severe skeletal discrepancies and were seen on the Orthognathic clinic but subsequently decided not to proceed with treatment. These patients were consented to be examined twice: at the time they were seen on the Orthognathic clinic and a second time at least 1 year later. The intention was that these individuals could act as a control group to allow for TMD changes which may occur over time in the absence of orthognathic treatment. Eighteen patients were initially recruited and, at the second time point, all of these individuals were sent a letter inviting them to return for a second examination and an incentive (a gift voucher) was offered. Unfortunately only 2 individuals responded to arrange appointments despite several reminders being sent out. It was therefore decided that it was not feasible to include this group within the study, thus only the orthognathic patients undergoing treatment were followed longitudinally.

4.2.4 Data collection and measurements

One researcher (S.A.) carried out all of the data collection for this part of the study and this included:

1. Questionnaire: self reported TMD symptoms and Quality of Life (OHIP-14)
2. Clinical examination using the RDC/TMD classification
3. Kinesiography examination

Details of all of the above procedures have previously been described in Chapter III.

Time points for observations

All of the required observations were undertaken at three time points during the course of treatment.

1. Prior to any treatment (T1)
2. Approximately 9-12 months into pre-surgical orthodontics ("prior to surgery") (T2)
3. Approximately six weeks following removal of orthodontic appliances (T3)

The above time points were chosen for the following reasons:

T1: To act as a true baseline for comparisons before any treatment had been started.

T2: This time point has been used as a baseline in many previous studies. This allowed comparison between T1 and T2 to determine whether there were any changes in signs and symptoms. This would then allow a conclusion to be drawn as to whether T2 can legitimately be used as a "proxy" baseline.

T3: By choosing debond as the end of treatment outcome, the final follow-up was at least 6 months post surgery for all patients, this allowed swelling and inflammation to subside and the presence of the fixed appliances could not affect the outcomes.

Data collection began in April 2006 (following TMJ examination calibration in March 2006). The final data collection date was the beginning of November 2009 and this

coincided with the end of SA's research time, as set by University College London enrolment. No patient follow-ups were possible beyond November 2009.

4.2.5 Statistical Analyses

Statistical analysis was carried out using SPSS version 14, (SPSS UK Ltd, Guildford Surrey, UK).

McNemar test

The McNemar test is undertaken on 2x2 contingency tables for dichotomous data to test the difference between paired proportions e.g. in studies in which patients serve as their own control or in studies with a "before and after" design (Petrie and Watson, 2006). Thus it was suitable when comparing presence or absence of TMD or other signs and symptoms, at the various time points.

Wilcoxon signed rank test

The Wilcoxon signed rank test, also known as the Wilcoxon matched pairs test, is a non-parametric test used to test the difference in median values for paired data. This test is the non-parametric equivalent of the paired *t*-test and was used in this study to compare the number of muscle sites that were tender to palpation at the time points assessed (Petrie and Watson, 2006).

Paired *t*-test

The paired *t*-test is a statistical technique used to compare the difference between two means when the two samples are related i.e. in 'before and after' studies. The first assumption in the paired sample t-test is that only matched pairs can be used and secondly, a normal distribution is assumed and the variance of the two samples must be the same (Petrie and Watson, 2006). A paired sample *t*-test was used for comparison of the continuous variables in this study (i.e. maximum opening) at the different time points.

4.3 Results

4.3.1 Orthognathic patient recruitment

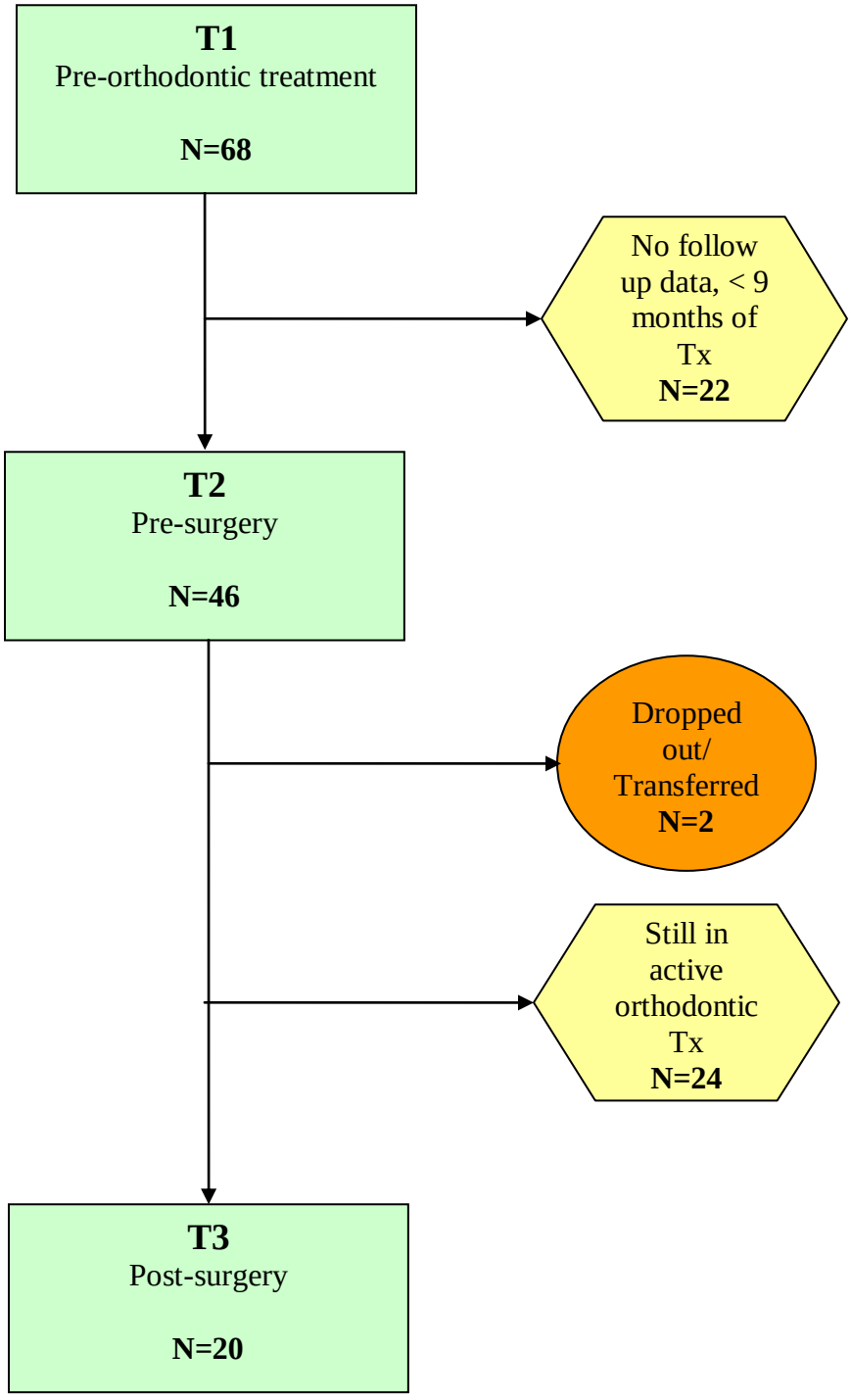


Figure 4.1 Progress of orthognathic patients through this study

At the first time point (T1) 68 orthognathic patients were recruited and examined (as described in Chapter III). Twenty two of this cohort provided pre-treatment data but were less than 9 months into pre-surgical orthodontics and could not provide T2 data within the time constraints of the study.

Forty-six patients were assessed at T2. Two patients were lost to follow up after T2; one of these patients transferred to another unit and the second patient could not be contacted.

Of the 68 patients recruited at T1, 20 patients had completed their course of orthognathic treatment and had appliances removed during the time frame of this study and were assessed at the third time point (T3). A further 24 patients were still in active post-surgical orthodontics at the cut-off date and could not be included for their final assessments.

4.3.2 Comparison between T1 and T2

Demographics:

	Gender		**Skeletal Base**			**MMPA**		
	Male	**Female**	**Class I**	**Class II**	**Class III**	**Average**	**High**	**Low**
N	27	19	5	19	22	20	22	4
%	59	41	11	41	48	43	48	9
Total N	46		46			46		

Table 4.1 Summary of the demographic details for the 46 patients at T2

Twenty seven males and 19 females were examined at T2. Forty eight percent of the patients were being treated for the correction of a skeletal Class III discrepancy, 41% for the correction of a skeletal Class II and only 11% involved skeletal Class I patients. In addition, 43% of patients had an average MMP angle; 48% had a high angle and 9% had a low MMP angle.

TMD Diagnosis:

The table below shows the distribution of patients with, and without, TMD at T1 and T2.

		Diagnosis at T2 (n=46)			**P Value**
		No TMD	**TMD**	**Total**	
Diagnosis at T1 (n=46)	**No TMD**	21	8	29	0.791
	TMD	6	11	17	
	Total	27	19	46	

NB: Using the Mc Nemar test

Table 4.2 TMD diagnosis at T1 and T2

Eleven patients presented with TMD at both T1 and T2 and 21 patients had no TMD at T1 or T2. There were 6 patients who presented with TMD at T1, but did not have TMD at T2 and 8 patients with no TMD diagnosis at T1 but who later developed it at T2. These results showed no statistically significant differences.

4.3.3 Comparison at T1 and T2: Patient reported symptoms

The patient self-reported symptoms were investigated at both T1 and T2 to determine whether any changes occurred. The results of the most relevant patient self-reported symptoms findings are highlighted below.

Headaches:

		Diagnosis at T2			**P Value**
		No	**Yes**	**Total**	
Diagnosis at T1	**No**	24	2	26	0.070
	Yes	9	11	20	
	Total	33	13	46	

NB: Using the Mc Nemar test

Table 4.3 Comparison of headaches at T1 and T2

Twenty four patients did not report headaches at either time point, whilst 11 reported headaches at both. Nine patients suffered from headaches at T1 but did not report them at T2, whilst 2 patients who did not report headaches at T1 reported them at T2. None of these differences were statistically significant.

Jaw pain on opening and closing:

		Diagnosis at T2			**P Value**
		No	**Yes**	**Total**	
Diagnosis at T1	**No**	22	9	31	0.803
	Yes	7	8	15	
	Total	29	17	46	

NB: Using the Mc Nemar test

Table 4.4 Comparison of jaw pain on opening/closing at T1 and T2

Of the 46 patients, 22 did not report any pain on opening or closing at T1 or T2, whilst 8 patients reported this at both time points. However, 7 patients who had jaw pain on opening and closing improved by T2 and 9 patients with no pain at T1 complained of this at T2. The differences were not statistically significant.

Muscle pain around the jaw

		Diagnosis at T2			**P Value**
		No	**Yes**	**Total**	
Diagnosis at T1	**No**	28	6	34	0.752
	Yes	4	8	12	
	Total	32	14	46	

NB: Using the Mc Nemar test

Table 4.5 Comparison of muscle pain around the jaw at T1 and T2

No statistically significant differences were found for muscle pain; twenty eight patients had no muscle pain at either time point, whilst 8 patients complained of pain at both T1 and T2. Four of the patients who had muscle pain at T1 did not report symptoms at T2, whilst 6 patients who had no symptoms at T1 had developed them at T2.

4.3.4 Comparison at T1 and T2: Clinical findings

Although all of the clinical signs were investigated, only the most relevant signs are reported here due to the relatively small sample size.

Pain over the lateral poles of TMJ:

		Diagnosis at T2			**P Value**
		No	**Yes**	**Total**	
Diagnosis at T1	**No**	39	5	44	0.219
	Yes	1	1	2	
	Total	40	6	46	

NB: Using the Mc Nemar test

Table 4.6 Comparison of pain over the lateral poles of the TMJ at T1 and T2

Only 1 patient had pain on palpation of the lateral poles of the TMJ at both T1 and T2, the majority of the patients (n=39) did not experience pain on palpation at either time point. There were, however, 5 patients who developed new symptoms of pain at T2 and 1 patient whose pain improved at T2. These findings were not statistically significant.

Clicking of the TMJ:

		Diagnosis at T2			P Value
		No	**Yes**	**Total**	
Diagnosis at T1	**No**	28	6	34	0.508
	Yes	3	9	12	
	Total	31	15	46	

NB: Using the Mc Nemar test

Table 4.7 Comparison of clicking of the TMJ at T1 and T2

No statistically significant difference was found between T1 and T2 for clicking of the TMJ. The majority of patients had no TMJ clicking (n=28), whilst 9 patients had clicking at both T1 and T2. Six patients who were symptom free at T1 developed clicking during pre-surgical orthodontics and 3 patients who initially presented with clicking had no clicking at T2.

Muscle pain on palpation:

		Diagnosis at T2					P Value
Diagnosis at T1	Number of muscles sites tender to palpation	0	1	2	≥3	Total	0.773
	0	27	3	2	0	23	
	1	4	0	0	1	4	
	2	1	0	1	1	3	
	≥3	0	1	3	1	5	
	Total	32	4	6	4	46	

NB: Using the Wilcoxon signed rank test

Table 4.8 Comparison of the number of muscles sites which were tender to palpation at T1 and T2

The majority of the patients did not experience any pain on muscle palpation at either T1 or T2 (n=27). Five patients had pain on palpation of 3 or more muscle sites at T1, compared

with 4 patients at T2. These differences were not statistically significant, however, the small number of subjects in each of the cells should be noted.

Maximum opening:

	Mean (mm)	Std. Deviation (mm)	**P Value**
Maximum opening at T1	48.70	8.151	P<0.001
Maximum opening at T2	51.85	7.794	

NB: Using the *t*-test

Table 4.9 Comparison of maximum opening at T1 and T2

A highly significant difference was observed for maximum opening (P<0.001), with the patients having an increased maximum opening at T2 compared with T1.

4.3.5 Comparison at T1 and T3

This section presents the findings at the start of treatment and following debond (T1 and T3).

Demographics:

	Gender		**Skeletal Base**			**MMPA**		
	Male	**Female**	**Class I**	**Class II**	**Class III**	**Average**	**High**	**Low**
n	12	8	1	7	12	11	7	2
%	60	40	5	35	60	55	35	10
Total N	20		20			20		

Table 4.10 Summary of the demographic details for the 20 patients who had completed orthognathic treatment (i.e had T1, T2 and T3 data available)

Twelve males and 8 females completed treatment in the time frame of this study. Twelve of the 20 cases were for the correction of a skeletal Class III discrepancy, 7 were for the correction of a skeletal Class II and only 1 patient had a skeletal Class I base. In addition, 11 patients had an average MMP angle; seven had a high angle and 2 had a low MMP angle. Further details of these patients can be found in Table 4.20.

TMD Diagnosis:

		Diagnosis at T3			**P Value**
		No TMD	**TMD**	**Total**	
Diagnosis at T1	**No TMD**	6	5	11	0.727
	TMD	3	6	9	
	Total	9	11	20	

NB: Using the Mc Nemar test

Table 4.11 TMD diagnosis at T1 and T3

When considering the presence or absence of TMD amongst the 20 patients who were examined at the initial time point and end of treatment, 6 patients suffered from TMD at both T1 and T3, whilst a further 6 patients had no TMD at either time points. Three patients who had TMD at T1 did not have TMD at the end of treatment, whilst 5 patients who were initially asymptomatic, had TMD at the end of treatment. These differences were not statistically significant.

4.3.6 Comparison at T1 and T3: Patient reported symptoms

Headaches:

		Diagnosis at T3			P Value
		No	**Yes**	**Total**	
Diagnosis at T1	**No**	12	1	13	0.371
	Yes	4	3	7	
	Total	16	4	4	

NB: Using the Mc Nemar test

Table 4.12 Comparison of headaches at T1 and T3

Headaches were reported by 3 patients at both T1 and T3, whilst 12 patients did not suffer from headaches at either time point. Four of the patients who initially suffered from headaches did not report this at T3 and only one patient developed new symptoms at T3. As with the previous results, no statistically significant difference in the prevalence was observed between the two time points.

Jaw pain on opening and closing:

		Diagnosis at T3			P Value
		No	**Yes**	**Total**	
Diagnosis at T1	**No**	14	2	16	0.617
	Yes	2	2	4	
	Total	16	4	20	

NB: Using the Mc Nemar test

Table 4.13 Comparison of jaw pain on opening/closing at T1 and T3

The majority of patients (n=14) did not report jaw pain on opening and closing at either time point. Two patients who were previously asymptomatic developed new symptoms at T3 and 2 patients experienced an improvement in their condition at T3. These differences in prevalence were not statistically significant.

Muscles pain around the jaw

		Diagnosis at T3			**P Value**
		No	**Yes**	**Total**	
Diagnosis at T1	**No**	11	4	15	0.724
	Yes	4	1	5	
	Total	15	5	20	

NB: Using the Mc Nemar test

Table 4.14 Comparison of muscles pain around the jaw at T1 and T3

With regards to muscle pain around the jaw, the results were in line with other self-reported symptoms and no significant difference in the prevalence of muscle pain existed between T1 and T3. Eleven of the 20 patients had no soreness at T1 or T3 and only 1 patient reported pain at both time points. Four patients experienced a worsening of their symptoms at T3 and a further 4 patients experienced an improvement.

4.3.7 Comparison at T1 and T3: Clinical findings

Pain over the lateral poles of the TMJ:

		Diagnosis at T3			**P Value**
		No	**Yes**	**Total**	
Diagnosis at T1	**No**	16	3	19	0.625
	Yes	1	0	1	
	Total	17	3	20	

NB: Using the Mc Nemar test

Table 4.15 Comparison of pain over the lateral poles of the TMJ at T1 and T3

Clinical examination revealed that 16 patients had no pain on palpation of the lateral poles of the TMJ at T1 or T3. Three previously asymptomatic patients had developed pain on palpation at T3 and one symptomatic patient improved. No statistically significance difference was found.

Clicking of the TMJ:

		Diagnosis at T3			**P Value**
		No	**Yes**	**Total**	
Diagnosis at T1	**No**	11	4	15	0.375
	Yes	1	4	5	
	Total	12	8	20	

NB: Using the Mc Nemar test

Table 4.16 Comparison of clicking of the TMJ at T1 and T3

Eleven patients had no signs of clicking at either T1 or T3, whilst 4 patients had signs at both time points. Four patients who were initially asymptomatic developed new clicks and one patient who initially had a click did not have this at T3. There were no statistically significant differences in the prevalence of the clicks between the two time points.

Muscle pain on palpation:

	Diagnosis at T3						P Value
Diagnosis at T1	Number of muscles sites tender to palpation	**0**	**1**	**2**	**≥3**	**Total**	0.903
	0	11	1	1	1	14	
	1	3	0	0	0	3	
	2	1	0	0	1	2	
	≥3	0	0	0	1	1	
	Total	15	1	1	3	20	

NB: Using the Wilcoxon sign rank test

Table 4.17 Comparison of the number of muscles sites tender to palpation at T1 and T3

Eleven patients did not have tenderness to palpation of their muscles of mastication at T1 or T3. One patient experienced pain on palpation of 3 or more muscle sites at T1 compared with three patients at T3, but this difference in prevalence was not statistically significant.

Maximum opening:

	Mean (mm)	Std. Deviation (mm)	**P Value**
Maximum opening at T1	47.65	8.689	0.552
Maximum opening at T3	49.50	8.294	

NB: Using the *t*-test

Table 4.18 Comparison of maximum opening at T1 and T3

The mean maximum opening improved from 47.65mm to 49.50mm at T3. However, this difference in means was not statistically significant.

4.3.8 Longitudinal follow up of the 20 patients who completed treatment

A summary of the findings for the 20 patients who completed orthognathic treatment is shown in Table 4.20

Twelve patients had no change in their TMD status between T1 and T3; five had a worsening of their condition and three patients showed an improvement. Of the cases where worsening of the TMD condition was observed (Table 4.19):

- OG4 - a average angle Class III patient developed new signs of clicking and pain on palpation of more than three muscles
- OG5 - a average angle Class III patient developed new signs of clicking
- OG12 - a high angle Class II patient developed new signs of clicking
- OG24 - a high angle Class III patient developed pain on palpation of the lateral poles and restricted opening
- OG27 - a low angle Class III patient developed new signs of clicking

No definite trend could be observed regarding TMD and antero-posterior/ vertical skeletal patterns, but in the majority of the cases where the condition worsened (n=4 of 5), the change in TMD diagnosis was due to the development of a new click.

The two patients who experienced an improvement in their TMD were of differing skeletal patterns (Table 4.19):

- OG14 - a high angle skeletal Class I patient had reduced muscular and TMJ lateral pole pain post-surgery
- OG16 - a high angle skeletal Class II patient had an improvement in clicking post-surgery

Due to the small numbers involved no trend could be shown for the two patients.

Deterioration in TMD			**Improvement in TMD**		
Pt ID	**Malocclusion**	**Change in TMD**	**Pt ID**	**Malocclusion**	**Change in TMD**
OG4	Class III Average angle	Clicking and Pain	**OG14**	Class I High angle	Pain on palpation of TMJ and muscular pain
OG5	Class III Average angle	Clicking	**OG16**	Class II High angle	Clicking
OG12	Class II High angle	Clicking			
OG24	Class III High angle	Pain on palpation of TMJ and restricted opening			
OG27	Class III Low angle	Clicking			

Table 4.19 Summary of patients who had either an improvement or deterioration in their TMJ status between T1 and T3.

Pt	Gender	Skeletal base	MMPA	Max opening			TMJ-lateral pole pain			Click			Muscle pain in > 3 muscles			TMD		
				T1	T2	T3	T1	T2	T3	T1	T2	T3	T1	T2	T3	T1	T2	T3
OG3	M	3	Average	52			N	N	N	N	N	N	N	N	N	N	N	N
OG4	F	3	Average	50			N	Y	N	N	Y	Y	N	Y	Y	N	Y	Y
OG5	M	3	Average	50			N	N	N	N	Y	Y	N	N	N	N	Y	Y
OG6	M	2	Average	25			N	N	N	N	N	N	N	N	N	Y	Y	N
OG7	F	3	Average	50			N	N	N	N	N	N	N	N	N	N	N	N
OG11	M	2	Average	44			N	N	N	N	N	N	N	N	Y	N	N	N
OG12	M	2	High	48			N	N	N	N	N	Y	N	N	N	N	N	Y
OG14	M	1	High	40			Y	N	N	N	N	N	N	N	N	Y	N	N
OG15	M		Low				N	N	N	N	N	N	N	N	N	N	N	N
OG16	F		High				N	N	N	Y	N	N	N	N	N	Y	N	N
OG17	F		High				N	N	N	Y	Y	Y	N	Y	N	Y	Y	Y
OG24	M		High				N	N	Y	N	N	N	N	N	N	N	N	Y
OG27	M		Low				N	N	N	N	Y	Y	N	N	N	N	Y	Y
OG35	F		Average				N	N	Y	N	N	N	N	N	Y	Y	N	Y
OG41	F		High				N	N	N	N	N	N	N	N	N	N	N	N
OG47	M		Average				N	N	N	Y	Y	Y	N	N	N	Y	Y	Y
OG48	F		Average				N	N	N	N	Y	N	N	N	N	N	Y	N
OG5	F		Average				N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
OG52	M		Average				N	N	N	N	N	N	N	N	N	Y	Y	Y[1]
OG53	M		High				N	N	N	Y	N	Y	N	N	N	Y	N	Y

Table 4.20 Longitudinal follow up of the 20 patients who completed treatment

[1] TMD diagnosis due to crepitus

4.4 Discussion

4.4.1 Orthognathic patient recruitment

Sixty eight orthognathic patients were initially recruited into this study and this sample size was comparable with, and in some case greater than, other research conducted in this field (Panula *et al.,* 2000; Pahkala and Heino, 2004). Although Rodrigues-Garcia *et al.* (1998) prospectively recruited 124 patients, this was a three site multicentre study with multiple examiners. Whilst every effort was made to recruit a larger number of patients, there were certain limitations to this which included:

- The number of patients attending for orthognathic treatment
- The number of patients consenting to take part in the study: 16 patients (19%) declined to take part and some patients had already consented to other research studies within the department hence could not take part in this study from an ethical view point.

Of the 68 patients who were recruited, only 20 completed their treatment and were debonded by November 2009. The average length of orthognathic treatment is 2.5 to 3 years and often longer when postgraduates undertake treatment, which clearly placed restrictions on the number of patients followed through to completion of treatment. Thus, as anticipated, only the patients recruited within the first year of this PhD had completed their treatment.

4.4.2 Skeletal Control group

A Class I control group provided a suitable comparison with the orthognathic cohort in Chapter III. It was intended that patients with skeletal discrepancies who had decided not to undergo orthognathic treatment would be beneficial controls for this chapter, in order to account for the potential changes in TMD over time. TMD signs and symptoms show fluctuations with time (Kuttila, 1998; Magnusson *et al.,* 2000) and this is part of normal variation. Thus an investigation with a non-treatment control group with skeletal discrepancies would have allowed determination of whether surgery had an effect on TMD status by taking time into account and reducing its effect as a potential confounding variable. Unfortunately this did not prove feasible, due to the number of

responses obtained (n=2) and this is clearly a limitation in this research. In addition, even if a sufficient sample size had been obtained, there would remain the issue of potential selection bias.

4.4.3 Comparison between T1 and T2 (N=46)

The comparison of TMD and the various signs and symptoms between T1 and T2 served two purposes:

1. To determine whether pre-surgical orthodontic treatment had any effect on the TMJ and thus on the signs and symptoms of TMD in orthognathic patients.
2. The majority of the studies that have investigated the effect of orthognathic surgery on TMD have used during pre-surgical orthodontics or pre-surgery at the baseline. It was hoped this comparison would therefore determine whether or not this time point can be used as a "proxy" baseline.

TMD Diagnosis (Table 4.2):

In 6 patients, the TMD diagnosis improved between T1 and T2, however TMD developed in 8 previously asymptomatic individuals. No changes were observed in the remaining 32 patients. No statistically significant differences in the prevalence of TMD were found between T1 and T2.

Although no significant differences were found in the proportion of patients with TMD at T1 and T2, fourteen of the 46 patients (30%) had a change in their TMD status. This would suggest that T2 is not an ideal baseline as individual changes and fluctuations in TMD do occur during pre-surgical orthodontics. This time point may be acceptable as a baseline if overall group changes are being studied but if paired data are investigated in the same way as in this study, this is clearly not the case.

Unfortunately comparison of the above results could not be made with other studies. Few of the prospective studies which investigated TMD longitudinally in orthognathic patients used pre-treatment examinations as the baseline. Of the few studies which did, patients were examined at the start of treatment but not then examined prior to surgery (Panula *et al.*, 2000; Pahkala and Heino, 2004). One study did examine patients both

pre-treatment and pre-surgery (Rodrigues-Garcia *et al.*, 1998) but did not report the pre-treatment results.

Patient reported symptoms (Tables 4.3 to 4.5):

No significant differences were observed between T1 and T2 for any of the patient reported symptoms (headaches, jaw pain on opening and closing and sore muscles around the jaw).

With regards to headaches, 35 patients experienced no change in their symptoms, compared with 9 who reported an improvement and 2 who complained of a deterioration. Patients complaining of headaches may experience an improvement in their condition at T2, but whether this improvement is perceived (placebo effect) as a result of the orthodontic intervention needs to be investigated in future studies.

Thirty patients experienced no changes in jaw pain on opening or closing, whilst a similar number of patients reported either worsening of their symptoms (n=9) or an improvement (n=7). The results for general muscle soreness were in line with previous findings and the majority of patients reported no change in their symptoms (n=36), compared with 4 patients who noted an improvement and 6 whose symptoms worsened. This would suggest that in the majority of cases there are no changes in self-reported pain symptoms during pre-surgical orthodontics.

Despite no significant differences being observed for patient self-reported symptoms between T1 and T2, 24% of the patients (n=11 of the 46) reported a change in headache related symptoms; 9 patients (20%) experienced an improvement compared with 2 patients who reported new headaches. In addition 35% of patients (n=14) experienced changes in jaw pain on opening/closing between T1 and T2 and 22% reported changes in muscle soreness. Thus, although these changes were not significant, they do appear to be sufficient to question the use of T2 as an acceptable baseline for TMD studies.

Clinical findings (Tables 4.6 to 4.9):

There were no significant changes for pain on palpation of the lateral poles of the TMJ between T1 and T2. Five patients did, however, experience worsening of pain, compared with one individual who improved. Similar findings were observed for

clicking of the TMJ where no changes were observed in 37 patients, an improvement was seen in 3 and new clicks developed in 6 patients.

The sample size in this component of the research was too small to discuss trends in the data confidently, but it would be interesting to further investigate these clinical parameters in future studies. As with patient self-reported symptoms, although no significant difference was observed between T1 and T2, changes in clinical signs were observed. Twenty percent of patients experienced changes in clicks and 13% changes in jaw pain. This would reiterate the concern as to whether T2 is appropriate to use as a baseline, and ideally, a T1 baseline examination should be used. Individual changes in TMD signs and symptoms do occur during pre-surgical orthodontic treatment in a reasonable percentage of patients.

The RDC/TMD criteria stipulate that a patient must experience pain on palpation of 3 or more muscle sites for a group 1 muscle disorder diagnosis. Only five patients in this study experienced pain in 3 or more muscles at T1 compared with 4 patients at T2 and this difference was not statistically significant (Table 4.8). As previously mentioned, the small sample size in this study does not allow for any trends to be reported, and further investigations are warranted.

A significant mean difference was observed for the mean maximum opening at T1 compared with T2, with an improvement in opening at T2 ($P<0.001$). This may be explained by the adaptation of the jaws and the improved "gape" as a result of frequent stretching and opening required at routine orthodontic visits over the previous months of treatment. However, it is debatable whether a 3mm change in opening (from 48.70mm to 51.85mm) is of clinical relevance.

The results from this study indicate that although pre-surgical orthodontics does not have a significant overall group effect on TMD and its signs and symptoms, on an individual basis changes between T1 and T2 do occur. Thus to answer the question "Does it matter when the baseline assessment is?", using the pre-surgical time point (T2) as a baseline is questionable. Another team of researchers who analysed a patient group pre-treatment and 2 weeks prior to surgery reported no significant change in TMD symptoms between the two time points, and identified the pre-surgical time point

as an appropriate baseline measurement (De Boever *et al.,* 1996). Enough doubt, however, has been raised with the findings of this study to question that conclusion.

4.4.4 Comparison between T1 and T3 (N=20)

This part of the analysis compared the results between T1 and T3, thus explored the effect that orthognathic treatment had on TMD, albeit accepting that time itself may have some effect on outcomes.

TMD Diagnosis (Table 4.11):

Of the 20 patients who were followed through to completion of treatment, 12 (60%) had no change in their TMD diagnosis, 3 (15%) patients experienced an improvement and a further 5 (25%) previously asymptomatic patients developed TMD. These findings were not statistically significant. Other studies that have investigated the effect of orthognathic surgery on TMD, diagnosed patients according to the CMI or Helkimo Indices (Panula *et al.,* 2000; Pahkala and Heino, 2004) and, as such, their results could not be directly compared with this study. Panula *et al.* (2000) reported that the prevalence of TMD at the pre-treatment time point was 73.3% and this reduced to 60% after a 4 year follow up, this difference represented a significant reduction (P=0.013). Pahkala and Heino (2004) also found that the severity of the dysfunction was reduced post-surgery and that surgical interventions were particularly beneficial for patients with myogenous symptoms rather than arthrogenous components of TMD.

In the current study, there was a slight increase in the prevalence of TMD post-surgery (from 45% to 55%), however, this finding should be interpreted with caution due to the small sample sizes involved. Further investigations with larger sample sizes but still using standardised classification techniques (such as RDC/TMD) should be undertaken to resolve this conflict.

Patient reported symptoms (Tables 4.12 to 4.14):

Fifteen patients reported no changes in headaches after treatment; however 4 patients reported that headaches improved and 1 patient reported development of headaches. These differences were not statistically significant. Other studies that have looked at the prevalence of headaches pre and post-treatment found improvements (Panula *et al.,*

2000; Pahkala and Heino, 2004). Panula *et al.* (2000) reported that 63% of patients suffered headaches at their first assessment compared with 25% at the final examination and this difference was significant. The difference between the two studies could be explained by the small sample size in this study but it must also be noted that only 35% in the current study suffered from headaches compared with 63% in the Panula *et al.* (2000) study, hence the baseline figures differed considerably.

Jaw pain on opening/closing and muscle pain around the jaw also showed no significant change in the prevalence of the symptoms between T1 and T3. This was again in contrast with the results reported by Rodrigues-Garcia *et al.* (1998), who found that there was a significant reduction in the prevalence of subjective facial pain and discomfort on opening following surgery. Again the small sample size in this study and different questionnaires being used could be a source of disparity between the results.

Clinical findings (Tables 4.15 to 4.18):

No significant differences were found for any of the clinical signs investigated in this study. When pain on palpation of the lateral poles of the TMJ was considered, 16 patients showed no change in their symptoms, 1 patient improved and 3 patients developed new symptoms. Similar results were observed with clicking, where 15 patients showed no change, 1 patient improved and 4 patients developed new clicks. Rodrigues-Garcia *et al.* (1998) reported that the percentage of patients with clicking on opening decreased significantly from 26.6% to 10.5% following surgery. Other authors have also reported a reduction in clicks post-surgery (Pahkala and Heino, 2004). The findings of this study may contradict these previous findings, although the small sample size must again be considered. With regards to pain on palpation of the muscles of mastication, one patient experienced pain in 3 or more muscles at T1 and a further two patients had this level of pain at T3. This is in contrast with other studies that have reported a reduction in muscle related symptoms post-surgery (Rodrigues-Garcia *et al.*, 1998; Pahkala and Heino, 2004), although as with previous results the small sample size in this study dictates that the findings are treated with caution.

In addition to the sample size which may lead to sampling variation, the different classification criteria used in these studies could clearly explain some of the differences found. For example, the Helkimo Index classifies someone as having myogenous

dysfunction if at least 1 muscle is positive to pain, which is in contrast with the RDC/TMD criteria where at least 3 muscle sites have to elicit a painful response for a positive diagnosis.

The Helkimo Index requires that each item evaluated on the clinical examination is scored and the sum of scores is used to define the dysfunction group and severity, thus a cut-off score must be decided on in order to formulate a case definition. The score produced from the Helkimo Index provides little information about the actual clinical presentation and a patient with a condylar fracture or with severe myofacial pain could have exactly the same score (Fonseca, 2000). With the RDC/TMD, subjects are assigned specific TMD diagnoses (e.g. myofacial pain, arthralgia) if particular combinations of signs and symptoms are present, this is both easier and quicker to use and gives a more accurate clinical picture. In addition, findings from different studies using the RDC/TMD can be compared more readily as calibration is less problematic with the RDC/TMD than the Helkimo Index.

The general quality of a prevalence study is influenced by the diagnostic method used and studies which use standardised criteria, such as the RDC/TMD, tend to be of higher quality than others which use non standardised diagnostic criteria (Giannakopoulos *et al.,* 2007). As such this TMD classification system is highly recommended for use in future studies.

4.4.5 TMD at T1 and T3 and the influence of skeletal pattern (Table 4.20)

The majority of studies that have reported positive effects on TMD after orthognathic surgery report an association between skeletal Class II deformities and improved signs/symptoms. Some studies have reported a decrease in signs and symptoms by more than 50% compared with the pre-operative state (Karabouta and Martis, 1985; Kerstens *et al.,* 1989; Magnusson *et al.,* 1990; De Clercq *et al.,* 1995). Subjects with skeletal Class III bases or a high mandibular plane angle (> 32°) seem to benefit considerably less (Kerstens *et al.,* 1989; White & Dolwick 1992; De Clercq *et al.,* 1995) or have signs and symptoms which are unpredictable (Farella *et al.,* 2007). However, TMD improvement in Class III patients has also been reported following orthognathic surgery (Magnusson *et al*., 1990; Le Bell *et al.,* 1993).

There were very small numbers of patients within each group in this study when patients were subdivided according to their skeletal base and MMP angle, and it was not possible to comment on any trends or correlations between specific skeletal features and TMD.

4.5 Conclusions

Although no significant differences were found between the prevalence of TMD pre-treatment (T1) when compared with prior to surgery (T2), sufficient individual changes in TMD signs and symptoms were observed to question the suitability of the "prior to surgery" time point as a baseline in future studies.

When comparing pre (T1) and post-treatment (T3) TMD changes, no significant differences were observed. It was noted that there was a tendency for worsening of clicks and pain in this study and these observations contradict previous studies. In contrast, headaches appeared to improve with treatment and this was in agreement with other studies. However, any findings in this study should be interpreted with caution due to the small sample size.

Thus this study would support the theory that TMD is a dynamic condition and signs and symptoms are likely to fluctuate throughout treatment. It is difficult to predict with any certainty the impact surgery may have on the TMJ and thus whether it causes TMD, worsens the condition or results in an improvement.

As TMD signs and symptoms do change throughout the course of treatment, clinicians must warn patients of this possibility during the informed consent process, regardless of whether they present with TMD at that time or not. Consent should make clear the dynamic nature of TMD and the unpredictability of what may happen during the orthognathic treatment process.

Chapter V: Temporomandibular Joint Information Course: Comparison of the instructional efficacy of an internet-based TMJ tutorial with a traditional face-to-face seminar.

Introduction, Aims and Objectives

Carrying out a thorough TMJ examination should be part of the routine assessment of patients undergoing orthodontic or orthognathic treatment, yet anecdotal evidence suggests this is rarely undertaken in practice. Perhaps part of the reason why TMJ examination is under utilised in graduate orthodontic programmes is a gap in the knowledge base. Many graduate orthodontic students may not have been exposed to, or taught how to undertake, a thorough TMJ examination as undergraduates. As such there is clearly a need to provide this teaching. Virtual learning environments (VLEs) are an innovative method of delivering information and there is a growing interest in their use by schools, colleges and universities. VLEs make it possible for a course designer to present the components required for a course of education or training through a single consistent and intuitive interface. By incorporating a TMJ information course (including teaching of a thorough TMJ examination) on a VLE platform it is hoped this will enable graduate students to enhance their TMJ examination and diagnostic skills.

5.1 Literature review

5.1.1 History of VLE

A virtual learning environment (VLE) is a set of teaching and learning tools designed to enhance a student's learning experience by including computers and the internet in the learning process. As such VLEs are vessels that facilitate computerised learning or e-learning. Many synonyms exist for these e-learning systems, and they are sometimes referred to as a Learning Management System (LMS), Course Management System (CMS), Learning Support System (LSS), Online Learning Centre (OLC), Learning Platform (LP) or Online Education. The concept of computerised learning has been in

existence since the 1960s, however for the history of virtual learning environments, the 1990s was a time of growth, primarily due to the increased popularity of the internet.

In 1960, the Plato system was developed at the University of Illinois and featured multiple roles. Students could study assigned lessons and communicate with teachers through online notes, instructors could examine the students' progress and in addition, communicate and take lessons. Authors could also do all of the above and create new lessons (Davis, 1980). In 1969 the internet was founded, adding an important milestone to education and technology. The Havering Computer Managed Learning System was developed in London in the 1970s and by 1980 was used by over 10,000 students and 100 teachers in various science technology, career guidance, and industrial training applications (Broderick *et al*., 1980). These early VLEs were 'purpose-built' or 'bespoke' systems mainly based on shared communication tools and course content, and were used by enthusiasts rather than whole departments or organisations.

With the 1990s came growing interest in technology and investments in commercial and off-the-shelf VLEs (Milligan, 1999). Early examples of these included the Lotus Learning Management System and Lotus Virtual Classroom developed in 1994 (owned by IBM) and WOLF (Wolverhampton Online Learning Framework) in 1995. WOLF was developed to deliver training materials to both small and medium enterprises. By 1999, WOLF was both adopted as Wolverhampton University's VLE and sold for commercial distribution to Granada Learning, who rebranded the product as Learnwise. WOLF is still in use at the University of Wolverhampton today and undergoing continual development to meet the ever-changing needs of education.

Off-the-shelf VLEs may be bought from, or sold to organisations, and may also be built upon by adding various components and software. Educational institutions tend to use commercial VLEs, such as Blackboard and WebCT, rather than purpose-built VLEs and many versions of these VLEs exist as they are continually updated.

Some of the more popular and commercially available off-the shelf VLEs in use today include WebCT, Blackboard and Moodle. Initially developed at the University of British Columbia, Vancouver in 1995, WebCT has become the world's most widely used VLEs, used by millions of students in 80 countries (http://www.manningawards.ca/awards/winners/mgoldberg-media.shtml).

Blackboard was founded in 1997 and by 1998 had released its first software product. Early trials of Moodle began in 1999, and it was finally released in 2002). In 2006 WebCT was acquired by Blackboard with the aim of providing a powerful platform for innovative technology infrastructure. As part of the acquisition terms the WebCT name is currently being phased out in favour of the Blackboard brand (Helfer, 2005). This has seen a number of colleges and universities shift to open source systems such as Moodle (http://www.insidehighered.com/news/2009/05/07/bb).

Moodle has become very popular among educators around the world as a tool for creating online dynamic web sites for their students (http://moodle.org). It is a user-friendly Course Management System (CMS) which allows students more interaction between each other and educators. Moodle is an open source system that is not owned by anyone and according to the Moodle Web site, "It is a free web application to download, that educators can use to create effective online learning sites" (Collison, 2009). Approximately four thousand institutions are currently using Moodle, with some institutions projecting substantial monetary saving associated with the shift from Blackboard to Moodle as it is not as resource intensive as Blackboard (Ewald, 2009). Moodle currently has over 29 million users across 200 countries with over 2.5 million courses registered on the site (http://moodle.org).

5.1.2 Features of VLEs

There is continual expansion in the use of Virtual Learning Environments by schools, colleges and universities. An example of this can be seen with Coventry University which provided a campus-wide online learning environment in 2000 and students at the university now have access to all of their modules online (Deepwell, 2001). In 2002 Bristol University conducted a four-month feasibility study into the use of Blackboard as part of the VIOLET (Virtual Integrated Online Environment for Teaching) project, the decision was then made to extend the use of Blackboard to cover more departments (Becta, 2008). This popularity is a likely consequence of the widespread use of computer-based educational activities, improvements in web technology, the escalating pressures to improve the quantity and quality of the educational experience, a shortage of teachers and an increasing pressure from the government to provide flexible training (Shah and Cunningham, 2009). A survey carried out by the Joint Information Systems

Committee (JISC) in 2005 indicated a high use of VLEs in all types of institutions, with 86% of further education colleges, 97% of pre−1992 universities and 90% of post−1992 universities reporting the use of at least one type of VLE. However, the use across various subject areas was inconsistent, ranging from 16% in medicine, dentistry and veterinary medicine to 82% in business management, accountancy, economics and law (Joint Information Systems Committee, 2008).

Although there is some debate about what constitutes VLEs, they are generally accepted to have a combination of some, or all, of the following features (Becta, 2008):

- Communication resources such as e-mail, bulletin boards and chat rooms.
- Collaborations such as online forums, intranets, electronic diaries and calendars.
- Tools to create online content and courses.
- Features to carry out online assessment and marking.
- Integration with the educational body's management information systems.
- Controlled access to curriculum resources.
- Student access to content and communications off site.

VLEs are essential components of a managed learning environment (MLE) (Fig 5.1), and there is a high level of interaction between the VLE and the surrounding MLE. This interaction consists of:

- Controlled access to the curriculum, which has been mapped to elements that can be separately assessed and recorded.
- Tracking of student activity and achievement against these elements, using simple processes for tutors to define and set up a course with accompanying materials and activities to direct, guide and monitor learner progress.
- Support of online learning, including access to learning resources, assessment and guidance; the learning resources might be self-developed or professionally authored and purchased, and can be imported and made available for use by learners.
- Communications between the learner, the tutor and other learning support specialists to provide direct support and feedback for learners, as well as peer

group communications that build a sense of group identity and a community of interest.

- Links to other administrative systems, both in house and externally.

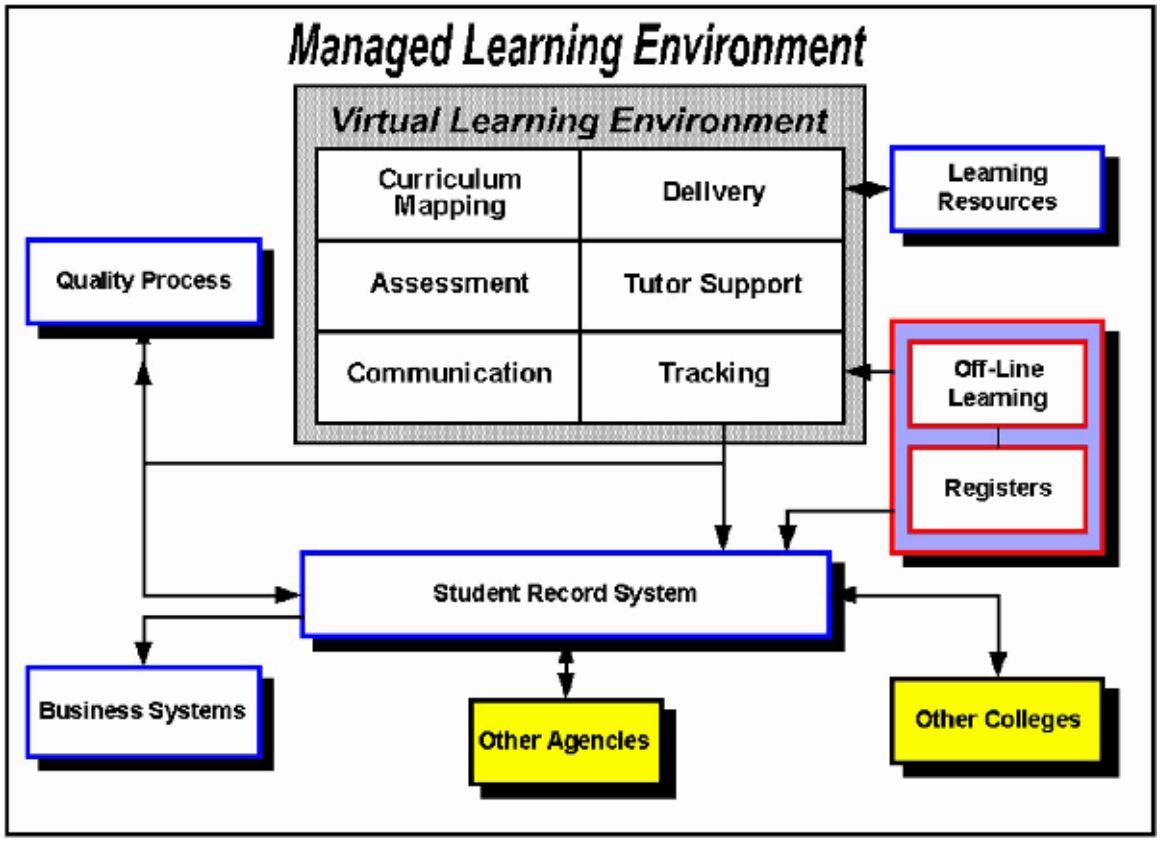


Figure 5.1 Components of a MLE (Taken from Becta ICT research report, 2001).

In addition to these features, it is generally regarded that:

- There is a level of security built into the system, including password protection.
- VLEs normally provide two views of the system, one for the tutor and one for the student.
- Tutors have access to a wide range of tools and privileges in a VLE that allow them to add materials, create tools and track student progress.
- MLEs and VLEs are browser based and use web technologies, but do not require knowledge of HTML in order to use or contribute content to the system.

- The use of web technology for VLEs means that the system can be accessed anywhere, including at school and home; with portable technologies, the "anytime, anywhere" learning model will be possible.
- The elements that go together to make up the system should interrelate and be interoperable, allow for the sharing of data, and provide a consistent interface for students and staff.

5.1.3 Research into VLEs

There has been a great deal of research into the benefits and uses of VLEs in education

Delivery

Potential benefits of VLE delivery include the ability to offer 'anytime, anywhere' access, a protected environment, the ability to link to resources on an intranet or internet, user-friendly interfaces and ease of web page and course content development (Becta, 2008). Musgrove (2001) examined the ability of a VLE (specifically WebCT) to enable distance learning, and found it invaluable in assisting universities in their delivery of web-based learning, through such features as an improved designer interface, a rich variety of communication tools and the capability to customise course delivery to suit individual preferences.

A study of WebCT use in course delivery was undertaken by the University of British Columbia, in order to investigate student acceptance of the system, and the academic effectiveness of various modes of course delivery (Goldberg, 1997). They found that approximately 30% of the access to online resources came from outside the university, indicating considerable use by students offsite. In addition students considered that online resources had improved their understanding of the course materials.

Curriculum mapping

A VLE improves communication between faculties and enables, for example, the electronic distribution of conventional reading lists and improved collaboration between academics and library staff (Stubley, 2002). Both academics and library staff have seen

the potential for providing added-value services through this link, and the 'reading list' is now known as the 'resource list'.

Assessment

VLEs have an important role in administering assessments and monitoring of students' marks. WebCT was used to construct, administer and mark a mid-term examination made up of randomly selected items from a question bank, as part of an undergraduate course in computer science at the University of Calgary. Jacobson and Kremer (2000) reported that students identified the following benefits:

- The flexibility of 'anytime, anywhere' access.
- Being able to sit the examination at a time most convenient to them.
- Being able to set up their work space for the examination.

However, students also perceived certain disadvantages:

- The potential for unethical conduct among their fellow students in an unsupervised examination.
- Difficulty in contacting an instructor during the examination, despite contact information for the instructor being made available.
- Confusion over time elapsing during the examination and uncertainty about how to set-up the workstation.
- Problems with home internet access.
- Weaknesses of multiple-choice questions, for example, it is not possible to demonstrate the thought processes that lie behind an answer, and there is no opportunity for partial marks.

Communication

The potential to share ideas and information and to join in online conferencing may help improve the quality of students' work and enable them to participate in virtual discussion forums. Some products have been linked to developing higher levels of learning and key skills by enabling students to engage in online discussions and nurturing self-study. Focusing on the use of VLEs to support student discussion and debate on a computing course, Wilson and Whitelock (1997) found that common uses included:

- Help with problem solving (49 %).

- Keeping in touch with fellow students (29 %).
- Contacting tutors (20 %).

Selinger (1997) evaluated the use of a VLE for an Open University postgraduate teacher education course and found that extensive use of the system encouraged collaboration among students. There was recognition that it enhanced good practice, leading to the development of an electronic community of teachers capable of encouraging long-term professional development.

FirstClass is a client/server groupware, online conferencing, and bulletin-board system, its primary markets are the higher-education and education sectors. A study of FirstClass involving PGCE students at the Open University by Kyriakidou (1999) concluded that:

- Electronic conferencing is available as a tool in enhancing student teachers' learning and teaching.
- Electronic conferencing enables students to gain some technological skills.
- The medium enhanced student teachers' professional development by promoting reflective discussion on educational issues.
- Problems in the use of the medium exist and further research should propose alternative solutions.
- The success of a conference depends on certain criteria, including the nature of the interaction and level of collaboration among participants; the moderator's input is crucial for the success of the activity, and further research is required on conference moderation.

5.1.4 VLEs in Medicine and Dentistry

Medical and dental training has followed traditional methods of delivery over many years; it has been predominantly based in the work place with students required to supplement this with textbook learning. This apprenticeship model however is disappearing in most parts of the world (Larvin, 2009) and the use of communication and information technologies to support and augment medical and dental educational practice is gradually emerging (Ellaway *et al.*, 2003). Early efforts by universities in e-

learning provision consisted mainly of loading lecture notes and slides onto a website. This would now be considered as resource distribution rather than e-learning as it failed to involve active learning. An article in the Lancet in 2001 stated that "within less than two student generations, communication and information technology has been repositioned as an integral component of the environment" (Ward *et al.*, 2001).

There are many reasons for this shift towards information and communication technology in the medical and dental fields. Dental education exerts high demands on universities and teaching hospitals (Ireland *et al.*, 2005). There are also ever increasing needs and demands by dentists and all other members of the dental team for continuing education and these are straining the resources of existing providers at a time of dynamic growth in the demand for postgraduate and continuing education (Eaton and Reynolds, 2008).

Alongside these issues is a reduction in institutional funding and major institutional changes, with a drop of 37% in funding per (UK higher education) full time student since 1989. Moreover, there has been a shift towards increasing financial dependence on research rather than teaching and rising burdens of audit and accountability required of educational practice (Ellaway *et al.*, 2003).

In addition, the number of academics and teaching staff is diminishing and the European Working Time Directive (EWTD) has reduced the contact time with both trainers and peers which may lead to the content in some educational programmes being compromised. Reduced training years at postgraduate level have also diminished experiential exposure and this has made formal skills training courses and simulation more important than ever (Larvin, 2009).

At the same time there are ever increasing developments and opportunities to expand online delivery and services for education. The options are varied and range from online web seminars to online courses and teaching modules. The USA currently leads in e-learning activity and by 2006 nearly 3.5 million students were participating in online learning at US higher education institutions, whilst almost 20% were taking at least one online course module (Allen, 2007). Thus, in more recent years, e-learning and VLEs

have become so common place in undergraduate medical courses in both the US and the UK that current trainees are already experienced users (Larvin, 2009).

Most teaching in the medical and dental fields falls into the hybrid category and uses a mixture of printed materials, electronic resources and face-to-face teaching (Eaton and Reynolds, 2008). This can also be termed a blended learning programme; that incorporates a variety of e-learning resources and combines it with conventional resources (Larvin, 2009). Many courses that are run by UK universities or the Royal College of Surgeons (e.g. the Faculty of General Dental Practice, UK) offer Certificate Diploma and Masters certificate programmes based on blended learning. This may involve participants in a series of short, face-to-face attendance courses, typically between one and five days duration, which are linked with practice based clinical work, home based written assignments and the production of a dissertation. All these activities are supported by communication information technology such as e-mailing assignments, attending lectures by video conferencing or as web casts, gathering information via the internet or joining online discussion forums and debates (Eaton and Reynolds, 2008).

In 2001 the Royal College of Surgeons of England reconfigured their Surgical Education and Training Programme (STEP) to incorporate e-STEP, an e-learning component (Larvin, 2009), and this was further updated in 2008 as STEP core. Early feedback confirmed that effective e-learning required new material to be created for comfortable on screen viewing and interaction, and should include texts supplemented by animations, audio and video, and online discussion to provide a real-life learning context. Detailed evaluations of e-Step were carried out after a pilot period of 12 months and repeated 36 months later (Larvin and Masih, 2002; Larvin *et al.,* 2006). Feedback gathered from surgical trainees across the UK indicated dissatisfaction with the traditional learning models, in particular reduced experiential learning opportunities, and loss of contact time with trainers and other trainees. Surgical trainees were almost all capable of using the e-learning resources and appreciated their added value. Preparation for skills can be achieved through e-learning, aided by online discussion with peers and trainers. Surgical outcomes also depend on clinical leadership and communication skills and e-learning provides trainees who have learned to use evidence

based material and guidelines the ability to foster cost effective use of health resources and this may potentially compensate for lack of experience (Larvin, 2009).

Guidelines have emerged over the last 7 years of experience of e-learning for surgical trainees:

- e-content must add value to existing resources, rather than simply duplicating them.
- e-learning should link into other e-resources as well as conventional materials to accommodate various learning styles and behaviours.
- e-learning can be a solitary activity, but teacher input and peer contact can be achieved through community discussion. It cannot however replace face-to- face contact.
- Formative online assessment is highly valued and represents a safe means of self assessment.
- Personalisation helps steer learners towards agreed objectives in a timely fashion and peer assessment data can provide strong motivation.
- e-learning should be enjoyable, leaving participants with a sense of achievement.

The University of Edinburgh re-designed and re-launched its undergraduate medical curriculum in 1998. The introduction of an electronic information system for the course was made practical by the development in technologies at that time. The first version of the Edinburgh Electronic Medical Curriculum (EEMeC) was launched in 1999 and it has proved to be an invaluable resource which helps to address the problems arising from introducing a new course and modern medical education in general (Ellaway *et al.*, 2003). For example:

- It provides clear representation to staff and students of the integrated nature of the course: for example, body systems are introduced at the start of the course and revisited in subsequent years, also themes such as ethics and pharmacology are woven throughout as full courses or embedded as concepts and practices. This differs from previous courses where academic departments held full autonomy for teaching their individual subjects with very little integration.

- It facilitates course management with tools allowing room bookings, electronic timetabling and notice boards (where messages are targeted to specific individuals or year groups thus avoiding bulk e-mails).
- It promotes and facilitates a greater degree of student-centred-learning. Students are expected to manage their learning and take a more holistic approach to their development as health professionals.
- It supports staff and students at distant locations, thus providing the "anytime, anywhere" level of access to all course documentation and tools over the internet.
- It has provision for online evaluation and feedback, replacing existing paper questionnaires.

There are however some negative aspects to this and these include:

- Loss of complexity: the complex form of communications required from a course cannot be entirely built into computer algorithms, thus EEMeC exists in a blended relationship with other elements of the course.
- Managing information flow: this is complex and requires coordination from many locations and in many ways. Individuals are required to ensure the relevant information is passed on to ensure the system is kept up to date.
- Access: although internet access is becoming ubiquitous in modern times, there are problems if individuals do not have this, or if connections are slow or non-functioning
- Hidden costs: Particularly for staff development and network maintenance.

On the whole, the evaluation of the EEMeC found that VLEs can provide medical education with a robust and adaptable central support and reference system. Traditional methods should still be used where they are effective, such as one-to-one or small group clinical teaching, thus VLEs are very much about supporting educational and course processes than about technology (Ellaway *et al.*, 2003).

In dental education, computer assisted learning (CAL) and other electronic learning resources have been shown to be as effective as other methods of traditional teaching (Ireland *et al.*, 2005). In fact, in some situations, examination results improved when

CAL was used. A study by Irvine and Moore found that students who undertook a CAL programme for mixed dentition analysis had better results than those who had traditional didactic teaching. Whilst more recently an instructional multimedia programme for teaching undergraduate orthodontics was found to be as effective as a traditional lecture (Aly *et al.*, 2004).

Questions sometimes arise regarding the effectiveness of e-learning for teaching clinical procedures where decision making skills are required. A study by Kay *et al.* (2001) found that the use of a CAL programme did not improve the sensitivity and specificity of dentists' restorative treatment decisions and as such had no effect on their decision making behaviour. Thus education delivered via CAL may have little benefit for complex topics.

In 2004 Bristol University Dental School developed a modular teaching resource housed within the Blackboard™ VLE which aimed to facilitate the academic orthodontic training for specialist registrars. It consisted of 40 online modules which provided comprehensive, up to date, peer reviewed and referenced summaries of orthodontic topics. The VLE also contained video lectures and short videos of clinical procedures, as well as communication tools such as a discussion board and video conferencing facilities (Mulgrew *et al.*, 2009). The resource had positive effects on postgraduate orthodontic teaching and learning with improvements in flexibility and efficiency of learning. Despite this, trainees welcomed the opportunity to have face-to-face interactions with their teachers and peers. Thus the most appropriate use for a VLE in orthodontic training appears to be a blended model.

5.1.5 Summary

The advent of e-learning has brought greater flexibility to the delivery of all levels of dental education and to the learning process. It provides teaching material and support anytime from anywhere in the workplace or home. E-learning also provides an advantage over traditional learning and teaching activities by permitting a wider spread of appropriate pedagogies. One of the benefits of e-learning is the ability to treat teaching materials as reusable teaching objects. Self-contained units are catalogued,

tagged with key words and saved. Thus the delivery of academic material through a VLE may improve the efficiency and effectiveness of dental education and yet it has the added advantage of flexibility for students. As such it has the potential to become a way to share resources amongst dental schools (Ireland *et al.*, 2005).

Aims and Objectives:

A web based TMJ tutorial was developed to compare how two groups of postgraduate students (VLE tutorial group followed by a face-to-face seminar group or *vice versa*) respond to these two different methods of teaching. Specifically assessing the skills gained by the postgraduates in examination and diagnosis of the TMJ and its conditions and learning experiences obtained from both courses. The aims were:

1) To determine whether there are any differences in the skills obtained by students after undertaking the VLE tutorial or the face-to face seminar.

2) To determine whether the order in which teaching is received makes a difference to the student's performance in the assessments.

3) To determine whether providing teaching twice makes a difference to the knowledge acquired by students.

4) To investigate the students' perceptions of either mode of teaching and their learning experiences.

5.2 Materials and Methods

5.2.1 Methods for developing the TMJ course

5.2.1.1 VLE Tutorial

Acquiring technical skills

In order to create a course for the virtual learning environment, it was important to learn the technical skills required to develop such a module. After consultation with the Learning Technology and Support Service (LTSS) at University College London (UCL), it was decided that the Moodle environment was most suited for the requirements of this study. Moodle is currently UCL's main VLE. Moodle is a password protected environment and can be accessed by all UCL staff and students who have registered user names and passwords. As it is the primary system used by UCL, there are training courses and support facilities for users and those wishing to develop content on this platform.

In the first instance it was necessary to enrol in an introductory course for the use of Moodle. This allowed the researcher (SA) to familiarise herself with this virtual learning environment and to understand the features and functionalities available through this platform. The initial "Getting started with Moodle" course was completed at the LTSS Department in November 2007.

Developing content of the VLE tutorial

The next stage of developing the course was deciding on the content that was to be hosted on the Moodle platform. Close liaison was established with a lecturer in the Oral and Maxillofacial Surgery Department/Facial Pain Unit with extensive knowledge of TMJ assessment and TMD diagnosis. This allowed development of the content to be included on the Moodle tutorial, as well as the list of appropriate assessment criteria for a later stage of the study.

The TMJ course content included:

- Table of contents
- Introduction and course information
- Anatomy of the TMJ
- Disorders of the TMJ tutorial (including diagnosis of TMD)
- Conducting a TMJ examination (multimedia file/ video demonstration)
- TMD forums/ Discussion boards
- Additional resources and supplementary reading.

Anatomy Tutorial: This was a basic anatomy tutorial which provided students with information on the anatomy of the TMJ and associated muscles of mastication.

Disorders of the TMJ: This tutorial guided the users through the conditions which may affect the TMJ. It also gave an overview of temporomandibular disorders (TMD) and how the classification of TMD has evolved.

Conducting a thorough TMJ examination: This section included a multimedia presentation (video) which demonstrated how to conduct a thorough TMJ examination and highlighted the important signs that need to be recorded. In addition, the supporting documentation (TMJ chart to be filled in by the clinician and TMD questionnaire that is given to patients) were made available to users to aid them with the process of diagnosing and classifying TMD in an efficient way.

The RDC/TMD classification criteria were also presented in a user friendly format, and could be printed out and kept in the clinical area for reference.

TMD Forums/Discussion board: The forum section gave users the opportunity to post their questions which would be answered within a 48 hour period. Additionally it provided the opportunity to debate the topic or share information.

Additional resources: These were links to external websites and resources. Whilst they were not compulsory, it was hoped that users would find these useful.

Content delivery and implementation

After the content had been developed, the course was uploaded on to the system and it was necessary for the researcher/course designer to enrol in an advanced Moodle course

to achieve this objective. This was undertaken in February 2008 and provided advanced techniques in managing Moodle, as well as a better understanding of its functionality and features. The LTSS teams were invaluable in this process of implementation and provided the necessary support.

Once the course had been successfully added to the Moodle platform, it was piloted and tested. Senior members of the Orthodontic Department at the Eastman Dental Institute were given access to the course and asked for feedback and suggestions. These suggestions were then incorporated and changes carried out accordingly. The postgraduate student users were enrolled and assigned usernames and passwords and could then begin to use the system when instructed.

5.2.1.2 Face-to-face seminar

A PowerPoint© presentation and practical demonstration was also prepared for a face-to-face seminar in a class room setting with similar information and content and following exactly the same format as the Moodle tutorial. One tutor (S.A.) prepared the content and delivered the seminar to all of the students, thus this ensured consistency in delivering the teaching. The seminar was of 50 minutes duration, of which the practical demonstration lasted 20 minutes and postgraduates had the opportunity to ask questions throughout. The students were given handouts of the RDC/TMD diagnostic criteria.

5.2.2 Cross-over Trial

In a cross-over trial the participants are randomly allocated to study arms where each arm consists of a sequence of two or more effects given consecutively. The simplest model is the AB/BA study.

This study followed the AB/BA study design. Participants allocated to the AB study arm received teaching method A first, followed by teaching method B, and *vice versa* in the BA arm. Thus it allowed the teaching received from A to be contrasted with the teaching received from B. Reducing the participant variation in this way makes cross-over trials more efficient than similar sized, parallel group trials in which each subject is exposed to only one method of teaching. In theory the effects of the teaching can be estimated with greater precision given the same number of participants (Senn, 1993).

The principal drawback of the cross-over trial is that the effects of one teaching method may "carry over" and alter the response to the subsequent teaching method. The usual approach to preventing this is to introduce a washout period (in this study an adequate break from teaching) which is long enough to allow the effects of the latter teaching to dominate.

Study details

Postgraduates were initially assigned by stratified random sampling to one of two groups:

i. Group 1: Moodle tutorial followed by the face-to-face seminar
ii. Group 2: Face-to-face seminar followed by Moodle tutorial.

There were 23 female and 7 male students in the study, with an age range of 26 to 36 years. Eighteen of the students were from the UK/EU and 12 were from countries outside the UK/EU; initial questioning of the students revealed none of them had undergone any formal teaching in TMJ examination beyond a basic undergraduate level. None of them had significant experience of the use of VLEs.

There were fifteen postgraduates per group and Group 1 were required to undertake the Moodle tutorial first. They were allowed to carry this out at their leisure but were given a two week deadline and the Moodle software tracked users who had logged-on and which elements they had completed. Group 2 were required to attend a face-to-face seminar on TMJ assessment and diagnosis which included information on carrying out an accurate and thorough TMJ examination and diagnosis according to the RDC/TMD classification.

Both groups had access to the same information but the content was conveyed using different methods. At the end of this process both groups were assessed in order to ascertain their knowledge in the skills of TMJ examination and diagnosis. These assessments were carried out within 3 weeks of the teaching episodes and were dependent on the student's schedule and availability. Postgraduates from both groups were required to examine a patient and diagnose their TMJ condition as appropriate. The researcher was present and observed all students during the examinations. The

postgraduates were then scored according to a checklist with pre-defined criteria as shown in Table 5.3.

A total of 29 procedures were recorded on the checklist (Appendix 13) for the assessments. The researcher independently scored each postgraduate and had previously examined all patients to determine their condition and set a gold standard for the examination. As discussed previously in Chapter 3 the assessor had previously undergone a 4-day calibration in TMJ examination procedures. In addition, the checklist and its criteria were developed in conjunction with an expert from the Oral and Maxillofacial Surgery Department/Facial Pain Unit who provided advice on how to consistently and accurately assess the postgraduates.

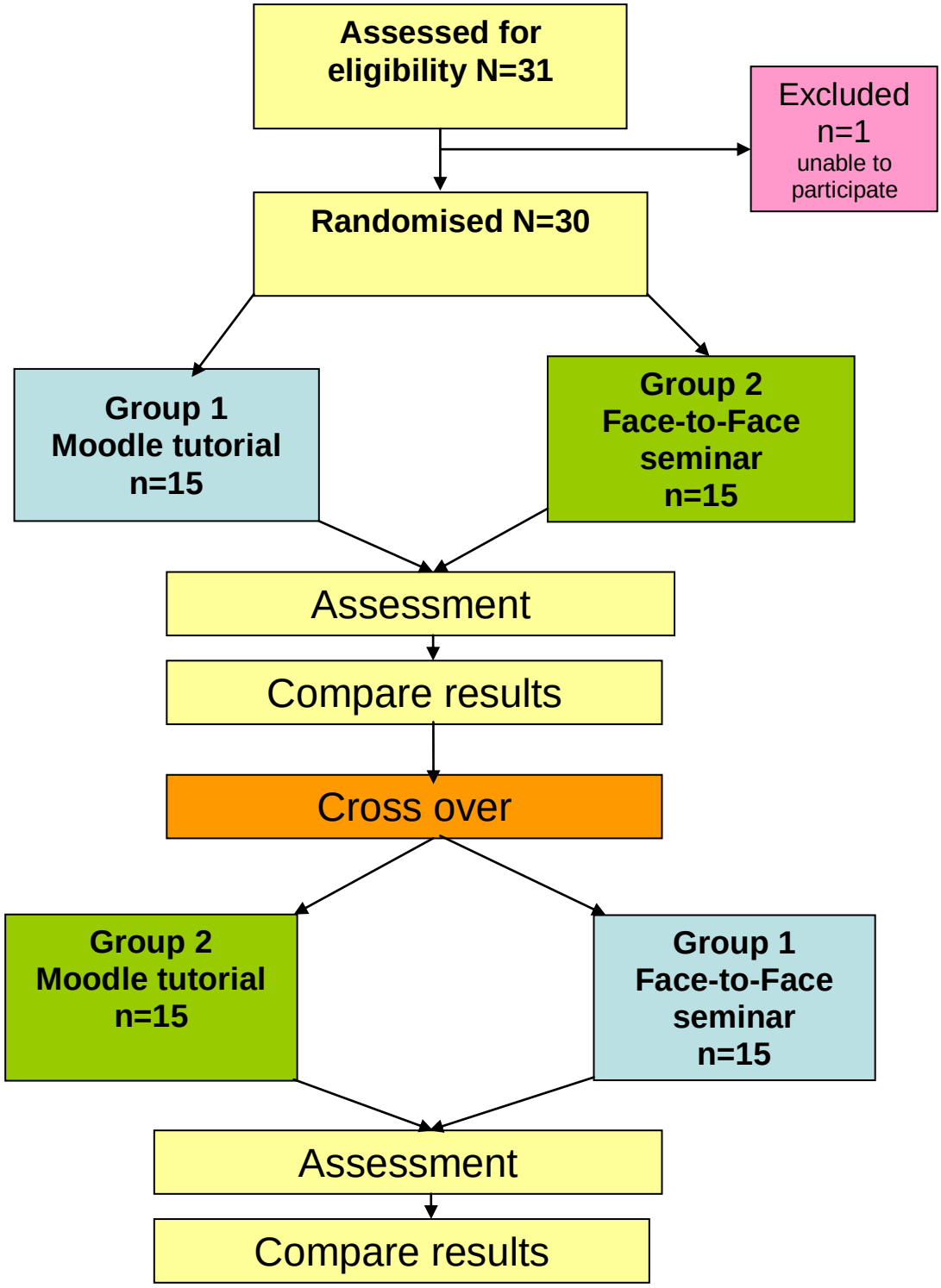


Fig 5.2 Cross over trial study design

At the end of each postgraduate's assessment, the assessment sheets were collected, compared with the gold standard and marked accordingly. The results of the assessment

were compared for each group based on their performance. The two groups then crossed over (Figure 5.2) and the other method of teaching was provided. There was a washout period of two months between the first and second episodes of teaching. Although one must appreciate that introducing this washout period was unlikely to negate what the postgraduates had learned during the first phase of teaching, it does help in minimising short term memory or surface learning. During the cross-over the postgraduates were unaware they would undertake the second mode of teaching and assessments, to avoid them revising during that period.

The groups were assessed again after the cross-over and within 3 weeks of the second mode of teaching, the students in Group 1 who had initially completed the Moodle tutorial had access to the VLE withdrawn, thus were unable to log-on and reinforce their knowledge. As previously described, the results of the two groups were then recorded for the second time. The postgraduates were asked to complete an anonymous questionnaire based on their learning experiences and how they rated both methods of teaching (Appendix 14).

Participants

First, second and third year postgraduate orthodontic students were recruited for the study and the two groups were assigned by stratified random sampling. None of the postgraduates had undergone formal teaching in TMJ examination. A total of 30 postgraduates were recruited for this study and the identifiers S1 to S30 used. Initially the year groups were independently allocated to either Group 1 or 2, ensuring an equal number of each year in both groups and the student identifications were then randomly assigned.

Patients

After each episode of teaching, postgraduates were required to undertake an assessment in TMJ examination and diagnosis. Subjects who presented with, and without, TMD signs and symptoms volunteered for this assessment. These subjects were 12 auxiliary staff and non-clinical student volunteers. All volunteers were given gift vouchers as a thank you for their time. The unique identifiers X1 to X12 represented the twelve subjects recruited to assist with the trial.

- Subjects were not examined by more than 3 postgraduates in any one day as repeated examinations on the same subjects were likely to fatigue the subject and may have elicited false positive results.
- Each postgraduate examined a different subject at the two assessments. This was to ensure the postgraduates were accurately diagnosing the subjects based on their examination and not from memory of their previous encounter.
- Subjects who were examined by 3 postgraduates after the first episode of teaching, were only examined by 2 postgraduates after the cross-over. This decision had no scientific basis but was introduced to ensure fairness to all subjects recruited.

As previously stated the twelve subjects had a range of conditions, some having no TMD signs and symptoms and others having definite signs and symptoms. As this was an exercise in carrying out an examination as well as diagnosing TMD conditions, it was intended that by randomising the patients, bias would be minimised (i.e. some postgraduates may have had harder patients to assess than others).

Participant and Patient distribution

Tables 5.1 and 5.2 demonstrate how the postgraduates were divided into the two groups and in addition to their assessment cohorts for the cross-over trial. It was necessary to have assessment cohorts (A to F for stage one and G to L for stage 2) as it was not feasible to assess all of the postgraduates at the same time or on the same day. Each assessment cohort consisted of 5 postgraduates. The assessments for the five postgraduates within each cohort were carried out on the same day and were completely independent. Postgraduates were not present for assessments undertaken by their colleagues.

Group 2: Face-to-face seminar (first episode of teaching)			Group 1: Moodle tutorial (first episode of teaching)		
Assessment Group	Student ID	Patient ID	Assessment Group	Student ID	Patient ID
A	S1	X1	**D**	S16	X3
	S2			S17	
	S3			S18	
	S4	X2		S19	X4
	S5			S20	
B	S6	X5	**E**	S21	X7
	S7			S22	
	S8			S23	
	S9	X6		S24	X8
	S10			S25	
C	S11	X9	**F**	S26	X11
	S12			S27	
	S13			S28	
	S14	X10		S29	X12
	S15			S30	

Table 5.1 Randomisation of the 30 postgraduates for first episode of teaching

Group 2: Moodle tutorial (second episode of teaching)			Group 1: Face-to-face seminar (second episode of teaching)		
Assessment Group	Student ID	Patient ID	Assessment Group	Student ID	Patient ID
G	S1	X4	**J**	S16	X2
	S2			S17	
	S3			S18	
	S4	X3		S19	X1
	S5			S20	
H	S6	X8	**K**	S21	X6
	S7			S22	
	S8			S23	
	S9	X7		S24	X5
	S10			S25	
I	S11	X12	**L**	S26	X10
	S12			S27	
	S13			S28	
	S14	X11		S29	X9
	S15			S30	

Table 5.2 Randomisation of the 30 postgraduates for the second episode of teaching following cross-over

Criteria for assessment:

The criteria on which the postgraduates were assessed are described in Table 5.3 below.

Procedure	**Criteria**
1. Correct application of force	*A domestic scale is used to ensure the student is generating 850-950g of force for the extra-oral muscles examination and 400-500g for the intra-oral muscles and joint examination.*
2. Lateral palpation	*Correct identification and palpation of lateral poles and report on any pain if present.*
3. Inter-auricular palpation	*The postgraduate is required to palpate in the external meatus by placing the right and left little fingers and applying pressure. The postgraduate is required to recognise pain if present.*
4. Click Present: Yes No	*Has the postgraduate recognised the presence or absence of a click?*
5. Classification of Click	*If present, can the postgraduate identify the nature of the click, i.e. whether it is in the opening cycle or closing cycle, painful or painless, consistent or intermittent?*
6. Crepitus Present: Yes No	*Has the postgraduate identified the presence or absence of crepitus correctly?*
7. Measurement of comfortable opening	*Compare the values obtained by the postgraduate to that of the gold standard. Is it within reasonable deviation of the gold standard (within +/– 5mm for opening measurements and +/– 2mm for lateral excursions)?*
8. Measurement of maximal opening	
9. Measurement of right lateral excursion	
10. Measurement of left lateral excursion	
11. Recognition of path of opening	*Has the postgraduate correctly identified the path of opening and recognised any deviations if present?*
12. Lateral pterygoid palpation	*For this section of the assessment the postgraduate has to be able to:* *1. Correctly identify the muscle groups and their anatomical positions* *2. Recognise the presence or absence of pain on palpation of these muscles*
13. Recognition of lateral pterygoid tenderness	
14. Mesial pterygoid palpation	
15. Recognition of mesial pterygoid tenderness	
16. Temporalis palpation	
17. Recognition of temporalis tenderness	

18. Masseter palpation **19**. Recognition of masseter tenderness	
20. Skeletal base assessment	*Correct identification of the patient's skeletal base by palpation with the index and middle finger with the patient in natural head position.*
21. Angle classification assessment	*Correct identification of the patient's Angle classification*
22. CO-CR identified	*The postgraduate should place the patient in centric occlusion, then identify the patients centric relation*
23. Direction of the slide	*If there are any premature contacts, the postgraduate should identify the direction of the slide from CO to CR*
24. Assessment of canine guidance/ group function	*The postgraduate should correctly identify the patient's lateral excursion*
25. Assessment of tooth wear	*Requires the postgraduate to assess the dentition and report on any findings of tooth wear if applicable*
26. Assessment of cheek ridging	*The postgraduate should examine the buccal mucosa for any signs of cheek ridging and accurately report the findings*
27. Assessment of tongue scalloping	*The postgraduate should examine the tongue and identify any tongue scalloping if present*
28. Followed correct sequence	*Has the postgraduate carried out all the required elements of this examination, and followed the recommended sequence of steps?*
29. Correct diagnosis of the condition	*Has the postgraduate correctly identified and diagnosed the patients TMD condition (if any) according to the RDC/TMD criteria?*

Table 5.3 Criteria for assessment of TMD

The 29 procedures included as assessment criteria were chosen after careful discussion with an expert in facial pain from the Facial Pain Unit, Department of Oral and Maxillofacial surgery, Eastman Dental Hospital (RL). It was important that these outcome measures were valid and reproducible and, as such, only procedures that could confidently be determined by the assessor were included. If a procedure on the check list did not apply to the patient (such as presence of a click) then the postgraduates were assessed on their ability to recognise the absence of a click and record this as such on the examination performa. Once the criteria were established, the researcher (SA) was calibrated by RL to ensure consistency in assessment.

Volunteers were recruited and examined by both RL and SA. Five restorative postgraduates were then asked to examine the volunteer and RL and SA independently assessed them carrying out a TMJ examination. The results of the assessments were compared between RL and the examiner and any discrepancies were discussed. This process was repeated on a further five Restorative postgraduates until it was confidently established that consistency in marking the assessments was reached.

Statistical Analyses

Statistical analysis was undertaken to establish whether any significant differences existed between the two groups. The objectives of the statistical analysis were to answer the following:

1. Is Moodle a better, or worse, method of teaching TMJ assessment when compared with face-to-face seminars?
2. If both methods of teaching are provided, does the order in which the teaching is received make a difference? (i.e. is Moodle followed by face-to-face better than face-to-face teaching followed by Moodle?)
3. Does teaching twice make a difference? If the student had a face-to-face seminar in the first instance does having further teaching with Moodle improve how well postgraduates do, and *vice versa*?

Statistical analyses were carried out using SPSS version 14, SPSS UK Ltd, Surrey, UK. Two-by-two contingency tables were constructed using the statistical package and Chi squared analyses undertaken on all of the 29 procedures. In view of the fact that there were many procedures that were being considered, the significance level was set at $P \leq 0.01$. It was felt that this would reduce the likelihood of finding a significant result purely by chance.

For comparison of paired variables a McNemar's test method was applied to 2×2 contingency tables. This was carried out for comparison of Group 1 initial and post cross-over assessments and Group 2 initial and post cross-over assessments (i.e. within group comparisons). The significance level was again set at $P \leq 0.01$.

The numerical results (obtained by grouping/ summing the 29 individual assessment procedures into four themes) were assessed for normality using histograms and box and whisker plots. The data did not follow a normal distribution therefore the Mann-Whiney U test was applied to the independent variables, whilst the Wilcoxon Signed Ranks test was applied to the paired variables. The significance level was set at $P \leq 0.05$ as fewer tests were conducted and the potential for obtaining spurious results through multiple testing was reduced.

5.3 Results

For ease of comparison, the 29 procedures on the checklist were categorised into four main themes:

1. Joint symptoms
2. Jaw movement
3. Muscle symptoms
4. Occlusal features

5.3.1 Individual Assessment results

5.3.1.1 Assessment Results after first teaching episode

Group 1 carried out the Moodle tutorial first whilst Group 2 attended a face-to-face seminar and practical demonstration. A summary of these findings are shown in Table 5.4

	Procedure undertaken	Correctly undertaken		Total	P Value[##]
		Group 1 (Moodle) N=15	Group 2 (FtoF) N=15		
Joint Symptoms	***Correct application of force***	2 13.3%	3 20.0%	5	1.000[#]
	Lateral Palpation	7 46.7%	3 20.0%	10	0.245
	Inter auricular palpation	9 60.0%	9 60.0%	18	1.000
	Identified presence/absence of click	7 46.7%	14 93.3%	21	**0.014**[#]
	Classification of click	9 60.0%	11 73.3%	20	0.439
	Identified presence/absence of crepitus	9 60.0%	13 86.7%	22	0.215[#]
Jaw Movements	***Measurement of comfortable opening***	12 80.0%	14 93.3%	26	0.598[#]
	Measurement of maximum opening	11 73.3%	9 60.0%	20	0.439
	Measurement of right lateral excursion	10 67.7%	6 40.0%	16	0.143
	Measurement of left lateral excursion	10 66.7%	7 46.7%	17	0.269
	Recognition of pathway of opening	7 46.7%	10 66.7%	17	0.269

Muscle Symptoms	***Recognition and correct palpation of lateral pterygoid muscle***	7 46.7%	9 60.0%	16	0.464
	Recognition of lateral pterygoid tenderness	12 80.0%	14 93.3%	26	0.598[#]
	Recognition and correct palpation of mesial pterygoid muscle	5 33.3%	0 0%	5	0.042[#]
	Recognition of mesial pterygoid tenderness	9 60.6%	8 53.3%	17	0.713
	Recognition and correct palpation of temporalis muscle	5 33.3%	4 26.7%	9	1.000[#]
	Recognition of temporalis tenderness	11 73.3%	15 100%	9	0.100[#]
	Recognition and correct palpation of masseter muscle	4 26.7%	5 33.3%	9	1.000[#]
	Recognition of masseter tenderness	12 80.0%	14 93.3%	26	0.598[#]
Occlusal Features	***Skeletal base assessment***	12 80.0%	15 100%	27	0.224[#]
	Angle classification	12 80.0%	14 93.3%	26	0.598[#]
	CO-CR identified	12 80.0%	14 93.3%	26	0.598[#]
	Direction of slide (if any) identified	12 80.0%	14 93.3%	26	0.598[#]
	Assessment of canine guidance/group function	10 67.7%	13 86.7%	23	0.390[#]
	Assessment of tooth wear	10 67.7%	14 93.3%	24	0.169[#]
	Assessment of cheek ridging	11 73.3%	12 80.0%	23	1.000[#]
	Assessment of tongue scalloping	9 60.6%	8 53.3%	17	0.713
	Followed correct sequence of steps	8 53.3%	6 40.0%	14	0.464
	Diagnosis of patient's condition	9 60.6%	11 73.3%	20	0.439

[#] Where the expected frequency of the 2 x 2 table is less than 5, Fisher's exact test was used rather than chi-squared.
[##] Significance indicated by P< 0.01

Table 5.4 Assessment results after first teaching episode

In "Joint Symptoms", there was a borderline significant difference in the ability of the two groups to identify the presence or absence of a click (p=0.014), with Group 2 (face-to-face seminar group) achieving better results. However when the remainder of the Joint Symptoms were considered, there were no significant differences for any of the other procedures. Both groups performed poorly in recognising the correct application

of force; only 13.3% of Group 1 and 20% of Group 2 were able to apply the correct force for examination of the joints and muscles. In Group 1, 46.7% palpated the lateral poles of the TMJ correctly, but only 20% of Group 2, however, there was no significant difference between the two groups.

There were no significant differences between Group 1 and Group 2 for the Jaw Movements theme. The majority of postgraduates (80.0% of Group 1 and 93.3% of Group 2) measured the comfortable opening of the mandible to within +/– 5mm from the gold standard, however fewer postgraduates were able to accurately record maximum mandibular opening examination to within +/– 5mm (73.3% of Group 1 and 60.0% of Group 2). When comparing lateral excursions, a similar number of postgraduates accurately diagnosed left and right lateral excursions to within +/– 2mm of the gold standard (n=17 and 16 for Groups 1 and 2 respectively).

When considering Muscle Symptoms, the majority of the postgraduates were able to correctly identify muscle tenderness, although fewer postgraduates carried out the muscle palpations in the correct manner. For example, 80% of Group 1 and 93.4% of Group 2 accurately identified the lateral pterygoid muscular state (i.e presence or absence of tenderness), but only 46.7% and 60.0% carried out the palpation correctly. Similar trends were seen with the remainder of the muscle groups. The results for medial pterygoid palpation were particularly poor, with only 33.3% of Group 1 and none of the postgraduates in Group 2 carrying out the palpations correctly. It must be acknowledged that is debatable whether the medial pterygoid muscle can actually be palpated with accuracy.

The results of the Occlusal Features category were in line with the previous findings for Joint Symptoms, Jaw Movements and Muscle Symptoms. No significant differences were apparent for any of the individual procedures and both groups performed well in these assessments. Eighty percent of Group 1 and 100% of Group 2 accurately recorded the skeletal classification. The results of the remainder of the procedures in this theme were similar, e.g. 80.0% of Group 1 and 93.3% of Group 2 correctly recorded the Angle's classification, Centric occlusion-Centric relation (Co-Cr) and direction of slide. However, all of these procedures are commonly occurring principles in orthodontic practice and postgraduates had ample experience in recording these parameters.

Finally, both groups were equally able to diagnose the patient's TMJ condition according to the RDC/TMD classification. Sixty percent of Group 1 and 73.3% of Group 2 were able to correctly classify the patient's TMJ status.

5.3.1.2 Assessment results after cross-over and second teaching episode

The following table summarises the results of the two groups after the cross-over. The second episode of teaching involved Group 1 attending the face-to-face seminar and Group 2 undertaking the Moodle tutorial.

	Procedure undertaken	Correctly undertaken		Total	P Value ##
		Group 1 (F2F) N=15	Group 2 (Moodle) N=15		
Joint Symptoms	***Correct application of force***	7 46.7%	7 46.7%	14	1.00
	Lateral Palpation	7 46.7%	5 33.3%	12	0.456
	Inter auricular palpation	12 80.0%	12 80.0%	24	0.674#
	Identified presence/absence of click	14 93.3%	15 100.0%	29	1.000#
	Classification of click	7 46.7%	14 93.3%	21	**0.014**#
	Identified presence/absence of crepitus	12 80.0%	15 100.0%	27	0.224#
Jaw Movements	***Measurement of comfortable opening***	15 100.0%	14 93.3%	29	1.000#
	Measurement of maximum opening	10 66.7%	14 93.3%	24	0.169#
	Measurement of right lateral excursion	14 93.3%	8 53.3%	22	0.035#
	Measurement of left lateral excursion	14 93.3%	8 53.3%	22	0.035#
	Recognition of pathway of opening	13 86.7%	14 93.3%	27	1.000#

Muscle Symptoms	***Recognition and correct palpation of lateral pterygoid muscle***	10 66.7%	4 26.7%	14	0.028
	Recognition of lateral pterygoid tenderness	15 100.0%	12 80.0%	27	0.224[#]
	Recognition and correct palpation of mesial pterygoid muscle	7 46.7%	6 40.0%	13	0.713
	Recognition of mesial pterygoid tenderness	12 80.0%	12 80.0%	24	1.000[#]
	Recognition and correct palpation of temporalis muscle	10 66.7%	5 33.3%	15	0.068
	Recognition of temporalis tenderness	14 93.3%	15 100.0%	29	1.000[#]
	Recognition and correct palpation of masseter muscle	10 66.7%	8 53.3%	18	0.456
	Recognition of masseter tenderness	15 100.0%	15 100.0%	30	-
Occlusal Features	***Skeletal base assessment***	15 100.0%	15 100.0%	30	-
	Angle classification	15 100.0%	15 100.0%	30	-
	CO-CR identified	15 100.0%	14 93.3%	29	1.000[#]
	Direction of slide (if any) identified	15 100.0%	14 93.3%	29	1.000[#]
	Assessment of canine guidance/group function	13 86.7%	14 93.3%	27	1.000[#]
	Assessment of tooth wear	13 86.7%	15 100.0%	28	0.483[#]
	Assessment of cheek ridging	12 80.0%	13 86.7%	25	1.000[#]
	Assessment of tongue scalloping	14 93.3%	11 73.7%	25	0.330[#]
	Followed correct sequence of steps	11 73.7%	11 73.7%	22	1.000[#]
	Diagnosis of patient's condition	12 80.0%	12 80.0%	24	1.000[#]

[#] Where the expected frequency of the 2 x 2 table is less than 5, Fishers exact test was used rather than chi-squared.

- Where no P value is given, a calculation was not possible as discordant pairs were not present

[##] Significance indicated by P< 0.01

Table 5.5 Assessment results after cross over and second teaching episode

The results after cross-over mirrored the initial assessment, and there were no significant differences between Group 1 and Group 2 for any of the procedures. When considering Joint Symptoms, both groups had identical results for the correct application of force (46.7%) and intra-auricular palpation (80.0%). There were no significant differences between the two groups for any of the procedures. The presence or absence of a click was correctly identified by 93.3 % of Group 1 and 100.0% of Group 2. Lateral pole palpation was performed poorly with only 46.7% of Group 1 and 33.3% of Group 2 carrying this out correctly. There was, however, borderline significance for the classification of clicks (P=0.014) with only 46.7% of Group 1 classifying them correctly compared with 93.3% of Group 2.

No significant differences were detected between the groups for any of the procedures relating to Jaw Movements. One hundred percent of Group 1 accurately measured the comfortable opening to within +/– 5mm of the gold standard compared with 93.3% of Group 2. More subjects in Group 2 (93.3%) recorded the maximal assisted opening correctly compared with Group 1 (66.7%), but there was a tendency for Group 1 to outperform Group 2 in recording both right and left lateral excursions (93.3% and 53.3% respectively for left and right excursions) and although this was not statistically significant, it may be clinically relevant.

With regards to Muscle Symptoms, the majority of postgraduates were able to accurately recognise the presence or absence of muscular tenderness, this was particularly so with the recognition of temporalis tenderness which all postgraduates recorded correctly. However, postgraduates were not as consistent in their ability to locate/ accurately palpate the muscles: 66.7% of Group 1 accurately palpated the lateral pterygoid muscle but only 26.7% of Group 2. A similar trend was seen with temporalis palpation, with 66.7% of Group 1 and 33.3% of Group 2 undertaking the procedure correctly, none of these differences were statistically significant though.

The results for the Occlusal Features theme were in line with previous results and no significant differences were observed between the two groups for any of the procedures and postgraduates in both groups performed well in this section.

Seventy three percent of postgraduates in Group 1 and Group 2 followed the correct sequence of steps, and in addition 80% of the postgraduates in both groups were able to give a correct diagnosis according to the RDC/TMD criteria.

5.3.1.3 Group 1 (Moodle followed by face-to-face teaching)

This table compares how the postgraduates in Group 1 performed after the first and second assessments having undertaken the Moodle tutorial in the first instance then attending a face-to-face seminar.

	Procedure undertaken	**Correctly undertaken**		**Total**	**P Value**[##]
		First time (Moodle)	**Second time (FtoF)**		
Joint Symptoms	***Correct application of force***	2 13.3%	7 46.7%	9	0.180
	Lateral Palpation	7 46.7%	7 46.7%	14	1.000
	Inter auricular palpation	9 40.0%	12 80.0%	21	0.375
	Identified presence/absence of click	7 46.7%	14 93.3%	21	**0.016**
	Classification of click	9 40.0%	7 46.7%	16	0.625
	Identified presence/absence of crepitus	9 40.0%	12 80.0%	21	0.375
Jaw Movements	***Measurement of comfortable opening***	12 80.0%	15 100.0%	27	-
	Measurement of maximum opening	11 73.3%	10 66.7%	21	1.000
	Measurement of right lateral excursion	10 66.7%	14 93.3%	24	0.125
	Measurement of left lateral excursion	10 66.7%	14 93.3%	24	0.125
	Recognition of pathway of opening	7 46.7%	13 86.7%	20	0.031

Muscle Symptoms	***Recognition and correct palpation of lateral pterygoid muscle***	7 46.7%	10 66.7%	17	0.375
	Recognition of lateral pterygoid tenderness	12 80.0%	15 100.0%	27	-
	Recognition and correct palpation of mesial pterygoid muscle	5 33.3%	7 46.7%	13	0.625
	Recognition of mesial pterygoid tenderness	9 40.0%	12 80.0%	21	0.375
	Recognition and correct palpation of temporalis muscle	5 33.3%	10 66.7%	15	0.063
	Recognition of temporalis tenderness	11 73.3%	14 93.3%	25	0.375
	Recognition and correct palpation of masseter muscle	4 26.7%	10 66.7%	14	0.031
	Recognition of masseter tenderness	12 80.0%	15 100.0%	27	-
Occlusal Features	***Skeletal base assessment***	12 80.0%	15 100.0%	27	-
	Angle classification	12 80.0%	15 100.0%	27	-
	CO-CR identified	12 80.0%	15 100.0%	27	-
	Direction of slide (if any) identified	12 80.0%	15 100.0%	27	-
	Assessment of canine guidance/group function	10 66.7%	13 86.7%	23	0.375
	Assessment of tooth wear	10 66.7%	13 86.7%	23	0.375
	Assessment of cheek ridging	11 73.3%	12 80.0%	23	1.000
	Assessment of tongue scalloping	9 40.0%	14 93.3%	23	0.063
	Followed correct sequence of steps	8 53.3%	11 73.3%	19	0.375
	Diagnosis of patient's condition	9 40.0%	12 80.0%	21	0.375

- Where no P value is given, a calculation was not possible as discordant pairs were not present
[##] Significance indicated by P< 0.01

Table 5.6 Group 1 assessments comparing the first and second episodes of teaching

Although there was a definite trend for results to improve after the second assessment, no significant differences were found for any of the 29 procedures on the checklist. The identification of presence/absence of a click (P=0.016) was of borderline significance, with 46.7% of Group 1 postgraduates identifying this correctly at the first assessment

and 93.3% at the second assessment. For 26 of the 29 procedures, the percentage of postgraduates who undertook procedures correctly at the second assessment increased. It remained the same for 1 procedure (lateral palpation) and decreased for two procedures (classification of a click and measurement of maximum opening). It must, however, be appreciated that the sample sizes in this study are small and increasing the sample size in future studies would be beneficial.

5.3.1.4 Group 2 (face-to-face teaching followed by Moodle)

This table summarises the results of the Group 2 postgraduates who had undertaken face-to-face teaching first and then the Moodle tutorial.

	Procedure undertaken	% Correctly undertaken		Total	P Value##
		First time (FtoF)	Second time (Moodle)		
Joint Symptoms	*Correct application of force*	3 20.0%	7 46.7%	10	0.289
	Lateral Palpation	3 20.0%	5 33.3%	8	0.688
	Inter auricular palpation	9 40.0%	12 80.0%	27	0.508
	Identified presence/absence of click	14 93.3%	15 100.0%	29	-
	Classification of click	11 73.3%	14 93.3%	25	0.375
	Identified presence/absence of crepitus	13 86.7%	15 100.0%	28	-
Jaw Movements	*Measurement of comfortable opening*	14 93.3%	14 93.3%	28	1.000
	Measurement of maximum opening	9 40.0%	14 93.3%	23	0.063
	Measurement of right lateral excursion	6 40.0%	8 53.3%	14	0.688
	Measurement of left lateral excursion	7 46.7%	8 53.3%	15	1.000
	Recognition of pathway of opening	10 66.7%	14 93.3%	24	0.219

Muscle Symptoms	***Recognition and correct palpation of lateral pterygoid muscle***	9 40.0%	4 26.7%	13	0.180
	Recognition of lateral pterygoid tenderness	14 93.3%	12 80.0%	26	0.625
	Recognition and correct palpation of mesial pterygoid muscle	6 40.0%	15 100.0%	21	-
	Recognition of mesial pterygoid tenderness	8 53.3%	12 80.0%	20	0.219
	Recognition and correct palpation of temporalis muscle	4 26.7%	5 33.3%	9	1.000
	Recognition of temporalis tenderness	15 100.0%	15 100.0%	30	-
	Recognition and correct palpation of masseter muscle	5 33.3%	8 53.3%	13	0.453
	Recognition of masseter tenderness	14 93.3%	15 100.0%	29	-
Occlusal Features	***Skeletal base assessment***	15 100.0%	15 100.0%	30	-
	Angle classification	14 93.3%	15 100.0%	29	-
	CO-CR identified	14 93.3%	14 93.3%	28	1.000
	Direction of slide (if any) identified	14 93.3%	14 93.3%	28	1.000
	Assessment of canine guidance/group function	13 86.7%	14 93.3%	27	1.000
	Assessment of tooth wear	14 93.3%	15 100.0%	29	-
	Assessment of cheek ridging	12 80.0%	13 86.7%	25	1.000
	Assessment of tongue scalloping	8 53.3%	11 73.3%	19	0.453
	Followed correct sequence of steps	6 40.0%	11 73.3%	17	0.063
	Diagnosis of patient's condition	11 73.3%	12 80.0%	23	1.000

- Where no P value is given, a calculation was not possible as discordant pairs were not present
Significance indicated by P< 0.01

Table 5.7 Group 2 assessments comparing the first and second episodes of teaching

The findings were similar to those for Group 1, and no significant differences were found between the first and the second assessments. The trend was for an improvement in assessment results (22 of the 29 procedures). For five procedures, the percentage of postgraduates who undertook the procedure correctly remained the same (measurement of comfortable opening, recognition of temporalis tenderness, skeletal base assessment

CO-CR identified and direction of slide identified). It must be borne in mind, however, that the skeletal base assessment results were already 100% at the initial assessment and there was therefore no room for further improvement due to the "ceiling effect". The percentage of postgraduates who undertook the procedure correctly decreased for 2 procedures (recognition/correct palpation of lateral pterygoid muscle and recognition of lateral pterygoid tenderness).

5.3.2 Assessment Results after grouping the procedures

Due to the complexity of analysing 29 individual procedures and the small sample sizes obtained it was also decided to analyse the results according to the summary scores for the four themes rather than individual procedures within the themes. As previously mentioned the four themes were as follows:

1. Joint symptoms
2. Jaw movements
3. Muscle symptoms
4. Occlusal features

5.3.2.1 Assessment after the first teaching episode

Theme	Group	Results of the assessment							P Value[##]
		Mean	Lower 95% CI	Upper 95% CI	Std Dev	Median	Min	Max	
Joint Symptoms	1	2.87	1.89	3.85	1.77	3	0	5	0.319
	2	3.59	2.84	4.22	1.25	4	1	5	
Jaw Movement	1	3.33	2.38	4.28	1.72	4	0	5	0.553
	2	3.07	2.19	3.94	1.58	3	0	5	
Muscle Symptoms	1	4.33	2.80	5.87	2.77	4	0	8	0.441
	2	4.60	4.14	5.00	0.83	5	3	6	
Occlusal Features	1	3.33	2.38	4.28	1.72	4	0	5	0.553
	2	3.07	2.19	3.94	1.58	3	0	5	
Total	1	13.87	10.37	17.36	6.31	11	4	23	0.787
	2	14.27	12.18	16.35	3.77	15	9	19	

[##] Significance indicated by P< 0.05

Table 5.8 Results for the assessment after first teaching episode

There were no significant differences observed between the assessment marks of the Group 1 and Group 2 postgraduates for the first assessment. These results mirror the individual results presented in the previous section. The findings for all 29 procedures summed (Total row) also indicated that there were no significant differences observed between Groups 1 and 2.

5.3.2.2 Assessment after the cross-over and second teaching episode

Theme	Group	Results of the assessment							P Value[##]
		Mean	Lower 95% CI	Upper 95% CI	Std Dev	Median	Min	Max	
Joint Symptoms	1	3.93	3.14	4.73	1.44	4	1	6	0.153
	2	4.53	3.99	5.08	0.99	5	2	6	
Jaw Movement	1	4.40	3.78	5.02	1.12	5	1	5	0.267
	2	3.87	3.06	4.67	1.46	5	0	5	
Muscle Symptoms	1	6.20	5.17	7.23	1.86	6	4	8	0.081
	2	5.13	4.18	6.09	1.73	5	3	8	
Occlusal Features	1	7.47	7.00	7.93	0.83	8	5	8	0.583
	2	7.40	6.65	8.15	1.35	8	3	8	
Total	1	22.00	19.79	24.21	3.98	23	16	27	0.416
	2	20.93	19.12	22.75	3.28	22	14	25	

[##] Significance indicated by P< 0.05

Table 5.9 Results for the assessment after the cross-over and second teaching episode

No significant differences were observed for the second assessment between Groups 1 and 2 for any of the four themes. In addition there was no significant difference for the 29 procedures combined (P=0.416).

5.3.2.3 Group 1: Moodle followed by face-to-face

Theme		Results of the assessment							P Value[##]
	Time	Mean	Lower 95% CI	Upper 95% CI	Std Dev	Median	Min	Max	
Joint Symptoms	1st	2.87	1.89	3.85	1.77	3	0	5	0.060
	2nd	3.93	3.14	4.73	1.44	4	1	6	
Jaw Movement	1st	3.33	2.38	4.28	1.72	4	0	5	0.012
	2nd	4.40	3.78	5.02	1.12	5	1	5	
Muscle Symptoms	1st	4.33	2.80	5.87	2.77	4	0	8	0.018
	2nd	6.20	5.17	7.23	1.86	6	4	8	
Occlusal Features	1st	3.33	2.38	4.28	1.72	4	0	5	0.001
	2nd	7.47	7.00	7.93	0.83	8	5	8	
Total	1st	13.87	10.37	17.36	6.31	11	4	23	0.001
	2nd	22.00	19.79	24.21	3.98	23	16	27	

[##] Significance indicated by P< 0.05

Table 5.10 Group 1 results comparing first and second assessments

When comparing the scores for Group 1 postgraduates before and after the cross-over, a significant difference was observed for three of the themes (Jaw Movements, Muscle Symptoms and Occlusal Symptoms: P= 0.012, 0.018 and 0.001), whilst a borderline significant difference was observed for Joint Symptoms. There was an improvement in the scores for the second assessment in all cases. This is in contrast with the non-significant findings observed when the procedures were looked at independently, however it is in line with the trend that was observed in the individual procedure analysis. In addition the difference between the total scores was also found to be highly significant (P=0.001), with postgraduates achieving better results at the second assessment than the first (mean of 22.00 compared with 13.87).

5.3.2.4 Group 2: Face-to-face followed by Moodle

Theme	Time	Results of the assessment							P Value[##]
		Mean	Lower 95% CI	Upper 95%CI	Std Dev	Median	Min	Max	
Joint Symptoms	1st	3.59	2.84	4.22	1.25	4	1	5	0.053
	2nd	4.53	3.99	5.08	0.99	5	2	6	
Jaw Movement	1st	3.07	2.19	3.94	1.58	3	0	5	0.190
	2nd	3.87	3.06	4.67	1.46	5	0	5	
Muscle Symptoms	1st	4.60	4.14	5.00	0.83	5	3	6	0.332
	2nd	5.13	4.18	6.09	1.73	5	3	8	
Occlusal Features	1st	3.07	2.19	3.94	1.58	3	0	5	0.001
	2nd	7.40	6.65	8.15	1.35	8	3	8	
Total	1st	14.27	12.18	16.35	3.77	15	9	19	0.001
	2nd	20.93	19.12	22.75	3.28	22	14	25	

[##] Significance indicated by P< 0.05

Table 5.11 Group 2 results comparing first and second assessments

A significant difference (P=0.001) was observed for Occlusal Features between the first and second assessments. With regards to Joint Symptoms, the difference in marks between the first and second assessment was of borderline significance. In contrast no significant difference was observed between the two assessments for the Muscle Symptoms or Jaw Movements themes, although there was a trend for the marks to improve in both themes. For the total marks achieved, there was a highly significant improvement between the first and second assessment .

5.3.2.5 Sum of all procedures

Thus in summary, when looking at the total scores obtained by all of the postgraduates, (regardless of which group they belonged in) there was a highly significant improvement between the first and second assessments (Table 5.12).

Assessment	Mean	Std Dev	Lower 95% CI	Upper 95%CI	Median	Min	Max	P Value##
1st	14.07	5.11	12.16	15.98	14	4	23	< 0.001
2nd	21.47	3.63	20.11	22.82	22.5	14	27	

Significance indicated by P< 0.05

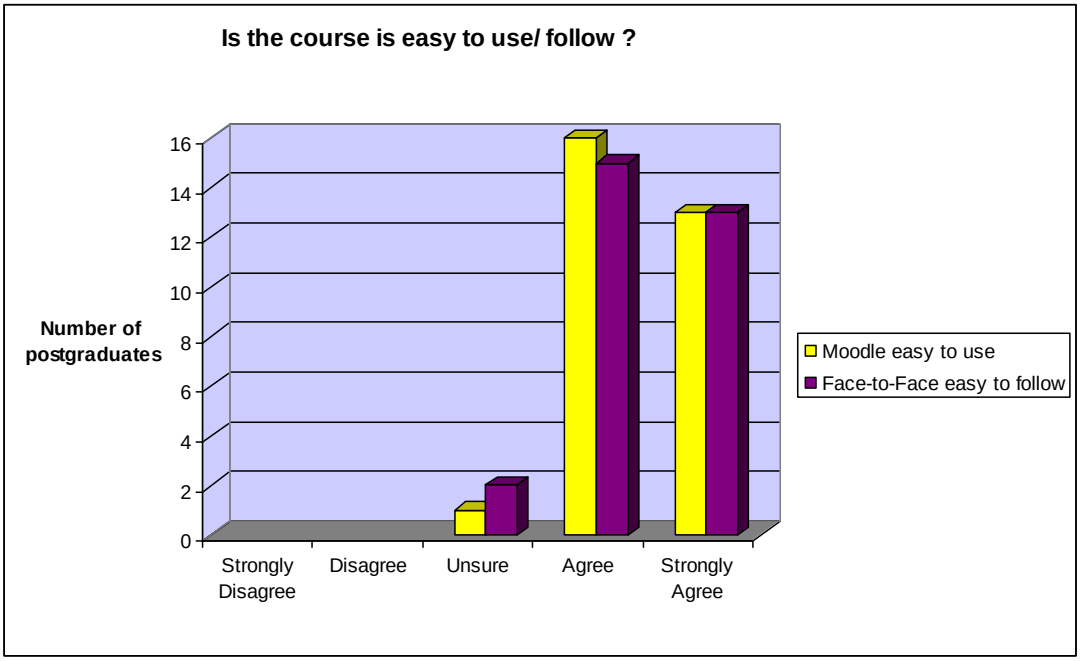
Table 5.12 Comparison of the total scores between the first and second assessments

5.3.3 Feedback questionnaire findings

Due to the relatively small sample size in the study, it was decided to present the results of the questionnaire (Appendix 14) graphically rather than statistically analysing the data. The procedures are presented for Moodle and face-to-face in the same bar chart to aid comparisons.

Figure 5.3 Bar chart comparing whether the course is easy to use or follow

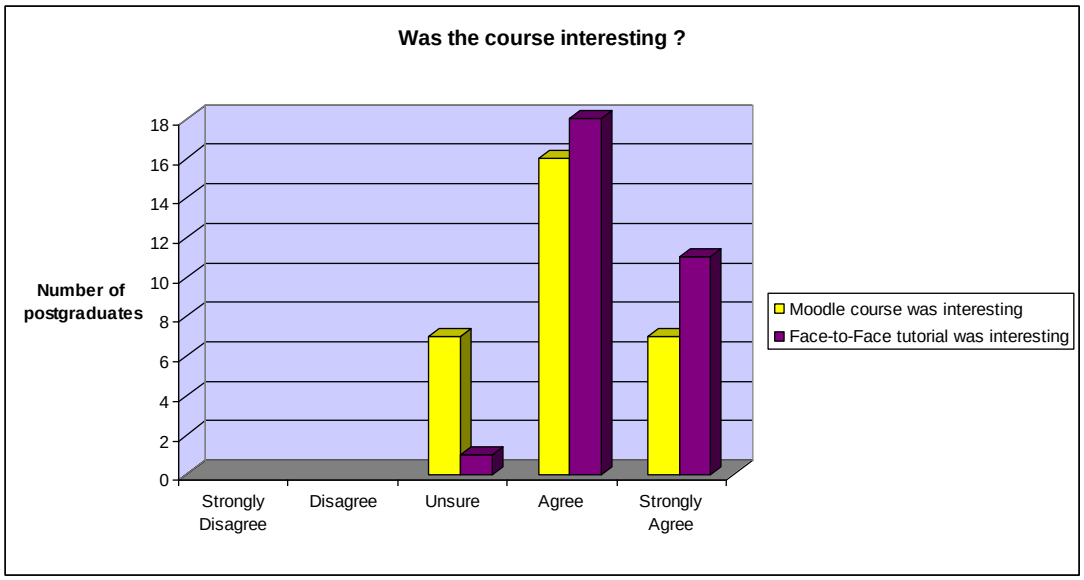
Questions 1 and 2 - Is the course easy to use/ follow?



The postgraduates felt that both courses were easy to follow and the majority either "Agreed" or "Strongly agreed" with the statement. Only 3 of the 30 postgraduates were unsure about the ease of following either of the courses.

Figure 5.4 Bar chart comparing whether the course was interesting

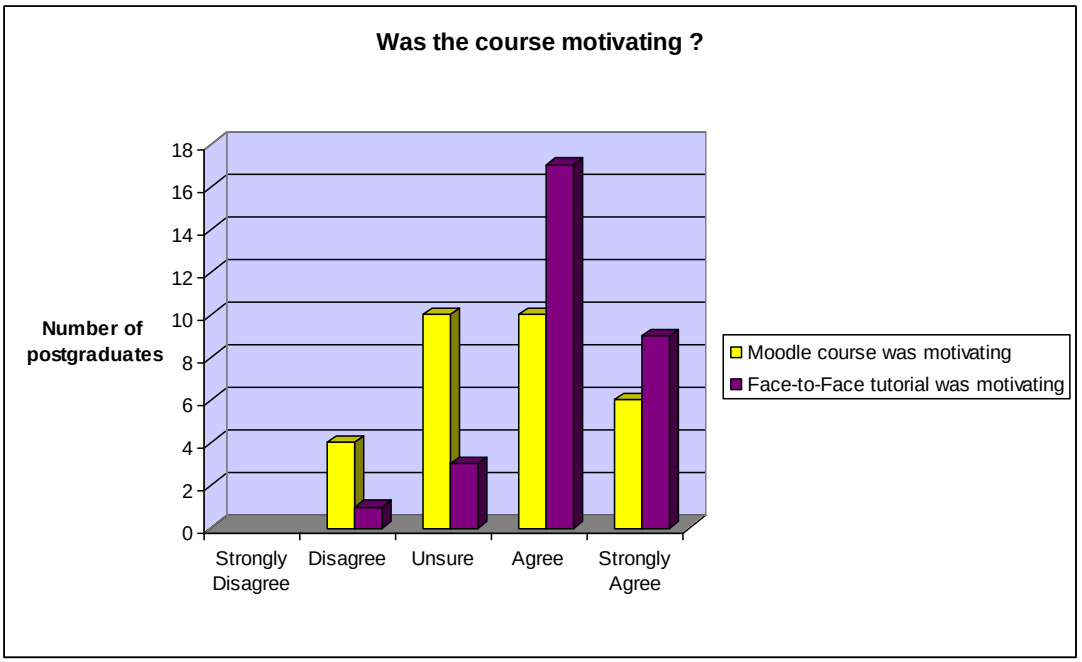
Questions 3 and 4 - Was the course interesting?



Most of the postgraduates "Agreed" or "Strongly agreed" that the courses were interesting. A total of 7 postgraduates however, were unsure about the level of interest the courses generated and 6 of these postgraduates felt unsure about the Moodle tutorial compared with 1 postgraduate for the face-to-face seminar.

Figure 5.5: Bar chart comparing whether the course was motivating

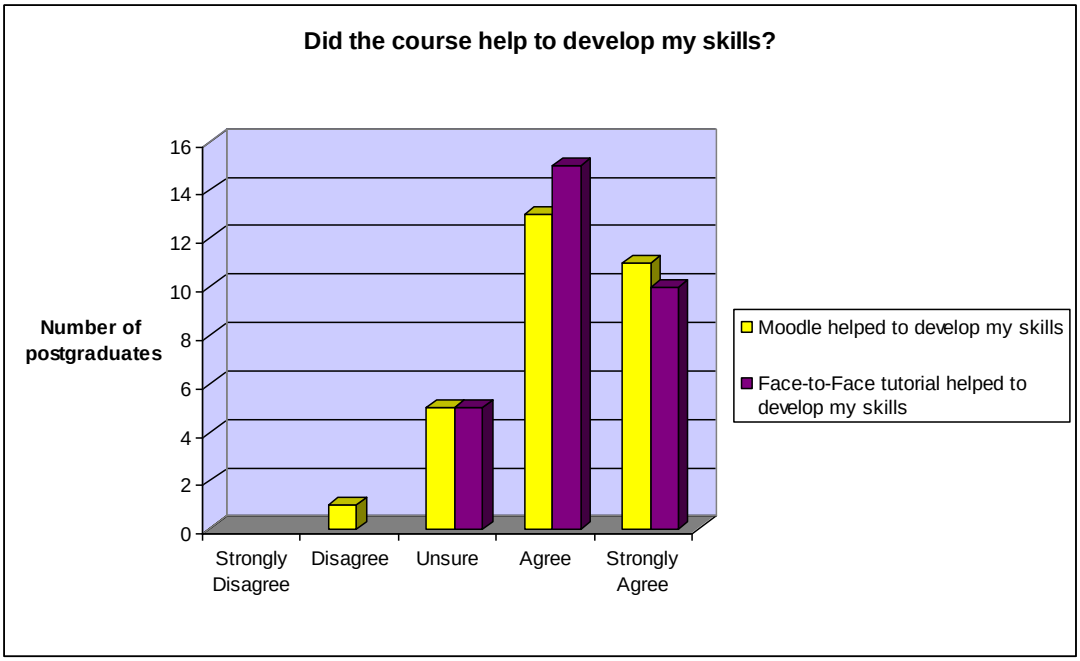
Questions 5 and 6 - Was the course motivating?



The majority of the postgraduates either “Agreed" or "Strongly agreed" that the face-to-face tutorial was more motivating (n=26). On the other hand 14 postgraduates either “Disagreed” or were “Unsure” about whether the Moodle course was motivating.

Figure 5.6 Bar chart comparing skills development from the course

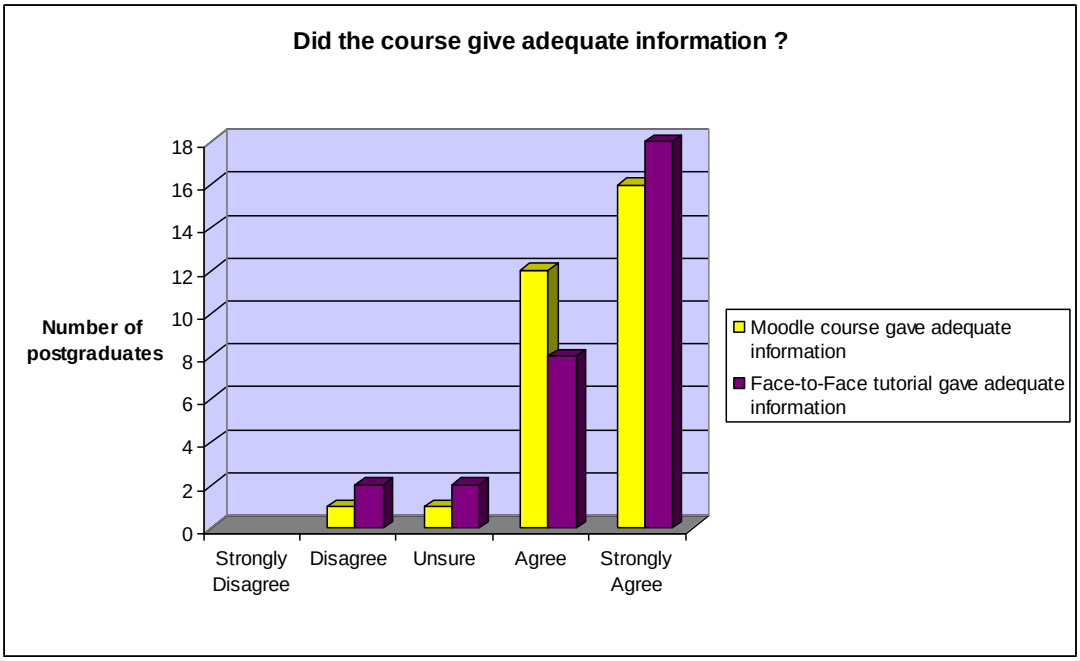
Questions 7 and 8 - Did the course help to develop my skills?



The responses to these questions were similar for both modes of teaching, and postgraduates recognised the ability of both courses to develop their TMJ examination skills. Only 1 student disagreed with this statement and 8 postgraduates were unsure.

Figure 5.7 Bar chart comparing the course information

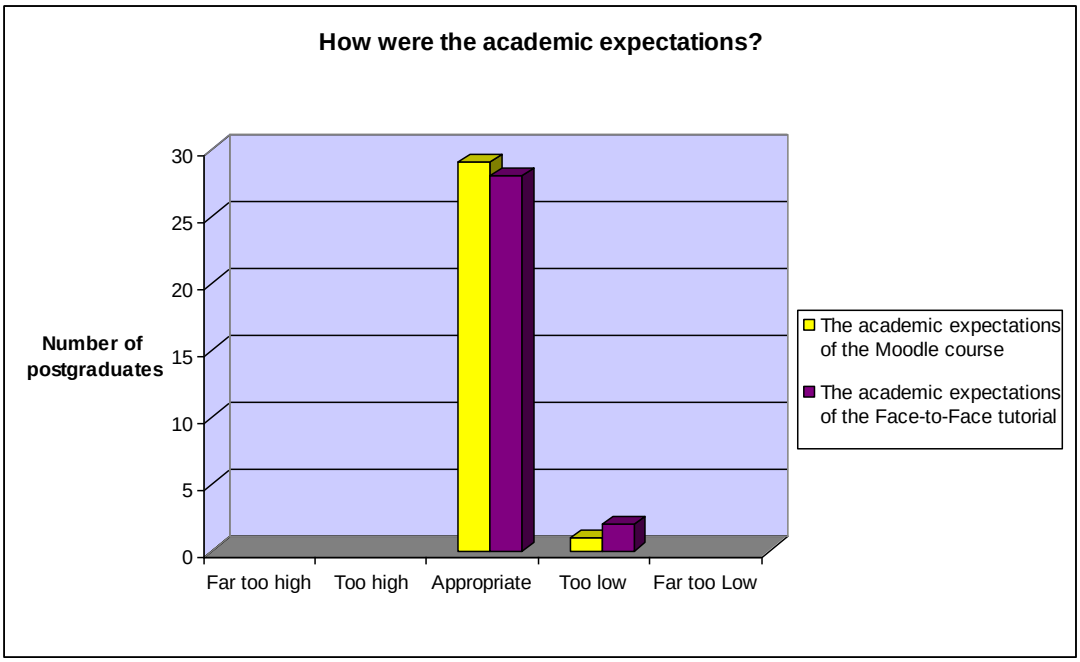
Questions 9 and 10 - Did the course give adequate information?



Most of the postgraduates believed that the course provided adequate information and content. Only 3 "Disagreed" with the level of information provided, while a further 3 postgraduates were "Unsure".

Figure 5.8 Bar chart comparing the academic expectations from the course

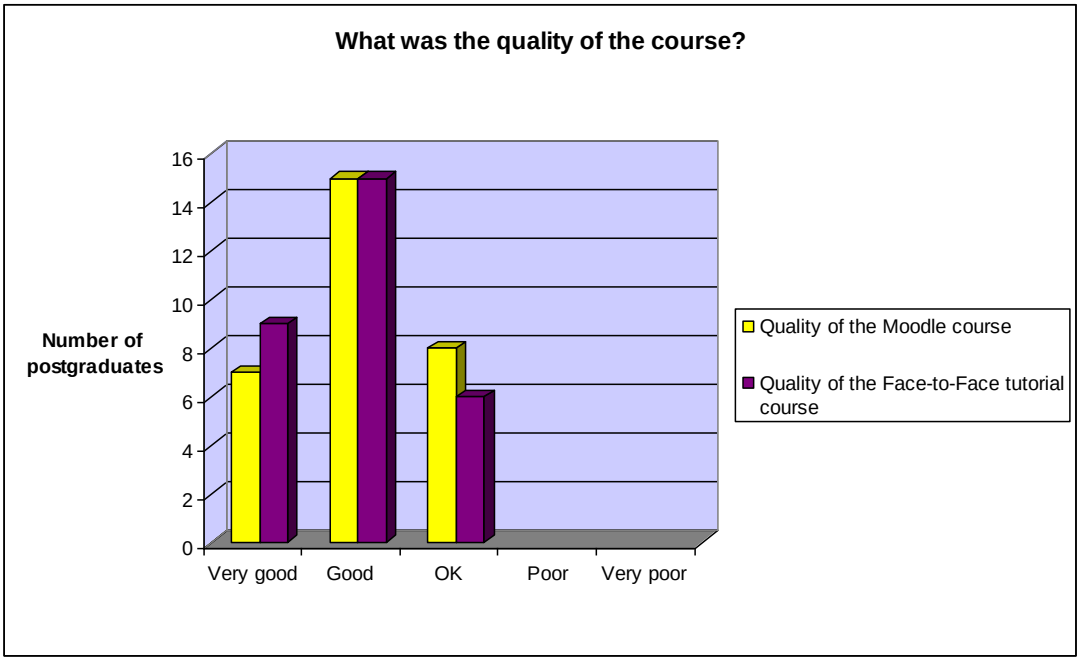
Questions 11 and 12 - How were the academic expectations?



Almost all of the postgraduates found the academic expectations of the courses to be "Appropriate".

Figure 5.9 Bar chart comparing the quality of the course

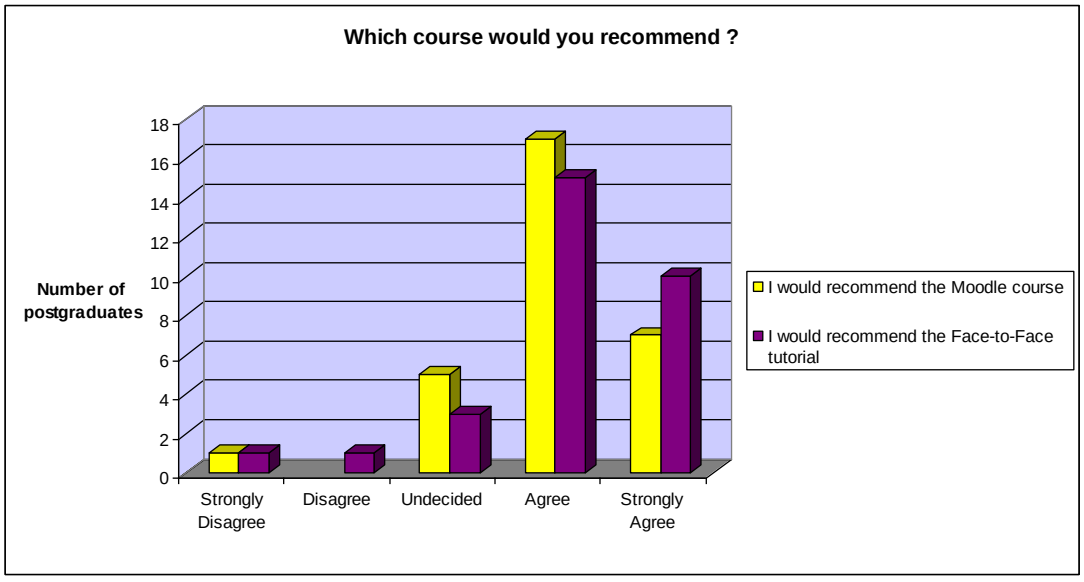
Questions 13 and 14 - What was the quality of the course?



On the whole the quality of both courses was regarded as "Good" or "Very good" and none of postgraduates considered the level to be either "Poor" or "Very poor".

Figure 5.10 Bar chart comparing course recommendations

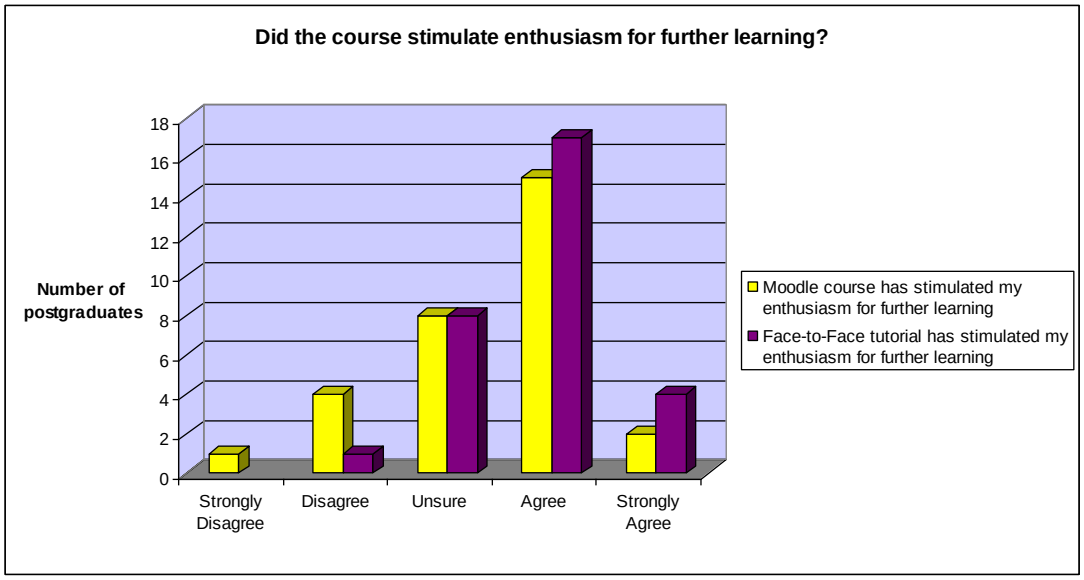
Questions 15 and 16 - Which course would you recommend?



When asked which course they would recommend 16 postgraduates said they would recommend the Moodle tutorial compared with the 14 for the face-to-face seminar. There were however a few negative responses and 9 postgraduates "Strongly disagreed, disagreed or were “Undecided" on which course they would recommend the course to others.

Figure 5.11 Bar chart comparing whether the course stimulated the postgraduates interest for further learning

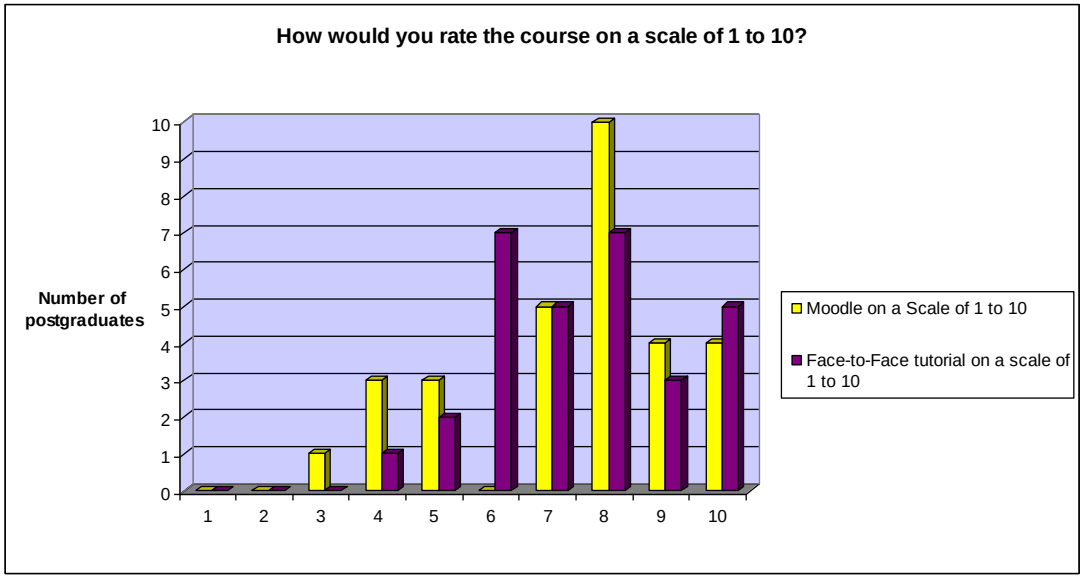
Questions 17 and 18 - Did the course stimulate interest for further learning?



This statement elicited mixed responses from the postgraduates. Although the majority "Agreed" that the courses stimulated their enthusiasm for further learning, 16 postgraduates were unsure about this, and 6 postgraduates either "Disagreed" or "Strongly disagreed".

Figure 5.12 Bar chart comparing the rating of both courses on a scale of 1 to 10

Question 19- How would you rate the Moodle tutorial/Face-to-face seminar on a scale of 1-10?



The rating values for both the two courses given by the postgraduates were varied. Although none of the postgraduates gave the courses very low ratings (1 and 2), a few considered the course less than favourably, with 7 postgraduates giving the Moodle tutorial and 4 postgraduates giving the face-to-face seminar a rating ≤ 5. In contrast, 18 postgraduates rated the Moodle tutorial very highly giving scores of ≥ 8, and 15 postgraduates gave the face-to-face seminar similar scores. The mean rating score for both the two courses was 7.4.

Table 5.13 Comments provided by postgraduates regarding the Moodle and Face-to-face seminar

Question 20 - What aspect of the course was most valuable/enjoyable?

	Comments
Moodle	*With the Moodle tutorial you can replay the examination, and repeat things that are not clear…..*
	You can stop and rewind to take notes
	More convenient and accessible
	I liked Moodle because you can go back to it again and again,
	I can take my time and do the course at my own convenience, also can go backwards and forwards over parts
	You can replay parts you miss
	Moodle was easier to understand and remember because it felt like doing something fun… like watching a movie.
	I could go back and reread and take notes
	Information is present to revise and re-watch at anytime
	You can watch it over and over again
	You can go through the teaching at anytime

	Comments
Face- to- Face	*Found it difficult to concentrate during the Moodle tutorial*
	Face-to-face teaching is more interesting and more engaging
	Real life is easier to understand
	Easier to follow and easier to understand
	Easier to understand
	Ability to ask questions and probably easier to retain information with person to person interaction
	Having a real patient in the face to face
	Moodle tutorial was too impersonal
	I enjoyed the ability to ask questions
	Can ask direct questions at the time to clarify things
	More motivating as you can ask questions

Question 21- If you could choose one course to enrol on which would it be?

Sixteen postgraduates choose the Moodle tutorial, compared with the fourteen postgraduates who choose the face-to-face seminar.

5.4 Discussion:

5.4.1 Developing the Moodle tutorial

Although the TMJ Information Course was developed in the Orthodontic Department of UCL Eastman Dental Institute, the topic is relevant to many disciplines including Prosthodontics, Oral Surgery and Facial Pain. As such it is a useful learning tool for many graduates and undergraduates. As the responsibility for providing this teaching is shared amongst the various departments, it can sometimes be overlooked. Creating this course module provides a central point for students to access the information.

There are undoubtedly many benefits associated with providing teaching modules on a VLE platform, however, the development stage of this study highlighted certain difficulties and drawbacks. Some postgraduates wanting to access the course from their home had log-in difficulties associated with the universities networking capabilities. In addition some experienced web-browser incompatibilities especially with respect to watching the TMJ examination video. Individual's internet band-width also affected their ability to efficiently complete the course and should a student experience any number of the above problems they are less likely to persevere and log-on again.

For the Moodle tutorial, it was possible to track user activity and identify the elements a student had completed, however it was not possible to determine the length of time each student spent on the content. Thus if a student skimmed through a tutorial or read it in-depth the projected usage would be the same. Nonetheless, traditional teaching methods do not overcome this obstacle, and even in a lecture, it is highly likely that some of those present may be preoccupied elsewhere.

The Moodle course incorporated a discussion board and forum for users to discuss the topic with each other and to provide interactivity between the students and the tutor. Unfortunately, however, this feature of Moodle was underutilised in this study.

5.4.2 Cross-over trial

By carrying out the cross-over trial it was hoped to determine how the two groups of postgraduates responded to the different methods of teaching, specifically with regards to the skills gained and the accuracy of their examination procedure and diagnosis. Thus establishing whether placing lectures and videos on a VLE could be as effective as training students for clinical procedures with face-to-face teaching, and whether this could be used to replace practical demonstrations when necessary.

Ideally baseline assessment results would have been obtained for the postgraduates prior to their enrolment onto either modes of teaching. In depth discussions went into the methodology of this trial and it was decided that in this cross-over trial it would not be feasible. The practicality of recruitment of the postgraduates for three phases of assessments was not possible due to the academic commitments of the postgraduates, time constraints and "fatigue" of the postgraduates and volunteers. In addition obtaining baseline assessments may influence future results, as the postgraduates would know what to expect in subsequent assessments. As such it was decided not to undertake baseline assessments.

Assessment results after first teaching episode (Tables 5.4 and 5.8)

The assessment results showed no significant difference in how well the postgraduates performed for each of the 29 procedures (Table 5.4). For ease of comparison the results of the individual procedures were also summed into the four main themes but, again, no significant differences were found between the performance of the Group 1 and 2 postgraduates. This indicated that both are equally effective educational tools (Table 5.8). Finally when the sum of all the themes was compared for Groups 1 and 2 (Table 5.8), no significant difference was observed, thus reinforcing previous findings.

Both modes of teaching was equally effective at delivering the information to the postgraduates and it appeared that both groups of postgraduates acquired similar skill sets in conducting a TMJ examination. With respect to diagnosis, 60.6% of the postgraduates in Group 1 and 73.3% in Group 2 accurately diagnosed the patient's condition, but this difference was not found to be statistically significant (P=0.439). As such the type of teaching the postgraduates received did not appear to influence their

ability to diagnose temporomandibular joint disorders. Others looking at the effectiveness of web based learning have come to the same conclusion. A study by Fordis *et al*. (2005) examined whether an internet based continuing medical education (CME) module could produce comparable changes (with respect to physicians' knowledge and behaviours that have an impact on patient care) as a "live", small group, interactive CME workshop. They found that online CME produced objectively measured changes in the behaviour of the physicians, as well as sustained gains in their knowledge that were comparable with those realised from the " live" CME group.

Second Assessment - after the cross over and second teaching episode (Tables 5.5 and 5.9)

After the cross-over and second episode of teaching, the postgraduates were assessed again and the results of each procedure were independently analysed as reported previously. There was no significant difference between the two groups and the findings were replicated when the procedures were grouped into four themes. Based on these results, it can be deduced that even after the cross-over both teaching modalities were equally effective and there were no significant differences in the marks postgraduates gained, and thus in the skills acquired. In addition, both groups of postgraduates performed equally well in the diagnosis of TMD (80% diagnosed the TMJ condition accurately in both groups).

It does not appear that the order in which the postgraduates had received the teaching made a difference, whether a student had Moodle followed by a face-to-face seminar or a face-to-face seminar followed by Moodle, the postgraduates performed similarly. It is clear that the ability of e-learning to promote educational objectives can be considerable, it has to be borne in mind however that quality e-learning is not only about exploiting computer power. The e-learning must include educational expertise and an awareness of the strength and limitations of this method of teaching (Eaton and Reynolds, 2008). Thus provided it is well designed and executed, online or web based courses can be equally effective in conveying information, and influencing changes to practice (Fordis *et al*., 2005).

Group 1- comparison of first and second assessments (Moodle followed by face-to-face) (Table 5.6 and 5.10)

The results of the Group 1 postgraduates were compared before and after the cross-over. When the analyses were conducted on the individual procedures, no significant differences were seen between the two assessments, although there was a definite trend for the marks to improve at the second assessment. When the procedures were grouped into 4 themes and the analyses repeated, a significant difference was found for three of the themes (Jaw Movements, Muscle Symptoms and Occlusal Features) with the postgraduates' performance improving at the second assessment (Table 5.10). The fourth theme (Joint Symptoms) showed a borderline significant improvement at the second assessment. When all 29 procedures were combined and compared between assessments, postgraduates were found to have higher marks at the second assessment and this was highly significant for three of the themes (Jaw Movements, Muscle Symptoms and Occlusal Symptoms). As such although Moodle or face-to-face teaching may be equally effective, having the teaching twice reinforces knowledge and there was a significant improvement in performance at the second assessment.

Group 2- comparison of first and second assessments (face-to-face followed by Moodle) (Tables 5.7 and 5.11)

As for the Group 1 findings, no significant difference were observed between the two assessments when the 29 procedures were looked at independently, although again there was a trend for the postgraduates to improve at the second assessment. When the results were grouped into four themes, a significant difference was seen for two of the themes (Joint Symptoms and Occlusal Features), whilst no significant differences were found in the remaining two themes (Jaw Movements and Muscle Symptoms). However, there was an obvious improvement at the second assessment even though it did not reach statistical significance. This finding may be due to the relatively small sample sizes in this trial and warrants further investigation.

When all 29 procedures were compared, a highly significant improvement was found at the second assessment (Table 5.11). Thus receiving the teaching twice improved the results and the performance of the postgraduates on the basis of their assessments Moodle and face-to-face teaching combined therefore appears to be better than either on its own and the order of teaching does not appear to make a difference.

Overall findings

To confirm the effectiveness of further teaching on the performance of the postgraduates, the total results of all the postgraduates were compared between the first and second assessments (Table 5.12). A highly significant difference was found in the results, with postgraduates attaining higher marks at the second. This is in line with what may be expected educationally.

There is always the possibility that postgraduates performed better the second time because they knew what to expect. Assessments are used by many instructors and organisations to improve the learning process and diagnostic assessments can direct students to suitable learning practices, stimulating attention and retrieval processes (Shepard and Godwin, 2004).

Repetition is a common pedagogy technique which helps to stimulate the memory. Repeating an encounter motivates awareness and the learning process is one of slow engagement, gradually building to the acquisition of an idea. Repetition can hasten and deepen the engagement process, thus for quality learning one should consciously design repetitive engagement into courses and daily teaching (Bruner, 2001).

Repeated teaching of the same topic is more effective than teaching a topic once and it is not uncommon in educational environments to provide revision lectures and tutorials. Having a lecture or other form of teaching on a VLE can be considered an invaluable educational tool, as it provides the resources for revision, and refreshing of knowledge without the need to schedule a live lecture, thus more efficient use of academics time.

5.4.3 Feedback

The questionnaire provided valuable feedback on different aspects of the courses, along with a gauge to assess the postgraduates' receptiveness to online learning. A number of dimensions were explored including:

1. Ease of use
2. Interest

3. Motivation
4. Skills gained
5. Adequate information
6. Academic expectation
7. Quality
8. Stimulated interest for further learning

In addition the postgraduates' preference was determined by asking three questions:

1. Would they recommend the course?
2. How would they rate the course on a scale of 1- 10?
3. If given one option which would they prefer?

An important place to begin discussing the findings is looking at which of the two methods of teaching the postgraduates preferred. Sixteen postgraduates preferred the Moodle tutorial, whilst 14 postgraduates preferred the face-to-face seminar, thus similar opinions were observed (Question 21). When asked whether they would recommend the course, the distribution of postgraduates who would recommend the Moodle tutorial was similar to those who would recommend the face-to-face seminar and the responses were positive, with the majority answering "Agree" or" Strongly agree" (Figure 5.10). Finally when asked how the postgraduates would rate the course, 18 postgraduates gave the Moodle tutorial a ranking of 8 and above, whilst 15 postgraduates gave the face-to-face seminar a ranking of 8 and above (Figure 5.12). This reflects previous studies, which reported that VLEs received positive feedback from students (Kings College London, 2002; Thornton *et al*., 2004)

With regards to the other questions, the results indicated an even spread of responses to the questions, with the majority being of the positive nature "Agree" or "Strongly agree", "Good" or "Very Good" (Figures 5.3 to 5.9). These findings collectively indicate that both courses were well received by the postgraduates and there is certainly a place for both in dental education. Twenty two postgraduates were either unsure or disagreed that the Moodle course and face-to-face tutorial stimulated their enthusiasm for further learning (Figure 5.11). This however, may be due to the topic being perceived as a “dry subject”.

Postgraduates could theoretically be given the option of which course they enrol on and some may find online learning beneficial due to travel constraints and clinical restrictions. However, it should be noted that a study looking at VLE use in dentistry found that some peripheral trainees placed a high value on face-to-face teaching and were prepared to travel in order to attend this form of teaching to allow peer group and peer teacher interaction (Mulgrew *et al.*, 2009). Indeed students have frequently cited fear of isolation and lack of a community environment as a shortcoming of VLEs (Shah and Cunningham, 2009).

Many constructive comments were made by the postgraduates and some had recurring themes. For example "*With the Moodle tutorial you can replay the examination, and repeat things that are not clear...*" was often cited as reason postgraduates preferred Moodle. On the other hand "*I enjoyed the ability to ask questions...*" was a comment often made by the proponents of the face-to-face seminar. Based on the interpretation of the comments the following advantages were derived for both courses.
With the Moodle tutorial advantages included:

1. Postgraduates could replay sections of the video and could go back to the course at any time.
2. Convenient and accessible at anytime and anywhere.
3. It was fun approach to learning because it was novel.

Advantages of face-to face teaching included:

1. It was more interesting and more engaging.
2. Real life tutorials were seen as easier to follow.
3. There was the ability to ask direct questions.

The findings from the cross-over trial and the feedback indicated that a strong case could be made for introducing clinical lectures on a VLE platform and this form of e-learning is, in general, well perceived by the new generation of graduate students. At the same time VLEs should not completely replace traditional lectures and tutorials as these are also very well regarded by students. The solution to this conundrum is the concept of blended learning. Blended courses combine online components of study with face-to-face classroom based interaction. Ruiz *et al*. (2006) recommended the integration of e-learning into curricula using a blended learning format rather than moving entirely to

computer-based programmes. To maximise the outcomes of an educational process VLEs should be aligned with the process of the course and not the other was around. As such VLEs should be adaptable to meet a course's needs and traditional methods are still used where they are most effective, such as in some one-to-one clinical teaching scenarios (Biggs, 1999).

A recent study by Carbonaro *et al*. (2008) looked at the effects and benefits of a newly developed blended learning course for health science students and compared this with the existing face-to-face format. As with this study, the students were assigned into either of the two groups, and completed a post-course Objective Structured Clinical Examination (OSCE). The results were similar to this study and no differences were found between the two groups in achieving team process skills. Both the blended learning group and the face-to-face groups demonstrated similar post class results. Interestingly, Carbonaro *et al*. (2008) found significant differences between the groups on the perceived positive achievement of the course learning objectives and the blended learning group were more convinced that their course provided them this. The novelty of using technology in the classroom may have played a role in the positive responses (Neimiec and Walberg, 1987), and could explain the encouraging feedback received by some students in this study.

VLE based information may also prove useful and relevant to GDPs or specialists to be run alongside Continued Professional Development (CPD) courses. CPD courses provide face-to-face teaching, but participants do not usually have the opportunity for revision lectures, thus VLEs can be used as a revision tool.

5.5 Conclusion

1) There were no differences in skills gained between students who were enrolled in the seminar and those who learned through a VLE tutorial, with regards to accuracy in TMJ examination and diagnosis.
2) Students had positive perceptions of VLE learning, and the feedback regarding this mode of teaching was comparable with the more traditional method of teaching (seminar).
3) VLEs are suitable for delivering clinical/practical demonstration concepts. They may also be particularly useful as a follow-up or revision tool, for example alongside CPD courses in order to reinforce the information at a later stage.

Blended learning and the incorporation of on-line learning into medical and dental education certainly appears to be the way forward. This is highlighted by the numerous institutions that have adopted this approach over the last decade (Ellaway *et al.,* 2003; Mulgrew *et al.,* 2009). The uptake of information and the skills that are attained by students are comparable to those expected from traditional teaching methods. There are the added benefits of easy access "anytime, anywhere" and the conservation of academic resources in what is already an overwhelmed profession. Provided courses are appropriately designed they can be instrumental in encouraging effective learning.

Appendix I

Appendix 1- Data abstraction forms

Data abstraction form: Full-text article ver1.0 15/03/06

Temporomandibular Joint Dysfunction in Orthognathic Surgery Patients

Reviewer: _____

Date : ___/___/___

Title: (First 5 words) _____

First author: _____

Journal: _____

Year____ Volume____ Pages____

Details of unpublished studies/ Conference proceedings etc.

Source/Meeting: _____

Title: _____

Authors: _____

Date: _____

☐ **STUDY ACCEPTED** ☐ **STUDY REJECTED**

Reasons for rejection

_____

_____

_____

_____

_____

Verification of Study Eligibility

	Yes	No	Unclear
1. Is it a randomised controlled trial, cohort study or case-control study?	☐	☐	☐
2. Have the patients undergone orthognathic surgery (i.e any of the following)	☐	☐	☐
Maxillary advancement			
Maxillary impaction			
Inferior repositioning of the maxilla			
Surgical maxillary expansion			
Mandibular advancement			
Mandibular set-back			
3. Has the study investigated patients with TMD?	☐	☐	☐
4. Does it include male and/or female adults over 14 years of age?	☐	☐	☐

No to any of the above rejects study

5. Does it include solely syndromic or solely cleft patients?	☐	☐	☐
6. Does it include solely individuals with a history of trauma	☐	☐	☐

Yes to any of the below rejects study

Intervention Characteristics

No of Patients_____
Ethnicity:_____
Females:_____
Males:_____
Age:_____

Control Group: □Yes □No □Not Specified
Females:_____
Males:_____

Malocclusion type:

Skeletal	Anterior-Posterior	□ Skeletal I □ Skeletal II □ Skeletal III □ Not Specified
	Vertical	□ High MMPA □ Low MMPA □ Avg MMPA □ Not Specified
	Transverse	□ Symmetry □ Asymmetry □ Not Specified

Incisal Classification
□ Cl I
□ Cl II div 1
□ Cl II div 2
□ Cl III
□ Not Specified

Type of surgical intervention:	Number	Extent of surgical moves (mm)
Maxillary advancement		
Maxillary impaction		
Inferior repositioning of the maxilla		
Surgical maxillary expansion		
Mandibular advancement		
Mandibular set-back		
Distraction osteogenisis		
Not Specified		
Other Specify:		

Types of Fixation
□ Plates
□ Screws
□ Suspension wiring
□ Intermaxillary fixation
□ Other (specify_____-)

Type of pre surgical orthodontics (tick as appropriate):

- Upper & Lower FA □
- Ortho (details not specified) □
- Upper FA only □
- Lower FA only □
- No Ortho □
- Adjunctive (e.g RME)□ (Specify_____)
- Other □

Observation Intervals:

- **T1** _____
- **T2** _____
- **T3** _____
- **T4** _____
- **T5** _____
- **T6** _____

	Yes	No	Unclear
Classification of TMD			
▪ Helkimo	□	□	□
▪ EACD	□	□	□
▪ Other_____	□	□	□

Primary Outcome Measure and Results

Time Interval of Exam:

	T1	T2	T3	T4	T5	T6
Clinical Examination						
Radiographic /Imaging						
MRI						
CT						
Cone Beam CT						
Ultrasound						
OPG						
Ceph						
PA Ceph						
Other						
Questionnaire(s)						

Patient self reported symptoms: (As reported from a questionnaire/interview)

Time Interval

		T1	T2	T3	T4	T5	T6
• Jaws stiffness/Fatigue	RHS						
	LHS						
	Not specified						
• TMJ sounds	RHS						
	LHS						
	Not specified						
• Jaw locking							
• Jaw Luxation							
• Difficulty in opening the mouth wide							
• Pain on movement of the mandible							
• Pain in face	RHS						
	LHS						
	Not specified						
• Pain in jaws	RHS						
	LHS						
	Not specified						
• Ear pain							

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• Grinding						
• Headaches						
• Other parafunction habits_____						
• Chewing difficulties						

Overall TMD symptoms

	T1	T2	T3	T4	T5	T6
No. of Patients with TMD						
Percentage of patients with TMD						
Percentaage of TMD improvement						

Clinical Observation

Time Interval

		T1	T2	T3	T4	T5	T6
Tender to palapation							
• **Lateral pole :**	**RHS**						
	LHS						
	Not Specified						
• **Inter-auricular :**	**RHS**						
	LHS						
	Not specified						
Joint noises							
• **Clicks :**	**RHS**						
	LHS						
	Not specified						
• **Crepitus:**	**RHS**						
	LHS						
	Not specified						
Range of motion							
• **Normal opening (mm)**							
• **Maximum opening (mm)**							
• **Limited opening**							
• **Lateral excursions (mm):**	**RHS**						
	LHS						

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Muscle tenderness							
• **Not specified**							
• **Temporalis:**	**RHS**						
	LHS						
	Not specified						
• **Masseter:**	**RHS**						
	LHS						
	Not specified						
• **Lateral pterygoid:**	**RHS**						
	LHS						
	Not specified						
• **Deviation on opening**							

Radiographic /Imaging findings:

	T1	T2	T3	T4	T5	T6
▪ **Disc displacement** ▪ **Condylar remodelling** ▪ **Changes within fossa** ▪ **Other _____**						

Additional primary outcomes

Quality of life/Patient centred outcomes:

Aesthetics:

Secondary Outcomes

Adverse effects:

Masticatory efficiency/ Chewing Ability:

Alternative Therapy e.g. ARPS:

Appendix 2- Quality Assessment Form

Title/Authors: _____

Selection

Study type:
□ Prospective □ Retrospective

Ethical approval reported:
□ Yes □ No

Were inclusion criteria specified?
□Yes □ No

If specified, were the inclusion criteria appropriate?
□Yes □ No

How were the subjects recruited?
□ Random sample □ Consecutive patients □ Volunteers
□ Not reported □Other_____

Were the subjects assembled at a similar point/ are groups similar at the baseline (e.g. all subjects examined pre-ortho, did all subjects enter the survey at a similar point in their disease progression)?
□Yes □ No □ Unclear

Were the groups in the study comparable on all the important confounding factors?
List of important confounding factors:

	Yes	**No**	**Not Reported**
Skeletal Form			
Age			
Gender			
TMD at starting point			
Para functional habits			
Psychogenic state			
*Others_*			

If not balanced on confounders, was there adequate adjustment for these confounding variables in the analysis?
□ ***Yes*** □***No*** □ ***Not reported***

Performance

Was the care protocol clearly defined and standardised for all subjects (i.e. all patients were subjected to the same sets of procedures prior to the intervention)?
□ ***Yes*** □***No*** □ ***Not reported*** □ ***N/A (No intervention)***

Was the exposure/intervention clearly defined (e.g. surgery type)?
□ ***Yes*** □***Not reported*** □***Unclear*** □ ***N/A (No intervention)***

Comparability of Intervention:
Is the intervention controlled for (e.g. same surgical procedures)?
□ ***Yes*** □***No*** □***Unclear*** □ ***N/A (No intervention)***

If no:
Were the subjects with different interventions grouped (e.g. Group 1 max advance, Group 2 mand advance, Group 3 max advance and mand setback?)
□ ***Yes*** □***No*** □***Unclear*** □ ***N/A (No intervention)***

Number of operators:
□ ***Single*** □***Multiple*** □***Unclear***

Measurement/outcome

Has the disease state/outcome been reliably ascertained or validated?
□ ***Yes*** □***No*** □***Unclear***

Were examiners calibrated / trained in taking measurements?
□ ***Yes*** □***No*** □***Unclear***

Number of examiners:
□ ***Single*** □***Multiple*** □***Unclear***

Was the outcome of interest clearly defined?
□ ***Yes*** □***No*** □***Unclear(defined but not in sufficient detail)***

Outcome assessment:
□ Clinical exam □Self report □ Both □Not reported

If Clinical Exam:
□ Masked
□ Unmasked
□ Unspecified

Is self reported symptoms were used, was the information provided by the patient validated against existing records?
□ ***Yes*** □***No*** □***Unclear***

Attrition
Was follow up long enough for outcomes to occur:
□ ***Yes*** □***No*** □ ***Not reported***

Was there a complete follow up (All subjects accounted for)
□ ***Yes*** □***No*** □ ***Not reported***

If no:

Were losses to follow up similar for all groups?
□ ***Yes*** □***No*** □ ***Not reported***
Were reasons for losses to follow up reported?
□ ***Yes*** □***No*** □ ***Unclear*** □ ***N/A***

If yes, (tick one):

□ Subjects lost to follow up unlikely to introduce bias.
□ Subjects lost to follow up likely to introduce bias.
□ No description of those lost

Likelihood of Bias:

	Selection	Performance	Measurement/outcome	Attrition
High				
Low				

Appendix 3- Ethical Approval

NHS
The National Hospital for Neurology and Neurosurgery
& Institute of Neurology Joint REC
(Research and Development)
1st Floor Maple House
149 Tottenham Court Road
London
W1P 9LL

Telephone: 020 7380 9940
Facsimile: 020 7380 9937

Email: suzanne.hodgson@uclh.nhs.uk

Our ref: NH/sh/05L065

15 February 2005

Dr Susan Cunningham
Senior Lecturer in Orthodontics
Department of Orthodontics
Eastman Dental Institute
256 Gray's Inn Road
London
WC1X 8LD

Dear Dr Cunningham,

Full title of study: *Factors affecting temporomandibular joint dysfunction (jaw joint problems) in patents with severe skeletal problems who are undergoing orthognathic intervention.*

REC reference number: *04/Q0512/100*

Thank you for your letter of 4th February 2005, responding to the Committee's request for further information on the above research and submitting revised documentation.

The Chair has considered the further information on behalf of the Committee.

Confirmation of ethical opinion

On behalf of the Committee, I am pleased to confirm a favourable ethical opinion for the above research on the basis described in the application form, protocol and supporting documentation as revised.

The favourable opinion applies to the research sites listed on the attached form. Confirmation of approval for other sites listed in the application will be issued as soon as local assessors have confirmed that they have no objection.

Conditions of approval

The favourable opinion is given provided that you comply with the conditions set out in the attached document. You are advised to study the conditions carefully.

Continued...

Approved documents

The final list of documents reviewed and approved by the Committee is as follows:

Document Type:	Version:	Dated:	Date Received:
Application	-	15/12/2004	16/12/2004
Investigator CV	-	15/12/2004	16/12/2004
Protocol	1	08/12/2004	16/12/2004
Copy of Questionnaire	1	08/12/2004	16/12/2004
Participant Information Sheet	2	-	07/02/2005
Participant Consent Form	1	08/12/2004	16/12/2004
Response to Request for Further Information	--	04/02/2005	07/02/2005

Management approval

The study should not commence at any NHS site until the local Principal Investigator has obtained final management approval from the R&D Department for the relevant NHS care organisation.

Membership of the Committee

The members of the Ethics Committee who were present at the meeting are listed on the attached sheet.

Notification of other bodies

The Committee Administrator will notify the research sponsor that the study has a favourable ethical opinion.

Statement of compliance

The Committee is constituted in accordance with the Governance Arrangements for Research Ethics Committees (July 2001) and complies fully with the Standard Operating Procedures for Research Ethics Committees in the UK.

REC Reference number: 04/Q0512/100 Please quote this number on all correspondence

With the Committee's best wishes for the success of this project,

Yours sincerely,

Dr Nicholas Hirsch
Chair

Enclosures *Standard approval conditions*

Site approval form (SF1)

Enclosure

Principal Investigator	Post	Research site	Site assessor	Date of favourable opinion for this site	Notes [1]
Dr Susan Cunningham	Senior Lecturer in Orthodontics	The Eastman Dental Hospital (UCLH Trust) Department of Orthodontics Eastman Dental Hospital 139 Gray's Inn Road	The National Hospital for Neurology and Neurosurgery & Institute of Neurology Joint REC	15/02/2005	

Approved by the Chair on behalf of the REC:

..... (Signature of ~~Chair~~/Administrator*)

*(*delete as applicable)*

Susanne Hodgson..... (Name)

[1] *The notes column may be used by the main REC to record the early closure or withdrawal of a site (where notified by the Chief Investigator or sponsor), the suspension of termination of the favourable opinion for an individual site, or any other relevant development. The date should be recorded.*

Appendix 4- Amendment to Ethical Approval 1

The National Hospital for Neurology and Neurosurgery & Institute of Neurology Joint REC
Research & Development
National Ethics Committee
1st Floor, Maple House
Ground Floor, Rosenheim Wing
25 Grafton Way
London
WC1E 5DB
Tel: 020 7380 9579
Fax: 020 7380 9937
Email: sasha.vandayar@uclh.nhs.uk
Website: www.uclh.nhs.uk

Dr Susan Cunningham
Senior Lecturer in Orthodontics
Department of Orthodontics, Eastman Dental Institute
256 Gray's Inn Road, London
WC1X 8LD

Our Ref: 06L 148

26 April 2006

Dear Dr Cunningham

Study title: **Factors affecting temporomandibular joint dysfunction (jaw joint problems) in patents with severe skeletal problems who are undergoing orthognathic intervention.**

REC reference: **04/Q0512/100**

Amendment number: **1**
Amendment date: **23 March 2006**

The above amendment was reviewed at the meeting of the Sub-Committee of the REC held on 20 April 2006.

Ethical opinion

The members of the Committee present gave a favourable ethical opinion of the amendment on the basis described in the notice of amendment form and supporting documentation.

In addition our Statistician commented that it would be harder to show a difference when comparing with a control group. A power calculation and details of how the comparison was to be done would have been required for a new study using this design.

Approved documents

The documents reviewed and approved at the meeting were:

Document	Version	Date
Notice of Substantial Amendment (non-CTIMPs)	1	23 March 2006
Participant Consent Form	2	23 March 2006
Protocol	2	11 April 2006

Membership of the Committee

The members of the Ethics Committee who were present at the meeting are listed on the attached sheet.

Research governance approval

All investigators and research collaborators in the NHS should notify the R&D Department for the relevant NHS care organisation of this amendment and check whether it affects research governance approval of the research.

Statement of compliance

The Committee is constituted in accordance with the Governance Arrangements for Research Ethics Committees (July 2001) and complies fully with the Standard Operating Procedures for Research Ethics Committees in the UK.

04/Q0512/100:	**Please quote this number on all correspondence**

Yours sincerely

Sasha Vandayar
Committee Co-ordinator

E-mail: Sasha.Vandayar@uclh.nhs.uk

Copy to: *R&D Department for NHS UCLH*

Enclosures *List of names and professions of members who were present at the meeting and those who submitted written comments*

University College London Hospitals NHS
NHS Foundation Trust

Version: 2
Date: 4th January 2005
Project ID: 04/Q0512/100

Eastman Dental Hospital
Orthodontic Department
256 Gray's Inn Road
London WC1X 8LD

Appointment Enquiries: 020 7915 1067/1068
Head of Department Secretary: 020 7915 1063
Departmental Secretaries: 020 7915 1160
Departmental Fax: 020 7915 1238

PATIENT INFORMATION LEAFLET

Title: Factors affecting jaw joint problems in orthognathic patients

Investigators: Dr S J Cunningham, Prof N Hunt , Miss S Al-Riyami

You are being invited to take part in a research study. Before you decide, it is important that you understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Ask us if there is anything that is not clear or if you would like more information.

The relationship between your "bite" and jaw joint pain/clicking etc. is a controversial one. It is generally believed that jaw joint problems are affected by many factors with the bite playing only a small part. A number of patients who undergo the type of treatment that has been suggested to you (orthognathic treatment) experience jaw joint problems. However we currently have very little information regarding what happens to these symptoms during and after treatment (ie. do they get better, worse or stay the same?).

Therefore this project aims to study orthognathic patients throughout their treatment and to determine what happens to any jaw joint symptoms and establish if there are any obvious explanatory factors.

We are asking all patients who are accepted for orthognathic treatment if they would be prepared to participate in the study, whether they have jaw joint problems or not. However, it is up to you to decide whether or not to take part. If you do decide to take part, you will be given this information sheet to keep and you will also be given a copy of your signed consent form. If you decide to take part you are still free to withdraw at any time, without giving a reason and this will not affect your care in any way. If you decide not to take part, this will not affect your care in any way.

If you do agree to participate, the study will involve:

- Completing a short questionnaire: *related to any jaw joint problems you may have and asking questions about how these may be affecting your "quality of life" (ie. How you feel about yourself, any restrictions on your life, work etc.)*
- A short examination: *of the jaw joint to see how you open/ close your jaw and how well you can move your jaw from side-to-side. We will also see whether there is any soreness/aching of the muscles which support your jaw joint. This examination is relatively quick and easy and does not differ greatly from the jaw joint examination undertaken routinely prior to orthodontic treatment.*
- A kinesiograph tracing: *this is a very easy procedure which shows us the range of movement of your lower jaw. The kinesiograph is a device which incorporates some sensors which "track" the position of your jaw as you open, close and move from side-to-side and this then generates a computer output or "tracing".*

This will be undertaken five times during your treatment:

- At the start of treatment
- 6-9 months into treatment
- At the end of the orthodontics and before the surgery
- When the braces are removed at the end of treatment
- 1 year following surgery

This should take about 20-30 minutes each time and we will aim to do it at the same time as one of your routine appointments.

All information that is collected about you during the course of the research will remain strictly confidential and will be available only to the investigators named on this sheet. The safety and security of the data will be the responsibility of the two principal investigators (Dr Cunningham and Prof Hunt). The data held about you will include the results of the above investigations (questionnaire, clinical examination and kinesiograph outcome) and also your age, gender (male or female), ethnicity and occupation. This information will be coded in such a way that it is completely anonymous and you can not be individually identified in any way. This data will not, under any circumstances, be passed on to anyone else outside the research team.

This study has been reviewed by the National Hospital for Neurology and Neurosurgery/Institute of Neurology Joint Research Ethics Committee. However, if you require further information please contact Dr Cunningham on 020-7915-1072.

If you would like to see a summary of the findings from the study when it is completed, please tell Dr Cunningham or any other Orthodontists involved in your treatment.

Thank you for considering taking part in the study

Appendix 6- Orthognathic patients consent form

University College London Hospitals NHS
NHS Foundation Trust

Eastman Dental Hospital
Orthodontic Department
256 Gray's Inn Road
London WC1X 8LD

Appointment Enquiries: 020 7915 1067/1068
Head of Department Secretary: 020 7915 1063
Departmental Secretaries: 020 7915 1160
Departmental Fax: 020 7915 1238

Centre Number:
UCLH Project ID number:

Patient Identification Number for this study:
Form version: 1 (8th December 2004)

CONSENT FORM

Title of project: Factors affecting jaw joint problems in orthognathic patients

Name of Principal investigators: Dr S Cunningham ,Prof N Hunt , Miss S Al Riyami

Please tick box

1. I confirm that I have read and understood the information sheet (Version 1 dated 8th December 2004) for the above study and have had the opportunity to ask questions. ☐
2. I confirm that I have had sufficient time to consider whether or not I wish to be included in the study ☐
3. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason, without my medical care or legal rights being affected. ☐
4. I understand that sections of any of my medical notes may be looked at by the researchers where it is relevant to my taking part in research. I give permission for these individuals to have access to my records. ☐
5. I agree to take part in the above study. ☐

Continued on next page

Centre Number:
Patient Identification Number for this study:

UCLH Project ID number:
Form version: 1 (8th Dec 2004)

CONSENT FORM

Title of project: Factors affecting jaw joint problems in orthognathic patients

Name of Principal investigator: Dr S Cunningham, Prof N Hunt, Miss S Al Riyami

Name of patient/parent	Date	Signature
Name of Person taking consent (if different from researcher)	Date	Signature

Dr S J Cunningham 020-7915-1072
Researcher (to be contacted if there are any problems)

Comments or concerns during the study

If you have any comments or concerns you may discuss these with the investigator. If you wish to go further and complain about any aspect of the way you have been approached or treated during the course of the study, you should write or get in touch with the Complaints Manager, UCL hospitals. Please quote the UCLH project number at the top this consent form.

1 form for patient
1 to be kept as part of the study documentation
1 to be kept with hospital notes

Appendix 7- Control group information leaflet and control consent form

University College London Hospitals NHS
NHS Foundation Trust

Eastman Dental Hospital
Orthodontic Department
256 Gray's Inn Road
London WC1X 8LD

Appointment Enquiries: 020 7915 1067/1068
Head of Department Secretary: 020 7915 1063
Departmental Secretaries: 020 7915 1160
Departmental Fax: 020 7915 1238

Version: 3
Date: 23rd March 2006
Project ID: 04/Q0412/100

CONTROL GROUP INFORMATION LEAFLET

Title: Factors affecting jaw joint problems in orthognathic patients

Investigators: Dr S J Cunningham and Miss S Al Riyami

You are being invited to take part in a research study. Before you decide, it is important that you understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Ask us if there is anything that is not clear or if you would like more information.

The relationship between your "bite" and jaw joint problems, such as soreness and clicking, is a controversial one. It is generally believed that jaw joint problems are affected by many factors, with the bite playing only a small part. These problems are relatively common and can affect any group of people. However, we currently have very little information regarding jaw joint problems in individuals with no bite problems.

This project aims to study individuals, like you, who have a normal bite and to compare the findings with those patients who have severe bite problems and need fixed braces and surgery for correction.

As such, we are asking individuals with a normal bite who DO NOT require surgery to participate in this study. We are also asking other patients who do require surgery to participate.

It is up to you to decide whether or not to take part. If you do decide to take part, you will be given this information sheet to keep and you will also be given a copy of your signed consent form. If you decide to take part you are still free to withdraw at any time, without giving a reason and this will not affect your care or legal rights in any way. If you decide not to take part, this will not affect your care or legal rights in any way.

If you do agree to participate, the study will involve:

- Completing a short questionnaire related to jaw joint problems and how this may be affect "quality of life".
- A short clinical examination of the jaw joint to see how well you open/close your jaw and how your jaw moves from side-to-side. We will also see whether there is any soreness of the jaw muscles. This examination is relatively quick and easy and does not differ greatly from a routine dental examination.
- A kinesiograph tracing: this is a very easy procedure which shows us how your lower jaw moves. The kinesiograph is a device which incorporates sensors which "track" the movement of your jaw and then feeds this information back to a computer.

These examinations will need to be undertaken once only and a convenient time can be arranged for this to be carried out. This should take about 20-30 minutes.

All information that is collected about you during the course of the research will remain strictly confidential and will be available only to the investigators named on this sheet. The safety and security of the data will be the responsibility of the two principal investigators (Dr Cunningham and Miss S Al Riyami). The data held about you will include the results of the above investigations (questionnaire, clinical examination and kinesiograph outcome) and also your age, gender (male or female), ethnicity and occupation. This information will be coded in such a way that it is completely anonymous and you can not be individually identified in any way. This data will not, under any circumstances, be passed on to anyone else outside the research team.

This study has been reviewed by the National Hospital for Neurology and Neurosurgery/Institute of Neurology Joint Research Ethics Committee. However, if you require further information please contact Dr Cunningham on 020 -7915 1064.

If you would like to see a summary of the findings from the study when it is completed, please tell Dr Cunningham or Miss S Al Riyami .

Thank you for considering taking part in the study

University College London Hospitals NHS
NHS Foundation Trust

Eastman Dental Hospital
Orthodontic Department
256 Gray's Inn Road
London WC1X 8LD

Appointment Enquiries: 020 7915 1067/1068
Head of Department Secretary: 020 7915 1063
Departmental Secretaries: 020 7915 1160
Departmental Fax: 020 7915 1238

Centre Number:
UCLH Project ID number:

Patient Identification Number for this study:
Form version: 2 (23rd March 2006)

CONSENT FORM

Title of project: Factors affecting jaw joint problems in orthognathic patients

Name of Principal Investigators: Dr S Cunningham and Miss S Al Riyami

	Please tick box
1. I confirm that I have read and understood the information sheet (Version 3 dated 23rd March 2006) for the above study and have had the opportunity to ask questions.	☐
2. I confirm that I have had sufficient time to consider whether or not I wish to be included in the study	☐
3. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason, without my medical care if applicable or legal rights being affected.	☐
4. I understand that sections of any of my medical notes(if applicable) may be looked at by the researchers where it is relevant to my taking part in research. I give permission for these individuals to have access to my records.	☐
5. I agree to take part in the above study.	☐

Centre Number:
Patient Identification Number for this study:
UCLH Project ID number:
Form version: 2 (23rd March 2006)

CONSENT FORM

Title of project: Factors affecting jaw joint problems in orthognathic patients

Name of Principal Investigator: Dr S Cunningham and Miss S Al Riyami

Name of patient/parent/participant	Date	Signature

Name of Person taking consent (if different from researcher)	Date	Signature

Dr S J Cunningham: (020) 7915-1072
Researcher (to be contacted if there are any problems)

Comments or concerns during the study

If you have any comments or concerns you may discuss these with the investigator. If you wish to go further and complain about any aspect of the way you have been approached or treated during the course of the study, you should write or get in touch with the Complaints Manager, UCL hospitals. Please quote the UCLH project number at the top this consent form.

1 form for patient
1 to be kept as part of the study documentation
1 to be kept with hospital notes

Appendix 8- TMD Questionnaire and OHIP-14

TMD QUESTIONNAIRE

Age: ☐

Gender *(please tick)*: Male ☐ Female ☐

Ethnicity *(please tick)*: White British ☐ White other ☐ Asian ☐ Oriental ☐ Black African/Afro-Caribbean ☐ Mediterranean ☐ Other ☐

Current or most recent occupation of head of household (Students: please classify parent's occupation)

☐

The following questions relate to any jaw joint symptoms which you may have had in the last 3 months.

Please indicate any symptoms that you have by ticking YES or NO. If the answer is YES, please indicate the frequency of the symptoms (ie. occasionally, frequently or all of the time).

1. **Headaches**
   Yes ☐ *Occasionally* ☐ *Frequently* ☐ *All of the time* ☐
   No ☐

2. **Earaches**
   Yes ☐ *Occasionally* ☐ *Frequently* ☐ *All of the time* ☐
   No ☐

3. **General facial pain**
   Yes ☐ *Occasionally* ☐ *Frequently* ☐ *All of the time* ☐
   No ☐

4. **Painful neck**
   Yes ☐ *Occasionally* ☐ *Frequently* ☐ *All of the time* ☐
   No ☐

5. **Jaw pain when opening or closing the jaw**

Yes ☐ *Occasionally* ☐ *Frequently* ☐ *All of the time* ☐

No ☐

6. **Jaw pain when biting or chewing**

Yes ☐ *Occasionally* ☐ *Frequently* ☐ *All of the time* ☐

No ☐

7. **Sore muscles around the jaw**

Yes ☐ *Occasionally* ☐ *Frequently* ☐ *All of the time* ☐

No ☐

8. **"Clicking" jaw (or other sounds from the jaw joint)**

Yes ☐ *Occasionally* ☐ *Frequently* ☐ *All of the time* ☐

No ☐

9. **Jaw "locks" open or closed**

Yes ☐ *Occasionally* ☐ *Frequently* ☐ *All of the time* ☐

No ☐

10. **Limited mouth opening**

Yes ☐ *Occasionally* ☐ *Frequently* ☐ *All of the time* ☐

No ☐

11. **Clenching of your teeth**

Yes ☐ *Occasionally* ☐ *Frequently* ☐ *All of the time* ☐

No ☐

12. **Grinding of your teeth**

Yes ☐ *Occasionally* ☐ *Frequently* ☐ *All of the time* ☐

No ☐

ORAL HEALTH PROFILE 14 (OHIP-14)

The following questions aim to find out how any problems with your face/ mouth affect your everyday life. Please circle the appropriate answer.

This questionnaire refers to problems you have had in the last month.

1. **Have you had trouble *pronouncing any words* because of problems with your teeth, mouth or dentures?**

0=Never 1= Hardly ever 2=Occasionally 3=Fairly often 4=Very often

2. **Have you felt that your *sense of taste* has worsened because of problems with your teeth, mouth or dentures?**

0=Never 1= Hardly ever 2=Occasionally 3=Fairly often 4=Very often

3. **Have you had *painful aching* in your mouth?**

0=Never 1= Hardly ever 2=Occasionally 3=Fairly often 4=Very often

4. **Have you found it *uncomfortable to eat any foods* because of problems with your teeth, mouth or dentures?**

0=Never 1= Hardly ever 2=Occasionally 3=Fairly often 4=Very often

5. **Have you been *self-conscious* because of your teeth, mouth or dentures?**

0=Never 1= Hardly ever 2=Occasionally 3=Fairly often 4=Very often

6. **Have you *felt tense* because of problems with your teeth, mouth or dentures?**

0=Never 1= Hardly ever 2=Occasionally 3=Fairly often 4=Very often

7. **Has your *diet been unsatisfactory* because of problems with your teeth, mouth or dentures?**

0=Never 1= Hardly ever 2=Occasionally 3=Fairly often 4=Very often

8. **Have you had to *interrupt meals* because of problems with your teeth, mouth or dentures?**

0=Never 1= Hardly ever 2=Occasionally 3=Fairly often 4=Very often

9. **Have you found it *difficult to relax* because of problems with your teeth, mouth or dentures?**

0=Never 1= Hardly ever 2=Occasionally 3=Fairly often 4=Very often

10. **Have you been a bit *embarrassed* because of problems with your teeth, mouth or dentures?**

0=Never 1= Hardly ever 2=Occasionally 3=Fairly often 4=Very often

11. **Have you been a bit *irritable with other people* because of problems with your teeth, mouth or dentures?**

0=Never 1= Hardly ever 2=Occasionally 3=Fairly often 4=Very often

12. **Have you had *difficulty doing your usual jobs* because of problems with your teeth, mouth or dentures?**

0=Never 1= Hardly ever 2=Occasionally 3=Fairly often 4=Very often

13. **Have you felt that life in general was *less satisfying* because of problems with your teeth, mouth or dentures?**

0=Never 1= Hardly ever 2=Occasionally 3=Fairly often 4=Very often

14. **Have you been *totally unable to function* because of problems with your teeth, mouth or dentures?**

0=Never 1= Hardly ever 2=Occasionally 3=Fairly often 4=Very often

Appendix 10- TMJ examination form

Patient identification number:

Date:

1. TMJ EXAMINATION
(Yes = √)

A. Tenderness on palpation

		R	L
(i)	Lateral		
(ii)	Intra-auricular		

B. Joint sounds

	R	L
Click		
Soft / Loud		
Consistent/Intermittent		
Opening/Closing/Both		
Early/ Mid / Late		
Painful/ Painless		
Single/Multiple		
Crepitus		
Painful / Painless		

C. Range of motion (mm):

Comfortable opening	**mm**	
Maximum opening	**mm**	
	R	**L**

Lateral	**mm**	**mm**
Overbite	**mm**	

D. Pathway of opening: (tick as appropriate)

Straight	
Lasting Deviation	**To LHS** **To RHS**
Transient Deviation	**To LHS** **To RHS**

2. MUSCLE EXAMINATION (Tenderness = √)

	R	**L**
Medial pterygoid		
Lateral pterygoid		
Origin of masseter		
Insertion of masseter		
Origin of temporalis		
Temporalis tendon		

3. OCCLUSION

Skeletal base (tick)	**I**	**II**	**III**
Angle's classification			
Are CO and CR coincident (tick)	**Yes**	**No** **If no, where is the first contact** **If no, what is the direction of the slide (tick)** Forward Left Right	
Canine guidance or group function	**R** CG GF	**L** CG GF	
Evidence of excessive wear	**Yes**	**No**	
Cheek ridging	**Yes**	**No**	
Tongue Scalloping	**Yes**	**No**	

Appendix 11- RDC/TMD Classification

Adapted from Manchester University Dental School (Davies *et al.*, 2005)

RDC/TMD Classification of Temporomandibular Disorders

1992 Original Paper: Research Diagnostic Criteria (LeResche and Dworkin)

2002 Approved by European Academy of Craniomandibular Disorders

•**Axis 1:** A set of operationalised research diagnostic criteria for use in evaluating and investigating masticatory muscle pain, disc displacements and degenerative diseases of the TMJ.

•**Axis 2:** A set of operational research diagnostic criteria to assess chronic pain, dysfunction, depression, non-specific physical symptoms, and orofacial disability.

Axis 1: Clinical TMD Conditions

Group 1: Muscle Disorders

1a Myofascial Pain

1. Report of pain or ache in the jaw, temples, face,preauricular area, or inside the ear at rest or during function; plus
2. Pain on palpation of three or more of the following muscle sites (right and left count as separate sites)

posterior, middle, or anterior temporalis, tendon of temporalis.

•origin, body, or insertion of masseter posterior mandibular region, submandibular region.

•lateral pterygoid area (using resisted movement test).

•At least one of the sites must be on the same side as the complaint of pain.

1b Myofascial Pain with Limited Opening

1. Myofascial pain as defined in 1a; plus
2. Comfortable (pain free) unassisted mandibular opening of less than 40mm inter-incisal; plus
3. Maximum assisted opening (passive stretch) of 5 or more mm greater than pain free unassisted opening (2)

Group 2: Disc Displacements

2a Disc Displacement with Reduction

•The articular disc is displaced from its position between the condyle and the eminence, to an anterior and medial or lateral position, but reduces on full opening, usually resulting in a noise (click).

Either: (a) Reciprocal clicking in TMJ reproducible on two of three consecutive trials; or (b) Click in TMJ on opening or closing, reproducible on two of three consecutive trials, and click during lateral excursion or protrusion, reproducible on two of three consecutive trials.

2b Disc Displacement Without Reduction, With Limited Opening (Lock)

•A condition in which the articular disc is displaced from its normal position between the condyle and the fossa to an anterior and medial or lateral position, associated with limited mandibular opening.

1.History of significant limitation in opening; plus

2.Maximum unassisted opening less than 35mm; plus

3.Passive stretch increases opening by 4mm or less over maximum unassisted opening.

4.Contralateral excursion less than 7mm and/or uncorrected deviation to the ipsilateral side on opening; plus

5.Either: (a) absence of joint sounds, or (b) presence of joint sounds not meeting criteria for disc displacement with reduction.

2c Disc Displacement Without Reduction, Without Limited Opening

•A condition in which the articular disc is displaced from its normal position between the condyle and the fossa to an anterior and medial or lateral position, not associated with limited mandibular opening.

1.History of significant limited opening plus

2. Maximum unassisted opening more than 35mm; plus

3. Passive stretch increases opening by 5mm or more over maximum unassisted opening.

4. Contralateral excursion more than 7mm; plus

5. Presence of joint sounds not meeting criteria for disc displacement with reduction

6. Imaging – Arthrogram or MRI reveals anterior displacement without reduction.

Group 3: Arthralgia, Arthritis, Arthrosis

3a Arthralgia: Pain and tenderness in the joint capsule and/or the synovial lining of the TMJ.

•Pain in one or both joint sites (lateral pole and/or posterior attachment) during palpation; plus one or more of the following self-reports of pain: pain in the region of the joint, pain in the joint during maximum unassisted opening, pain in the joint during assisted opening, pain in the joint during lateral excursion. For a diagnosis of simple arthralgia, coarse crepitation must be absent.

3b Arthritis: Inflammatory condition within the joint that results from a degenerative condition of the joint structures

1. Arthralgia; plus
2. Either a or b (or both)

a. Coarse crepitus in the joint

b. Imaging – Tomograms show one or more of the following: erosion of normal cortical delineation, sclerosis of parts or all of the condyle and articular eminence, flattening of joint surfaces, osteophyte formation.

3c Arthrosis: Degenerative disorder of the joint in which joint form and structure are abnormal.

1. Absence of all signs of arthralgia, plus
2. Either a or b (or both)

a.Coarse crepitus in the joint.

b.Imaging – Tomograms show one or more of the following: erosion of normal cortical delineation, sclerosis of parts or all of the condyle and articular eminence, flattening of joint surfaces, osteophyte formation.

Appendix 12- Amendment to Ethical Approval 2

The National Hospital for Neurology and Neurosurgery & Institute of Neurology Joint REC
Research & Development
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30 Guilford Street
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WC1N 1EH
Tel: 020 7905 2703
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Email: S.Vandayar@ich.ucl.ac.uk
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Dr Susan Cunningham
Senior Lecturer in Orthodontics
Department of Orthodontics, Eastman Dental Institute
256 Gray's Inn Road, London
WC1X 8LD
Our Ref: 09L 007

22 January 2009

Dear Dr Cunningham

Study title: **Factors affecting temporomandibular joint dysfunction (jaw joint problems) in patients with severe skeletal problems who are undergoing orthognathic intervention.**
REC reference: **04/Q0512/100**
Amendment number:
Amendment date: **18 December 2008**

The above amendment was reviewed at the meeting of the Sub-Committee of the REC held on 22 January 2009.

Ethical opinion

The members of the Committee present gave a favourable ethical opinion of the amendment on the basis described in the notice of amendment form and supporting documentation.

Approved documents

The documents reviewed and approved at the meeting were:

Document	Version	Date	
Protocol	2	11 April 2006	
Follow up invitation	1	14 December 2008	
Notice of Substantial Amendment (non-CTIMPs)	2	18 December 2008	
Covering Letter	1	18 December 2008	

Membership of the Committee

The members of the Committee who were present at the meeting are listed on the attached sheet.

R&D approval

All investigators and research collaborators in the NHS should notify the R&D office for the relevant NHS care organisation of this amendment and check whether it affects R&D approval of the research.

Statement of compliance

The Committee is constituted in accordance with the Governance Arrangements for Research Ethics Committees (July 2001) and complies fully with the Standard Operating Procedures for Research Ethics Committees in the UK.

04/Q0512/100:	**Please quote this number on all correspondence**

Yours sincerely

Miss Sasha Vandayar
Committee Co-ordinator

E-mail: S.Vandayar@ich.ucl.ac.uk

Enclosures — List of names and professions of members who were present at the meeting.

Copy to: *UCLH NHS Trust*

The National Hospital for Neurology and Neurosurgery & Institute of Neurology Joint REC

Attendance at Sub-Committee of the REC meeting on 22 January 2009

Dr Yogi Amin	Chair
Dr Lorraine Ludman	Vice Chair

Appendix 13- TMD assessment checklist

Assessment Checklist: TMD Examination

Operator: Date:
Assessor:

Item	N/A	Done Correctly	Incorrect	Unclear
1. Correct application of force				
2. Lateral Palpation				
3. Inter-auricular palpation				
4. Click Present: Yes No				
5. Classification of Click				
6. Crepitus Present: Yes No				
7. Measurement of comfortable opening				
8. Measurement of maximal opening				
9. Measurement of right lateral excursion				
10. Measurement of left lateral excursion				
11. Recognition of path of opening				
12. Lateral pterygoid palpation				
13. Recognition of Lateral Pterygoid tenderness				
14. Mesial pterygoid palpation				
15. Recognition of Mesial Pterygoid tenderness				
16. Temporalis Palpation				
17. Recognition of Temporalis tenderness				
18. Masseter palpation				
19. Recognition of Masseter tenderness				
20. Skeletal base assessment				
21. Angle classification assessment				
22. CO-CR identified				
23. Direction of the slide				
24. Assessment of canine guidance/ group function				
25. Assessment of tooth wear				
26. Assessment of cheek ridging				
27. Assessment of tongue scalloping				
28. Followed correct sequence				
29. Diagnosis				

Appendix 14- TMD feedback questionnaire

TMD COURSE EVALUATION

Please rate the following aspects of the course, using a scale from 1 to 5 where:
1 = Strongly Disagree and 5 = Strongly Agree

Write your **comments** in the space provided, continuing on the other side of the page if you need more space.

Please **circle** your chosen response:

1. The Moodle TMD course was easy to use

Strongly Disagree	*Disagree*	*Unsure*	*Agree*	*Strongly Agree*
1	2	3	4	5

Comment:

2. The face to face tutorial was easy to follow

Strongly Disagree	*Disagree*	*Unsure*	*Agree*	*Strongly Agree*
1	2	3	4	5

Comment:

3. I found the Moodle course interesting

Strongly Disagree	*Disagree*	*Unsure*	*Agree*	*Strongly Agree*
1	2	3	4	5

Comment:

4. I found the face to face tutorial interesting

Strongly Disagree	*Disagree*	*Unsure*	*Agree*	*Strongly Agree*
1	2	3	4	5

Comment:

5. I found the Moodle course motivating

Strongly Disagree	*Disagree*	*Unsure*	*Agree*	*Strongly Agree*
1	2	3	4	5

Comment:

1

6. I found the face to face tutorial motivating

Strongly Disagree	*Disagree*	*Unsure*	*Agree*	*Strongly Agree*
1	2	3	4	5

Comment:

7. The Moodle course helped to develop my skills in TMJ examinations

Strongly Disagree	*Disagree*	*Unsure*	*Agree*	*Strongly Agree*
1	2	3	4	5

Comment:

8. The face to face tutorial helped to develop my skills in TMJ examinations

Strongly Disagree	*Disagree*	*Unsure*	*Agree*	*Strongly Agree*
1	2	3	4	5

Comment:

9. The content of the Moodle course gave adequate information

Strongly Disagree	*Disagree*	*Unsure*	*Agree*	*Strongly Agree*
1	2	3	4	5

Comment:

10. The content of the face to face tutorial gave adequate information

Strongly Disagree	*Disagree*	*Unsure*	*Agree*	*Strongly Agree*
1	2	3	4	5

Comment:

11. The academic expectations of me on the Moodle course were acceptable

Far too high	*Too high*	*Appropriate*	*Too low*	*Far too low*
1	2	3	4	5

Comment:

12. The academic expectations of me on the face to face tutorial were acceptable

Far too high	*Too high*	*Appropriate*	*Too low*	*Far too low*
1	2	3	4	5

Comment

13. Overall, the quality of the Moodle course was:

Very good	*Good*	*Ok*	*Poor*	*Very Poor*
1	2	3	4	5

Comment:

14. Overall, the quality of the face to face tutorial was:

Very good	*Good*	*Ok*	*Poor*	*Very Poor*
1	2	3	4	5

Comment:

15. I would recommend the Moodle course to others

Strongly Disagree	*Disagree*	*Undecided*	*Agree*	*Strongly Agree*
1	2	3	4	5

Comment:

16. I would recommend the face to face tutorial to others

Strongly Disagree	*Disagree*	*Undecided*	*Agree*	*Strongly Agree*
1	2	3	4	5

Comment:

17. The Moodle course has stimulated my enthusiasm for further learning

Strongly Disagree	*Disagree*	*Unsure*	*Agree*	*Strongly Agree*
1	2	3	4	5

Comment:

18. The Face to face tutorial has stimulated my enthusiasm for further learning

Strongly Disagree	*Disagree*	*Unsure*	*Agree*	*Strongly Agree*
1	2	3	4	5

Comment:

19. On a scale of 1- 10 how would you rate the: (please circle as appropriate 1=Excellent, 10=Poor)

Moodle course	1	2	3	4	5	6	7	8	9	10
Face to face tutorial	1	2	3	4	5	6	7	8	9	10

20. What aspect of the course was most valuable/enjoyable ?

21. If you could choose one course to enroll on for TMJ teaching which would it be? (please tick √)

☐ **Moodle course** ☐ **Face to face tutorial**

Why? (please provide comments)

Thank you for your consideration !

Appendix II

Publications resulting from this research

ONLINE ONLY

Orthognathic treatment and temporomandibular disorders: A systematic review. Part 1. A new quality-assessment technique and analysis of study characteristics and classifications

Salma Al-Riyami,[a] David R. Moles,[b] and Susan J. Cunningham[c]
London, United Kingdom

Introduction: Orthognathic treatment is undertaken to correct jaw discrepancies and involves a combination of orthodontics and surgery. The effects of orthodontic treatment on temporomandibular disorders (TMD) have been widely debated in the literature, but fewer studies focus on the effects of orthognathic treatment on TMD. **Methods:** A systematic review was conducted to (1) determine the percentage of orthognathic patients with signs or symptoms of TMD, (2) establish the range of signs or symptoms, and (3) examine studies that followed patients longitudinally through treatment to determine the effect of orthognathic intervention on TMD symptoms. **Results:** Of 480 identified articles, 53 were eligible for inclusion in this review. Part 1 of this 2-part article describes the methodology of conducting this review, the difficulties encountered (including the quality-assessment issues), and a narrative analysis of study characteristics and classification methods. Part 2 reports the remaining results, evidence tables, and meta-analyses. **Conclusions:** The diversity of diagnostic criteria and classification methods used in the included studies makes interstudy comparisons difficult. There is a definitive need for well-designed studies with standardized diagnostic criteria and classification methods for TMD. (Am J Orthod Dentofacial Orthop 2009;136:624.e1-624.e15)

Temporomandibular joint disorders (TMD) can be defined as multifactorial disturbances of the masticatory system.[1] Luther[2] used the term TMD to signify the variety of symptoms and signs assigned to the temporomandibular joint (TMJ) and its related structures. Van der Weele and Dibbets[3] commented that "many different definitions of TMJ dysfunction have come into existence and consequently, even in a single individual the diagnosis of TMJ dysfunction depends on the definition used." Thus, it is apparent that clinicians cannot agree on a precise definition.

TMD patients frequently experience the following: (1) painful symptoms such as headaches, facial pain, pain in the jaw joints or on jaw movement, ear pain, and neck pain; (2) dysfunctional signs such as limited jaw movement, jaw deviations, clicking, jaw locks, and dislocation; (3) dental destruction, traumatic occlusion, and wear of the dentition; and (4) parafunctional habits such as clenching and grinding.

TMD is believed to be multifactorial, with occlusion playing only a minor part. McNamara et al[4] estimated the contribution of occlusal factors to the characterization of TMD as approximately 10% to 20%, based on a review of relevant literature. This, however, does not imply a cause-and-effect relationship. Other potential etiological factors include trauma, systemic diseases, habits, posture, psychosocial factors, stress, and bruxism. Little is known about the precise etiology and mechanisms of action of the condition, and, since disagreement is still evident about the diagnosis and classification of the various subtypes of TMD, this inevitably impacts on research in this field.

It should be no surprise that TMD, and its relevance to dentistry, has been a highly debated topic in recent years.[5] To this end, conflict arises in the dental community when views are expressed about topics such as condyle position, malocclusion, orthodontic treatment, and TMD.

The evidence in the literature as to whether malocclusion causes TMD is conflicting. Proffit[6] stated, "the prevalence of TMD in the population is between 5% and 30%, which is less than the number of people

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The authors report no commercial, proprietary, or financial interest in the products or companies described in this article.
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Submitted, October 2008; revised and accepted, February 2009.
0889-5406/$36.00

doi:10.1016/j.ajodo.2009.02.021

with moderate degrees of malocclusion (50% to 75%). It seems unlikely that occlusal patterns alone are enough to cause TMD.[6] However, some studies have found that certain malocclusions (Class III, deep bites, and anterior open bites) are correlated with symptoms of TMD.[7,8]

There is also much controversy over the relationship between orthodontic treatment and TMD; orthodontists are divided over this. Changes in the occurrence and resolution of joint sounds and muscle pain have been studied in patients before and after orthodontic treatment with fixed appliances.[9-11] These studies concluded that orthodontic treatment seems to be neither a major preventive nor a significant cause of TMD.

Orthognathic treatment is undertaken to correct skeletal discrepancies and involves a combination of orthodontics and surgery. There is a lack of consistency of methods and outcomes in the published research about the association between major skeletal disharmonies and their potential effect on TMD. If the relevance of TMD to orthognathic treatment is considered, the viewpoints expressed include that orthognathic intervention might resolve or induce TMD, or have no effect. The studies described below are examples of the differing viewpoints.

Wolford et al[12] undertook a retrospective study of 25 patients with preexisting TMD who had undergone orthognathic surgery. They concluded that orthognathic patients can experience worsening of their condition postoperatively. In contrast, White and Dolwick[13] assessed 75 patients, of whom 49% had preoperative TMD symptoms. They found that, of those with symptoms, 89.1% showed improvement, whereas 10.8% either had increased symptoms postsurgery or remained the same. Since the influence of orthognathic surgery on TMD is unclear, there is a definite need for further investigations evaluating TMD in patients having orthognathic interventions.

The purposes of this systematic review were to (1) investigate the percentage of orthognathic patients affected by TMD, (2) establish signs or symptoms, and (3) examine studies that followed patients longitudinally during treatment to determine how the intervention to correct the skeletal discrepancy affected TMD symptoms.

MATERIAL AND METHODS

The initial stage included development of the following the focused questions.

1. In patients undergoing orthognathic treatment to correct dentofacial deformities, what percentage also have TMD?
2. What proportion of orthognathic patients who do not have signs or symptoms of TMD preoperatively develop TMD signs or symptoms postsurgery?
3. In patients who have signs or symptoms of TMD preoperatively, how do these signs or symptoms change after treatment?

The following studies were considered for inclusion.

1. Randomized controlled trials (RCTs). Because of logistical and ethical considerations, it was expected that few, if any, RCTs would be available in this area.
2. Cohort studies. These were included if there were at least 10 patients in the study. This criterion was applied to distinguish between genuine cohorts and case series.
3. Case-control studies. These studies were used to identify factors that might contribute to TMD by comparing patients with control subjects.

Studies were included if the subjects were male or female patients (14 years or over) of any ethnicity who had received orthognathic treatment. Studies were excluded if they included subjects (1) with craniofacial syndromes or cleft lip or palate; (2) with a history of facial fractures from trauma; (3) undergoing orthognathic surgery purely to correct TMD; (4) who had orthognathic treatment and concomitant joint disc surgery; and (5) that were animal.

Studies were included if they included subjects having orthognathic treatment to correct severe jaw discrepancies, such as (1) maxillary advancement, (2) superior repositioning (impaction) of the maxilla, (3) inferior repositioning of the maxilla, (4) surgically assisted rapid maxillary or palatal expansion, (5) mandibular advancement, (6) mandibular setback, (7) distraction osteogenesis, or (7) any combination of these reported in the literature.

The main outcome measures of interest were (1) percentages of patients with TMD signs or symptoms, examined at all intervals reported, before and after treatment (up to 5 years posttreatment); and (2) changes in TMD status—whether the signs and symptoms improved, worsened, or remained the same.

Our search strategy included attempts to identify relevant studies irrespective of language: (1) electronic searching with detailed search strategies (Table I) developed for MEDLINE by using the Ovid interface; (2) bibliographies and reference lists of identified publications and reviews checked for references to studies outside the hand-searched journals and any other relevant studies; and (3) personal communications with experts

Table I. Electronic search strategy for identification of studies

Search Strategy for MEDLINE via OVID
1 ((jaw adj1 joint adj1 (pain or click or lock$ or nois$ or sound)) 2 (jaw adj1 (pain or click or lock$ or nois$ or sound)) 3 pterygoid hypersensitivity dysfunction 4 ((mm?ast|ter adj1 (Pain or ache or tender)) 5 (jaw or oral or mouth) 6 ((limited or reduced or restricted or decreased) adj1 (opening or lateral excursion$ or excursion$ or interincisal or vertical$)) 7 5 and 6 8 ((pterygoid or masseter or temporalis) adj1 (Pain or ache or spasm or tender$)) 9 (muscle adj1 (Pain or ache or spasm or tender$)). 10 5 and 9 11 exp Temporomandibular Joint Dysfunction Syndrome 12 exp Temporomandibular Joint Disorders 13 TMD 14 exp Trismus 15 exp Facial Pain 16 myofacial pain 17 lateral pole 18 otalgia 19 exp Jaw Fractures 20 ((jaw$ adj2 fracture$) or (condyl$ adj2 fracture$)) 21 exp Osteotomy, Le Fort 22 exp Osteotomy, Le Fort 23 (maxillo adj1 advancement) 24 (orthognathic adj1 surg$) 25 (orthognathic adj1 treatment) 26 (jaw$ adj1 surg$) 27 (mand$ adj2 surg$) 28 (maxill$3 adj2 surg$) 29 BSSO 30 (sagittal adj2 split adj2 osteotom$) 31 (retrognath$ and (surgery or surgical$)) 32 (prognath$ and (surgery or surgical$)) 33 superior maxillary repositioning 34 maxillary impaction 35 inferior repositioning of maxilla 36 mandibular setback 37 BVSS 38 (vertical adj2 subsegment adj1 osteotomy) 39 (distraction adj1 osteogen$) 40 1 or 2 or 7 or 8 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 41 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26 or 27 or 28 or 29 or 30 or 31 or 32 or 33 or 34 or 35 or 36 or 37 or 38 or 39 42 40 and 41

and specialists in the field to obtain further information about unpublished studies and ongoing trials. These people were considered experts if they had an established track record of publications in research on orthodontics and facial pain.

A total of 480 titles and abstracts were identified by the search strategy, and 2 examiners (S.A., S.J.C.) considered them for possible inclusion. At the first stage of screening, 350 articles were excluded because they did not fulfill the inclusion criteria. Examiner agreement was assessed by using kappa scores; this was found to be substantial (kappa = 0.723). After discussion, it was agreed to include 130 articles in the second stage of evaluation. The full texts of these articles were obtained and assessed. The kappa scores for agreement at the second stage were also acceptable (kappa = 0.762). After discussion, it was agreed to include 60 articles in English.

Data extraction and management

The next stage in the process was to design a form for data extraction. This incorporated information on characteristics such as the number of patients in the study, patients' sex, age ranges, and malocclusion types and interventions. The form also recorded the methods used for classification of TMD and the observational time intervals. Primary outcome measures and results were recorded in table format, and a distinction was made between patient-reported symptoms and clinical signs. Data were then extracted from the 60 eligible full-text articles. This process was independently carried out by both investigators (S.A., S.J.C.). At this stage, 7 articles were found not to meet the inclusion criteria and were excluded. The data extraction forms completed by both investigators were compared; any discrepancies were identified and discussed until agreement was reached. A total of 53 articles were finally summarized for inclusion in this review. However, some studies contained a continuation of the same patient material in more than 1 counted article.

Quality assessment of the studies in systematic reviews is necessary to limit bias, gain insight into potential comparisons, and guide interpretation of findings. From the results of the search, it became apparent that most articles were case-control and cohort studies. Thus, it was initially decided to use the Newcastle-Ottawa scale,[14] which was developed to assess the quality of nonrandomized studies. However, on piloting this scale, it became evident that it could not be applied appropriately to studies involving TMD research and was better suited for epidemiologic studies.

We decided to develop a quality-assessment scale specifically for this study that would be better suited to this research. The main types of potential research bias were identified and included as subsections of a quality-assessment form. These were selection, performance, measurement and outcome, and attrition.[15]

1. Selection bias (allocation bias) is the systematic differences between comparison groups in prognosis or responsiveness to treatment. Randomization of large numbers of patients with concealment of

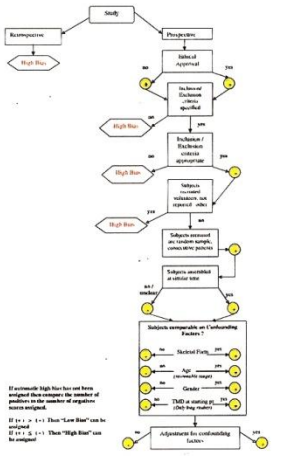

Fig 1. Criteria for study selection.

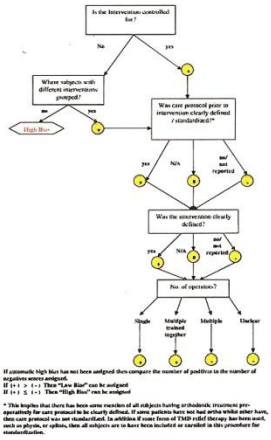

Fig 2. Criteria for study performance.

their allocation to different groups reduces this bias. Whether inclusion and exclusion criteria were reported and appropriate, and how the subjects were recruited into the study (eg, volunteers or consecutive patients) were evaluated to determine the likelihood of this bias.

2. Performance bias is the systematic differences in care provided, apart from the intervention evaluated. Standardization of the care protocol and blinding (masking) of clinicians and participants minimizes this bias. The number of operators involved in the studies and grouping of the interventions were some criteria examined to evaluate the potential for this bias.
3. Measurement bias (detection bias, ascertainment bias) is the systematic differences between comparison groups in how outcomes are ascertained. Blinding of study participants and outcome assessors reduce this bias. For this study, the use of a universally accepted measure (such as the Helkimo index[16]) was considered essential to minimize bias.
4. Attrition bias (exclusion bias) is the systematic differences between comparison groups in terms of withdrawal or exclusion of participants from the study. Inclusion of such participants in the analysis (combined with a sensitivity analysis) minimizes

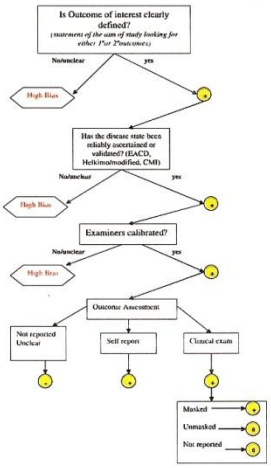

Fig 3. Criteria for measurements and outcomes.

this bias. In this study, a follow-up period longer than 6 months was considered necessary to minimize the risk of bias. In addition, the number of patients lost to follow-up should not exceed 20%.

The approach was then refined by incorporating other principles of quality-assessment tools. Criteria were developed for all 4 sections and incorporated into flow charts (Figs 1-4). Both investigators met to discuss the flow charts and calibrate themselves for the 53 eligible articles, and kappa scores were calculated. The kappa scores were considered acceptable (Table II).

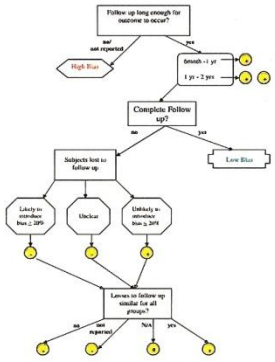

Fig 4. Criteria for attrition.

The results of the systematic review were predominantly narrative, involving a structured summary and discussion of the study characteristics and findings. Hence, the narrative synthesis used subjective rather than statistical methods to determine the direction of the effect, the size of the effect, whether the effect was consistent across studies, and the strength of evidence for the effect. This was carried out because, for most studies, a meta-analysis was not either feasible or appropriate. On the few occasions when it was possible and appropriate to undertake meta-analyses, these were done, and the results are presented in part 2.

RESULTS

The data of the 53 eligible articles are summarized in Tables III, IV, and V.

A total of 53 articles were analyzed for the review (Table III). Most (41) had a cohort design, 8 were case-control studies, and only 3 were part of larger RCTs. Almost half (20) did not explicitly state whether the study was retrospective or prospective, although, with most of these, it could be assumed with a high degree of certainty based on the details in the study. Based on these assumptions, there were 21 retrospective and

Table II. Agreement and kappa scores for the quality assessment

	Kappa	95% CI	Agreement (%)
Selection	0.312*	0-0.904	92.5
Performance	0.827	0.664-0.990	92.5
Measurement and outcome	0.737	0.616-1.000	94.3
Attrition	0.822	0.629-1.000	94.3

*Although this kappa score for selection (0.312) does not appear to be acceptable, the percentage of agreement was 92.5% (there was disagreement between the 2 investigators on only 4 of the 53 articles); this is in line with the other results. The low kappa score can be explained by the difficulties associated with the use and interpretation of kappa scores. The value of kappa depends on the proportion of subjects in each category. Hence, in this case, although there were disagreements about only 4 articles, the direction of the difference was 1 sided and not evenly spread (they were all classified as having a high risk of bias by S.A. and a low risk of bias by S.J.C.).

28 prospective studies; the remaining 4 articles were not sufficiently clear to determine whether the studies were prospective or retrospective.[17-20]

Forty-one studies followed patients longitudinally, with clinical examinations before and after surgery. Signs and symptoms of TMD before surgery were compared with those after surgery, although the postsurgical time interval varied from 6 months to 4 years. In 7 studies, records of the patients were examined and surveys or questionnaires were sent to patients, thus providing self-reported assessments of TMD.

In 8 studies, radiologic changes or other imaging modalities (eg, magnetic resonance imaging or arthrography) were used as diagnostic tools for TMD. It was not possible to collectively synthesize these results into evidence tables because each of these 8 studies looked at different parameters. Although some studies assessed condylar resorption before and after surgery by using panoramic radiographs,[21,22] others assessed changes in condylar position postsurgery, albeit with different criteria (eg, superimposition via the Pullinger index).[23,24] Two studies used magnetic resonance imaging to assess articular disc positions before and after surgery, and both indicated that displaced discs were corrected or improved after surgery in some patient groups.[25,26]

The sites of the research for the studies that comprised this systematic review spanned the globe. Almost all continents were represented, from the North America to Europe and Asia. The sites ranged from private practices to university hospitals, and multi-center studies were also represented.

Signs and symptoms of TMD were evaluated by patients' self reports, clinical examinations, or radiographic findings. In most studies (44), clinical examinations were conducted, and self-reports were used in 26 studies (Table IV). Clinical examinations and self-reports were combined in 20 studies. In only 4 studies did the patients' self-reports alone provide the information regarding TMJ status. Radiographic findings contributed to the diagnosis of TMD or TMJ findings in 8 studies.

Most studies did not use a formal classification to diagnose TMD. Of the 53 studies, 37 did not classify TMD according to published criteria. This implies a potential for great variability in the diagnosis of TMD. Only 16 studies diagnosed TMD by using a validated scale, and 12 of these used the Helkimo or the modified Helkimo index,[46] whereas 4 studies classified TMD according to the craniomandibular index.[27] No study classified TMD according to the Research Diagnostic Criteria (RDC) TMD criteria,[28] a classification system recommended for research.[29] However, the RDC TMD was described in 1992, and approved and adopted by the European Academy of Craniomandibular Disorders in 2002, but only 40 of the included studies were published after 1992 that could have used the RDC TMD criteria.[30]

The results of the quality assessment are presented in Table V. Each investigator scored the articles independently, according to the 4 quality-assessment categories (selection, performance, measurement, and attrition). If at least 1 category achieved a high bias risk score, then the article was considered to be at high risk of bias overall. This assessment meant that all 53 eligible articles were judged to be at high risk of bias.

DISCUSSION

From the results of this review, clearly there is great variability among studies of an association between TMD and orthognathic treatment. This variability encompasses how TMD was classified, the signs and symptoms recorded, the time intervals reported, and other factors.

Perhaps most important, however, was the great variation in the malocclusions in the studies. Although some studies included patients with a specific skeletal discrepancy, others included various skeletal deformities, so that comparisons were not always possible and, when carried out, could be a source of heterogeneity. Most studies that reported a reduction in TMD signs and symptoms after orthognathic treatment reported this association in skeletal Class II patients. A decrease in the prevalence of signs and symptoms by more than 50% postsurgery compared with the presurgery state was reported in some studies,[13,15,16] whereas fewer subjects with skeletal Class III or a high mandibular plane angle (>32°) seemed to benefit from

Table III. Study characteristics

Author, year	Study design	Prospective/ retrospective*	Description	Site*
Aghabegi et al, 2001	Cohort	Retrospective	83 patients surveyed; records examined and survey sent to patients	Eastman Dental Institute, London, United Kingdom
Aoyama et al, 2005	Cohort	Retrospective	37 consecutive patients compared before and after BSSO	Tokyo Medical and Dental University, Tokyo, Japan
Athanasiou and Melsen, 1992	Cohort	(Prospective)	36 adult patients followed longitudinally presurgery and again 6 months later	Royal Dental College, Aarhus, Denmark
Athanasiou and Yücel-Eroğlu,1994	Cohort	(Prospective)	82 consecutively treated adults with various dentofacial deformities received combined orthodontic-surgical management	Royal Dental College, Aarhus, Denmark
Athanasiou et al, 1996	Cohort	(Prospective)	43 patients studied for functional alteration in stomatognathic system after orthodontic-surgical management	Royal Dental College, Aarhus, Denmark
Azumi et al, 2004	Cohort	(Retrospective)	13 patients evaluated on short-term effects of mandibular distraction osteogenesis	Tohoku University, Sendai, Japan
Bailey et al, 2001	Cohort	Retrospective	2074 patients' records examined to evaluate trend in referral patterns for orthognathic surgery and acceptance of treatment	University of North Carolina, Chapel Hill, NC
Berstige et al, 2004	Cohort	Prospective	222 patients undergoing BSSO evaluated pre- and postoperatively for clinical parameters	Multi-center study, Radboud University, Nijmegen, The Netherlands and Rijnstate Hospital, Arnhem, The Netherlands
Borstlap et al, 2004	Cohort	Prospective	222 patients analysed for radiological changes in the TMJ after BSSO	Multi-center study, Radboud University, Nijmegen, The Netherlands and Rijnstate Hospital, Arnhem, The Netherlands
Cutbirth et al, 1998	Cohort	(Retrospective)	100 mandibular deficiency patients who underwent BSSO; records evaluated	University of Texas, San Antonio, Tex
Dahlberg et al, 1995	Cohort	Prospective	53 consecutive patients examined clinically and with bilateral arthrography	University Hospital of Lund, Lund, Swedon
De Boever et al, 1996	Cohort	(Prospective)	102 patients assessed for the relationship between TMD and malocclusion	Multi-center study, University of Texas Health Science Center, San Antonio, Tex
De Clercq et al, 1995	Cohort	Retrospective	317 consecutive patients who underwent orthognathic surgery; records evaluated pre- and postoperatively	General Hospital St John, Bruges, Belgium
De Clercq et al, 1998	Cohort	Retrospective	296 patients questioned postoperatively	General Hospital St John, Bruges, Belgium
Dervis and Tuncer, 2002	Case control	(Prospective)	50 orthognathic patients investigated for alterations in signs and symptoms of TMD compared with healthy controls	University of Istanbul, Istanbul, Turkey
Egermark et al, 2000	Cohort	Retrospective	52 patients examined for signs and symptoms of TMD 5 years after surgery	Department of Oral and Maxillofacial Surgery, Halmstad, Sweden
Feinerman and Piecuch, 1995	Cohort	Retrospective	66 patients examined after BSSO	University of Connecticut, Farmington, Conn
Flynn et al, 1999	Cohort	N/R	40 patients who had received mandibular advancement surgery evaluated for TMD	Indiana University, School of Dentistry, and private practice in orthodontics, Mesa, Ariz
Forssell et al, 1998	Cohort	Prospective	100 consecutive patients interviewed concerning their surgery	Turku University, Turku, Finland
Gaggl et al, 1999	Cohort	Prospective	25 patients examined before and after orthognathic surgery	University Hospital, Graz, Austria
Hackney et al, 1989	Cohort	(Prospective)	18 patients studied for changes in intercondylar width and angle and correlated with TMJ symptoms after BSSO	University of Texas Health Science Center, San Antonio, Tex
Herbosa et al, 1990	Cohort	(Prospective)	29 patients treated with LeFort 1 osteotomy or segmental procedures and changes in condylar position compared	St Mary's Health Center, St Louis, Mo

Table III. Continued

Author, year	Study design	Prospective/ retrospective*	Description	Site†
Hoppenreijs et al, 1998	Cohort	Retrospective	259 patients with VME and AOB analyzed regarding TMJ sounds, condylar remodeling, and resorption	Multi-center study, Rijnstate Hospital Arnhem, The Netherlands
Hu et al, 2000	Cohort/case control?	(Prospective)	50 patients studied for changes in TMJ function and condylar position after mandibular setback	West China University of Medical Sciences, Chengdu, China
Hwang et al, 2000	Cohort	(Retrospective)	11 patients evaluated for condylar resorption after orthognathic surgery	Department of Cranio-Maxillofacial Surgery, University Hospital, Zurich, Switzerland
Hwang et al, 2004	Case control	(Retrospective)	34 patients studied to identify nonsurgical risk factors for condylar resorption after orthognathic surgery	Seoul National University Dental Hospital, Seoul, South Korea
Kalliela et al, 2005	Cohort	Retrospective	40 consecutive patients who underwent BSSO advancement maintained 2.2 years postoperatively	Department of Oral and Maxillofacial Surgery, Helsinki University, Helsinki, Finland
Karaboota and Martis, 1985	Cohort	N/R	280 patients evaluated for TMD before and after BSSO	Department of Oral and Maxillofacial Surgery, University of Thessaloniki, Thessaloniki, Greece
Kerstens et al, 1989	Cohort	N/R	480 patients observed for pre- and postoperative TMJ symptoms; patients had various dentofacial deformities and were operated on for dysgnathia	Department of Oral and Maxillofacial Surgery, Free University of Amsterdam, Amsterdam, The Netherlands
Lai et al, 2002	Cohort	(Prospective)	23 patients who had BSSO were analyzed for skeletal stability and TMJ signs and symptoms.	Niigata University Graduate School of Medical and Dental Sciences, Niigata, Japan
Landes, 2004	Case control	(Prospective)	30 patients evaluated; dynamic proximal segment positioning by retrospective sonography vs splint and plane technique; clinical dysfunctions and disc dislocation also compared pre- and postoperatively	Goethe University Medical Centre, Frankfurt, Germany
Link and Nickerson, 1992	Cohort	(Prospective)	39 patients undergoing orthognathic intervention evaluated for TMJ internal derangement pre- and postsurgery	Vanderbilt University School of Medicine, Nashville, Tenn
Little et al, 1986	Cohort	Retrospective	17 patients retrospectively evaluated for the effects of surgical orthodontic correction on the TMJ and related structures.	University of Louisville School of Dentistry, Louisville, Ky
Milosevic and Samuels, 2000	Case control	(Prospective)	42 patients evaluated; postorthodontic prevalence of TMD and functional occlusion contacts were assessed in surgical and nonsurgical subjects	Multi-center study, Department of Clinical Dental Sciences, University of Liverpool, Liverpool, United Kingdom
Motamedi, 1996	Case study	Retrospective	13 patients evaluated and compared for long-term outcomes of bilateral and unilateral osteotomies of the mandible	Baqiyattalah Medical Centre, Tehran, Iran
Nemeth et al, 2000	RCT	Prospective	127 patients evaluated before and 2 years after surgery for signs and symptoms of TMDs	Multi-center study, private clinic, Austin, Tex. University of Texas Health Science Center, San Antonio, Tex
Nurminen et al, 1999	Cohort	Retrospective	28 orthognathic patients questioned regarding motivation for starting treatment, satisfaction with results evaluated on the bases of replies to a questionnaire and clinical examination	Institute of Dentistry, Turku University, Turku, Finland
Onizawa et al, 1995	Case control	(Prospective)	30 patients investigated for alterations in TMJ function after orthognathic surgery; the study also compared the findings with those of healthy volunteers	Department of Oral and Maxillofacial Surgery, Medizinische Hochschule, Hannover, Germany

Table III. Continued

Author, year	Study design	Prospective/ retrospective*	Description	Site†
Pahkala and Heino, 2004	Cohort	(Prospective)	72 patients observed before and 2 years after surgical-orthodontic treatment for pre- and postoperative TMD	Kuopio University Hospital, Kuopio, Finland
Panula et al, 2000	Case control	Prospective	60 patients investigated in a controlled prospective 4-year follow-up study to examine the influence of orthognathic treatment on signs and symptoms of TMJ dysfunction	Multi-center study, Vaasa Central Hospital, Seinajoki, Finland; Central Hospital, University of Oulu, Oulu, Finland
Raveh et al, 1988	Cohort/case control?	N/R	103 patients underwent sagittal split osteotomy and findings including dysfunction reported; new techniques for reproduction of condylar rotation also evaluated	University of Berne, Berne, Switzerland
Rodriguez-Garcia et al, 1998	RCT	Prospective	124 patients with Class II malocclusion examined; the relationship between malocclusion and TMD before and after BSSO examined	Multi-center study, University of Texas Health Science Centre, San Antonio, Tex
Schwarzrock et al, 1994	Cohort	Prospective	103 patients evaluated for skeletal stability, TMJ function, and inferior alveolar nerve function; patients had mandibular hypoplasia and were treated with BSSO	Department of Oral and Maxillofacial Surgery, Rijnstate Hospital, Arnhem, The Netherlands
Scott et al, 1997	RCT	Prospective	58 patients studied to determine the agreement between prospective clinical examinations and retrospective chart review in identifying signs and symptoms of TMD	Multi-center study, University of Texas Health Science Center, San Antonio, Tex
Smith et al, 1992	Cohort	Prospective	22 patients examined for signs and symptoms of TMD postorthognathic surgery	University of Detroit, School of Dentistry, Detroit, Mich
Timmis et al, 1986	Cohort	Prospective	28 BSSO patients evaluated; signs and symptoms of TMD and masticatory dysfunction investigated	University of Texas Health Science Center, San Antonio, Tex
Ueki et al, 2001	Cohort	(Prospective)	42 patients investigated for the relationship between changes in condylar long axis and TMJ function after BSSO	Department of Oral and Maxillofacial Surgery, Kanazawa University, Kanazawa, Japan
Ueki et al, 2002	Cohort	(Prospective)	42 patients studied to compare changes in TMJ morphology and clinical symptoms after BSSO	Department of Oral and Maxillofacial Surgery, Kanazawa University, Kanazawa, Japan
Upton et al, 1984	Cohort	Retrospective	102 patients responded to a questionnaire exploring the relationship of surgical correction of skeletal disharmony with TMJ pain and dysfunction	University of Michigan, Ann Arbor, Mich
Westermark et al, 2001	Cohort	Retrospective	1515 patients; article reports TMD before and after orthognathic surgery based on patients' own reports	Karolinska Hospital, Stockholm, Sweden
White and Dolwick, 1992	Cohort	Retrospective	75 patients studied retrospectively to assess the prevalence and variance of TMD in an orthognathic population	Department of Oral and Maxillofacial Surgery, University of Florida College of Dentistry, Gainesville, Fla
Wolford et al, 2003	Cohort	Retrospective	25 bimaxillary surgery patients; treatment records evaluated for TMD signs and symptoms	Private practice; Baylor College of Dentistry, Dallas, Tex
Zhao et al, 2001	Cohort	Retrospective	94 patients evaluated for the objective relationship between preoperative psychological status and attitude and postsurgical experience of treatment	University of Hong Kong, Hong Kong

BSSO, Bilateral sagittal split osteotomy; *VME*, vertical maxillary excess; *AOB*, anterior open bite.
*Items in brackets were asserted to be either prospective or retrospective based on study information; †if the site was not given, the first author's country was stated.

Table IV. Classification of TMD

	How outcome was measured or assessed				Classification			
Author, year	Self-report	Clinical examination	Radiography	Other	Helkimo and modified Helkimo	EACD	CMI	No formal TMD classification
Agbabiaje et al, 2001	✔	✔						✔
Aoyama et al, 2005		✔						✔
Athanasiou and Melsen, 1992		✔			✔			
Athanasiou and Yucel-Eroglu, 1994		✔			✔			
Athanasiou et al, 1996		✔	✔		✔			
Azuma et al, 2004		✔	✔					✔
Baisley et al, 2001		Unclear						✔
Borstlap et al, 2004		✔						✔
Borstlap et al, 2004	✔	✔	✔					✔
Cutbirth et al, 1998		✔						✔
Dahlberg et al, 1965		✔		Arthrography				
De Boever et al, 1996		✔					✔	
De Clercq et al, 1995		✔						✔
De Clercq et al, 1998	✔							
Dervis and Tuncer, 2002	✔	✔			✔			
Egemark et al, 2000	✔	✔			✔			
Feinerman and Piecuch, 1995	✔	✔						✔
Flynn et al, 1990	✔	✔						✔
Forsell et al, 1998	✔							✔
Giuggi et al, 1999		✔	✔					✔
Hackney et al, 1989	✔	✔						✔
Herbosa et al, 1990		✔	✔					✔
Hoppenreijs et al, 1998		✔						✔
Hu et al, 2000	✔	✔						✔
Hwang et al, 2000			✔					✔
Hwang et al, 2004			✔					✔
Kalliela et al, 2005	✔	✔			✔			
Karaboota and Martis, 1985		✔						✔
Kerstens et al, 1989	✔	✔						✔
Lai et al, 2002		✔						✔
Landes, 2004		✔			✔			
Link and Nickerson, 1992		✔						✔
Little et al, 1986	✔	✔			✔			
Milosevic and Samuels, 2000		✔			✔			
Motamedi, 1996		✔	✔					✔
Nemeth et al, 2000	✔	✔					✔	
Nurminen et al, 1999	✔	✔						✔
Onizawa et al, 1995	✔	✔						✔
Pahkala and Heino, 2004	✔	✔			✔			
Panula et al, 2000	✔	✔			✔			
Raveh et al, 1988		✔						✔
Rodriguez-Garcia et al, 1998	✔	✔					✔	
Schwarzrock et al, 1994		✔					✔	✔
Scott et al, 1997		✔						✔
Smith et al, 1992	✔	✔			✔			
Timmis et al, 1986		✔						✔
Ueki et al, 2001	✔	✔						✔
Ueki et al, 2002		✔	✔					✔
Upton et al, 1984	✔							✔
Westermark et al, 2001	✔	✔						✔
White and Dolwick, 1992	✔							✔
Wolford et al, 2003	✔	✔						✔
Zhao et al, 2001	✔							✔

EACD, European Academy of Craniomandibular Disorders; *CMI*, Craniomandibular Index.
*Condylar morphology scale and Pullonger index used; †included use of visual analog and Likert scales.

Table V. Quality assessment

Author, year	Selection SA	Selection SJC	Performance SA	Performance SJC	Measurement SA	Measurement SJC	Attrition SA	Attrition SJC	Overall bias
Agbabiaje et al, 2001	High	High	Low	Low	High	High	Low	Low	High
Aoyama et al, 2005	High	High	High	High	High	High	Low	Low	High
Athanasiou and Melsen, 1992	High	High	High	High	High	High	Low	Low	High
Athanasiou and Yucel-Eroglu, 1994	Low	Low	Low	Low	High	High	Low	Low	High
Athanasiou et al, 1996	High	High	High	High	High	High	High	High	High
Azuma et al, 2004	High	High	Low	Low	High	High	Low	Low	High
Baisley et al, 2001	High	High	High	High	High	High	Low	Low	High
Borstlap et al, 2004	High	High	Low	Low	High	High	Low	Low	High
Borstlap et al, 2004	High	High	Low	Low	High	High	Low	Low	High
Cutbirth et al, 1998	High	High	High	High	High	High	Low	Low	High
Dahlberg et al, 1965	High	High	High	High	High	High	Low	Low	High
De Boever et al, 1996	High	High	Low	Low	Low	Low	Low	Low	High
De Clercq et al, 1995	High	High	High	High	High	High	Low	High	High
De Clercq et al, 1998	High	High	High	High	High	High	Low	Low	High
Dervis and Tuncer, 2002	High	High	High	High	High	High	Low	Low	High
Egemark et al, 2000	High	High	Low	Low	High	High	Low	Low	High
Feinerman and Piecuch, 1995	High	Low	High	High	High	High	Low	Low	High
Flynn et al, 1990	High	High	High	High	High	High	Low	Low	High
Forsell et al, 1998	High	High	High	High	High	High	Low	Low	High
Giuggi et al,1999	High	High	High	High	High	High	High	High	High
Hackney et al, 1989	High	High	High	High	High	High	High	High	High
Herbosa et al, 1990	High	High	High	High	High	High	Low	Low	High
Hoppenreijs et al, 1998	High	High	High	High	High	High	Low	Low	High
Hu et al, 2000	High	High	Low	Low	High	High	Low	Low	High
Hwang et al, 2000	High	High	Low	High	High	High	Low	Low	High
Hwang et al, 2004	High	High	High	High	High	High	Low	Low	High
Kalliela et al, 2005	High	High	High	High	High	High	Low	Low	High
Karaboota and Martis, 1985	High	High	Low	Low	High	Low	High	Low	High
Kerstens et al, 1989	High	High	High	High	High	High	Low	Low	High
Lai et al, 2002	High	High	Low	High	High	High	Low	Low	High
Landes, 2004	High	High	High	High	High	High	Low	Low	High
Link and Nickerson, 1992	High	High	Low	High	High	Low	High	High	High
Little et al, 1986	High	Low	Low	Low	High	High	High	High	High
Milosevic and Samuels, 2000	High	High	High	High	High	High	Low	Low	High
Motamedi, 1996	High	High	High	Low	Low	High	High	High	High
Nemeth et al, 2000	High	High	High	High	High	High	Low	Low	High
Nurminen et al, 1999	High	High	Low	Low	Low	Low	Low	Low	High
Onizawa et al, 1995	High	High	High	High	High	High	Low	Low	High
Pahkala and Heino, 2004	High	High	High	High	High	High	Low	Low	High
Panula et al, 2000	High	Low	High	High	High	High	Low	Low	High
Raveh et al, 1988	High	High	High	High	High	High	Low	Low	High
Rodriguez-Garcia et al, 1998	High	Low	Low	Low	Low	Low	Low	Low	High
Schwarzrock et al, 1994	High	High	High	Low	Low	Low	High	High	High
Scott et al, 1997	High	Low	Low	Low	High	High	Low	Low	High
Smith et al, 1992	High	High	Low	Low	High	High	Low	Low	High
Timmis et al, 1986	High	High	High	High	High	High	Low	Low	High
Ueki et al, 2001	High	High	High	High	High	High	High	High	High
Ueki et al, 2002	High	High	Low	Low	High	High	Low	Low	High
Upton et al, 1984	High	High	High	High	High	High	Low	Low	High
Westermark et al, 2001	High	High	High	High	High	High	Low	Low	High
White and Dolwick, 1992	High	High	High	High	High	High	Low	Low	High
Wolford et al, 2003	High	High	High	High	High	High	Low	Low	High
Zhao et al, 2001	High	High	High	High	High	High	Low	High	High

This table indicates the level of bias assigned to each section (selection, performance, measurement, and attrition) of the quality-assessment forms by both researchers (S.A. and S.J.C.) and the overall bias assigned to each study. If a study scored as high bias in any section, it was automatically given an overall high-bias rating.

surgery.[13,18,31] Thus, the participants' skeletal deformity could have had a direct impact on TMD, especially after surgery.

It was encouraging that most studies identified TMD by clinical examinations, and some studies supplemented this with either the patients' self-reports or, less frequently, radiographic examinations. However, even with clinical examinations, most studies did not appear to classify TMD according to a validated or universally acceptable scale (ie, Helkimo, modified Helkimo, or Craniomandibular Index). The authors of these studies appeared to have used their own methods of classifying TMD, according to nonstandardized criteria; this made it virtually impossible to make valid comparisons between studies. The exceptions to this were the 12 studies that used the Helkimo index. Although the shortcomings of the lack of a universally acceptable scale or outcome measure in reporting TMD has not previously been explored in orthognathic populations, it was identified in other epidemiologic studies relating to TMD.[2]

In studies in the United States, clicking sounds were reported in 8% to 41% of adults,[39] and TMD-related pain was reported to be 12%.[33] In Scandinavia, estimates ranged from 16% to 59% for reported symptoms, and from 33% to 86% for clinical signs.[34] Thus, this discrepancy between studies in the United States and Europe might not necessarily reflect true differences between these populations but, instead, could be because the diagnostic criteria differed between the studies. Some studies might have relied on self-reports of pain and dysfunction, whereas others included diverse clinical assessments to diagnose TMD.[35]

Most studies were cohort studies, which, in terms of the hierarchy of evidence, is approximately halfway up the pyramid. The areas of potential bias in these studies included selection bias from how patients were included and measurement bias from the unmasked (unblinded) assessment of subjective outcomes. Although an RCT would provide greater protection from bias, this type of study design is not feasible for patients undergoing orthognathic interventions in most cases.

Quality assessment of studies is an essential feature of systematic reviews and is necessary to limit bias, gain insight into potential comparisons, and guide interpretation of findings.[36] In the past decade, research has focused on 2 main issues: which components of the quality assessment can predict valid results, and which tools (scales or checklists) best assess quality.[37] Egger et al[38] found that the quality of allocation concealment and double blinding were both strongly related to reported treatment effect sizes. Although many quality scales and checklists have been proposed over the years,[39,40] the answer to the second question is unclear, and many doubt that a generic quality-assessment tool that would prove valid in all cases can ever be found.[37]

For this study, a quality-assessment tool was developed that was more appropriate for this research than previously devised generic tools proved to be. The development of this tool, along with establishing the criteria for assigning the risk of bias were major challenges in this review. The quality-assessment forms and flow charts that we developed were reliable and reproducible, and can be recommended for assessing the quality of nonrandomized TMD studies in the future.

CONCLUSIONS

Assessing the methodologic quality of TMD studies is a major challenge because of the nature of these studies. Most generic quality-assessment tools focus on epidemiologic studies or RCTs, and are not compatible with the design features of longitudinal TMD studies that usually involve a nonrandomized intervention. Greater attempts should be made to develop quality-assessment tools for TMD research, such as that developed in this study. Many researchers neglect to specify basic, yet important, information about their studies, such as whether they are retrospective or prospective. Providing this information should be encouraged to enable an appropriate quality assessment. The EQUATOR network (enhancing the quality and transparency of health research) has provided ready access to validated reporting guidelines that encourage authors to provide clear and transparent reporting of the facts relating to their research.[41] For example, STROBE (reporting of observational studies in epidemiology) checklists for cohort and case-control studies can help to address shortcomings in the reporting of research findings.[42]

The diversity of diagnostic criteria and classification methods in the various TMD studies makes interstudy comparisons virtually impossible. This reinforces the need for well-designed studies with standardized diagnostic criteria and classification methods for TMD.

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Orthognathic treatment and temporomandibular disorders: A systematic review. Part 2. Signs and symptoms and meta-analyses

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Introduction: There have been conflicting viewpoints in the literature regarding the effects of orthognathic treatment on temporomandibular disorders (TMD). A systematic review was conducted to determine the percentage of orthognathic patients with TMD, establish the range of signs and symptoms, and follow patients longitudinally through treatment for any changes in signs and symptoms. **Methods:** Part 1 of this 2-part article described the methodology of this review, with a narrative analysis of the study characteristics and the TMD classification methods. Part 2 describes the percentage of patients suffering from TMD and the signs and symptoms reported. Meta-analyses were conducted on data from clinically similar studies. **Results:** Pain decreased after surgery for both self-reported symptoms and clinically diagnosed pain on palpation. However, postsurgical results were more varied for joint sounds. The percentage of patients with clicking had a tendency to decrease postsurgery, but improvements in crepitus were questionable. The results from all meta-analyses in this review were subject to considerable statistical heterogeneity, and it was not possible to draw strong inferences relating to the percentage of orthognathic surgery patients with TMD with any degree of certainty. **Conclusions:** Although orthognathic surgery should not be advocated solely for treating TMD, patients having orthognathic treatment for correction of their dentofacial deformities and who are also suffering from TMD appear more likely to see improvement in their signs and symptoms than deterioration. (Am J Orthod Dentofacial Orthop 2009;136:626.e1-626.e16)

Functional and esthetic considerations often prompt patients to seek orthognathic treatment to correct jaw discrepancies; this involves a combination of orthodontics and surgery. Yet it has been reported that orthognathic surgery can introduce unwanted alterations in the temporomandibular joint (TMJ), giving rise to temporomandibular dysfunction (TMD).[1]

There are few high-quality studies in the field of TMD research that attempt to reduce bias, and there are even fewer high-quality articles regarding the association between major skeletal disharmonies and their effects on TMD.[2] If the bearing of orthognathic treatment on TMD is considered, the viewpoints include that orthognathic intervention might induce or resolve TMD, or have little or no effect on TMD.[3,4]

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A systematic review was conducted to determine the percentage of orthognathic patients with signs and symptoms of TMD, and to establish the range of signs and symptoms. In addition, we examined studies that followed patients longitudinally throughout treatment to determine whether intervention to correct skeletal discrepancies affects TMD signs and symptoms. After an extensive search strategy and full-text screening, 53 articles fulfilled the criteria for inclusion in this review.

Analysis of the results of systematic reviews can be narrative or quantitative (involving statistical analysis). Although often associated with quantitative analysis, it is acceptable for a systematic review not to contain a meta-analysis.[5] The results of this review were predominantly narrative, and we used subjective rather than statistical methods to determine the direction of the effect, the approximate size of the effect, whether the effect was consistent across studies, and the strength of evidence for the effect. This was carried out because, for most of the studies, a statistical analysis was either not feasible (eg, because of differences in the choices of outcome measures between studies) or inappropriate (eg, because of substantial clinical heterogeneity).

Meta-analysis is a statistical analysis of the results from independent studies; it generally aims to produce a single estimate of effect.[6] This should be carried out only after assessing the methodologic quality of the

studies and only if there is sufficient homogeneity to warrant pooling the studies' estimates. Studies to be pooled should ideally be free from clinical and methodological diversity (eg, using different classification systems for recording TMD). Meta-analysis is a 2-stage process involving the calculation of an appropriate summary statistic for each of a set of studies followed by combining these statistics into weighted averages. The selection of a meta-analysis method should take into account data type, choice of summary statistics, observed heterogeneity, and known limitations of the computational methods.[7]

MATERIAL AND METHODS

The methodology for conducting the systematic review, including focused questions, criteria for inclusion of studies, search strategy, data extraction, and quality assessment, were described in Part 1 of this study. Part 2 focuses on the remaining results, the evidence tables, and the methods involved in conducting the meta-analyses.

Most of the included studies did not use a validated scale to measure TMD, so it was not appropriate to include them in a meta-analysis because of heterogeneity in the assessment of TMD. Meta-analyses were carried out on only the 12 studies that used the Helkimo index[8] to classify TMD in patients at presurgery and postsurgery (Table I).

Although the patients in these studies had differing combinations of skeletal deformities and malocclusions, and had received various orthognathic interventions, there was sufficient homogeneity to carry out a meta-analysis on (1) the percentage of patients affected by TMD presurgery (of the 12 studies identified, 7 were eliminated because of incomplete or duplicated data, and thus only the 5 studies with complete preoperative results were pooled)[9-13]; (2) patients with skeletal Class II deformity having bilaterial sagittal split osteotomy (BSSO) advancement procedures[9,10,13]; and (3) patients with vertical maxillary excess (VME) having LeFort 1 maxillary impaction procedures[14,15] (although the vertical relationships of the patients in these subgroups were not specified).

The basic principles of conducting a meta-analysis, as described by the Cochrane Handbook, were followed.[16] A summary statistic was calculated for each study; it described the treatment effects or the effect size. A pooled treatment effect estimate or effect size estimate was then calculated as a weighted average of the treatment effects. Random-effects meta-analyses were undertaken. This assumes that each study is estimating different treatment effects. The center of this symmetric (normal) distribution describes the average of the effects, and its width describes heterogeneity. Finally, the standard error of the pooled treatment effect or effect size was used to calculate a confidence interval that indicates the precision of the pooled estimate.[7,17]

For this study, random-effects meta-analyses were conducted by using the statistical program Stata (version 10.1, Stata Corp, College Station, Tex).

RESULTS

The percentages of patients with self-reported symptoms are shown in Table II. Of the 53 studies, only 18 presented information regarding the symptoms reported by patients.

In the 4 studies that followed subjects longitudinally, the percentages of subjects reporting joint sounds decreased after surgery in 2 studies: from 28% to 3%[13] and from 24% to 20%.[18] The prevalence of joint sounds remained the same in 1 study at 30%[19] and increased in another study from 38% to 43%.[20]

Painful symptoms commonly reported by patients included TMJ, jaw, face, and muscle pain. In the 3 studies that reported both presurgical and postsurgical results, the percentages of patients reporting TMJ pain decreased after surgery.[13,18,21] A similar trend was seen with jaw, face, and muscle pain. The percentages of patients experiencing headaches were lower after surgery in the 6 studies that provided this information.

Clinical TMD signs are given in Table III. In studies that presented both presurgical and postsurgical clinical data, there was a tendency for the percentages of patients affected by joint clicking to decrease after surgery (in 22 of 24 studies). Only 2 studies found higher percentages of patients with clicking after surgery.[11,22] With regard to crepitus, the findings were varied. Some studies reported decreases in crepitus after surgery,[11,13,23,24] whereas others reported that it either remained the same[9,25,26] or increased.[12,27,28]

The percentage of patients affected by TMJ pain on palpation decreased after surgery in 14 of 18 studies. However, pain increased in 3 studies[29-31] and remained the same in 1 study.[32] Muscle pain on palpation was also a commonly reported TMD symptom, and, when the presurgical and postsurgical findings were compared, 9 of 11 studies showed decreases in the percentages of patients affected by muscle pain after surgery. Only 1 study[31] reported an increase in symptoms, and another found that it remained the same.[33]

Maximal incisal opening decreased after surgery, but there was a tendency for this to improve with time. Gaggl et al[23] reported maximal incisal openings of 47.5 mm

Table I. TMD findings in studies using the Helkimo index

		Initial time interval		*Follow-up time interval*				
Study, year	*Dysfunction severity*	*Initial time interval*	*Affected (%)*	*Follow-up time interval*	*Affected (%)*	*Same (%)*	*Better (%)*	*Worse (%)*
Athanasiou and Melsen, 1992	Di0[a]	Presurgery	33	6 mo postsurgery	33			
	Di1		58		58			
	Di2		8		8			
Athanasiou and Yücel-Eroğlu, 1994	Di0	Presurgery	34	6 mo postsurgery	38			
	Di1		49		51			
	Di2		17		11			
Athanasiou et al, 1996	Di0	Presurgery	28	6 mo postsurgery	26			
	Di1+ Di2		72		74			
Dervis and Tuncer, 2002	Results not reported by dysfunction severity							
Egermark et al, 2000	Di0	Presurgery	N/R	2.2-9.5 y postsurgery	35			
	Di1		N/R		50			
	Di2		N/R		13			
	Di3		N/R		2			
Kallela et al, 2005	Ai0	Presurgery	50	1-5 y postsurgery	80			
	Ai1		18		10			
	Ai2		32		10			
	Di0		43		58			
	Di1		50		38			
	Di2		7		5			
	Di3		0		0			
Landes, 2004	Results not reported by dysfunction severity							
Little et al, 1986	Ai0[b]	Presurgery	53	1-4.7 y postsurgery	41			
	Ai1		24		47			
	Ai2		24		13			
	Di0		N/R		35			
	Di1		N/R		53			
	Di2		N/R		12			
	Di3		N/R		0			
Milosevic and Samuels, 2000	Di0	Presurgery	N/R	At least 6 mo postdebond	57			
	Di1		N/R		43			
	Di2		N/R		0			
	Mi0[c]		N/R		10			
	Mi1		N/R		50			
	Mi2		N/R		40			
Pahkala and Heino, 2004	Di0	Presurgery	22	Mean of 1.9 y postsurgery	33			
	Di1		36		58			
	Di2		31		8			
	Di3		11		0			
Panula et al, 2000[d]	Ai0	Presurgery	~12	Mean of 2.5 y postsurgery	~50			
	Ai1		~68		~48			
	Ai2		~20		~2			
	Di0		~4		~8			
	Di1		~13		~38			
	Di2		~75		~54			
	Di3		~8		~0			
Smith et al, 1992	Ai0	Presurgery	27	6-7 mo postsurgery	23	50	32	18
	Ai1		46		73			
	Ai2		27		4			
	Di0		18		9	64	18	18
	Di1		46		68			
	Di2		36		23			
	Di3		0		0			

[a]Helkimo's dysfunction index: *Di0*, no dysfunction; *Di1*, mild dysfunction; *Di2*, moderate dysfunction; *Di3*, severe dysfunction; [b]Helkimo's anamnestic index: *Ai0*, no symptoms; *Ai1*, mild symptoms; *Ai2*, severe symptoms; [c]Helkimo's mandibular mobility index: *Mi0*, normal mobility; *Mi1*, mild impairment; *Mi2*, severely impaired; [d]Percentages are approximate and were taken from the graph in the published article.

Table II. Percentages (rounded up) of patients with self reported TMD symptoms

		Joint sounds			*Pain*						*Jaw movement*			*Other symptoms*		
Study, year	*Time interval*	*Click*	*Pop*	*Crepitus*	*TMJ*	*Jaw*	*Face*	*Muscles*	*Movement*	*Ear*	*Unspecified Fatigue*	*Limited opening*	*Jaw locking*	*Jaw deviation*	*Headache*	*Chewing difficulty*	*Parafunction*
Aghabeigi et al. 2001	Preop	38			45							3					
	Postop	43			38							14					
De Clercq et al. 1998	Preop	30			23							19	18			N/R	N/R
	1-2.5 y postop	30			4.3 ± 2.1*							21	18			57	15
Dervis and Tuncer, 2002	Preop				17										20		16
	2 y postop				3.4 ± 2.2*											16	12
Egermark et al. 2000	2-9.5 y postop	50													83		69
Flynn et al. 1999	1-5 y postop	33		5	20							40		8		18	23
Frossell et al. 1998	1 mo preop				3.5 ± 1.9* (TMJ problems)										3.6 ± 2.1*		
	1 y Postop				1.9 ± 1.1* (TMJ problems)										1.7 ± 1.3*		
Hackney et al. 1989	Preop				17												
	6-12 mo postop				11												
Kalliela et al. 2005	Preop	28		3	28			15				20		3			
	1 y postop	8		8	8			8				8		0			
	Longest follow-up	3		3	13			5				5		0			
Nurminen et al. 1999	Preop					32									32	68	
Pahkala and Heino, 2004	Preortho													6	46		
	Mean 1.9 y postop													1	13		
Panula et al. 2000	Preortho														61		
	1 y postop														18		
	Longest follow-up														20		
Rodrigues-Garcia et al. 1998	Preortho						46					2.0b ± 1.60[†]					
	2 y postop						32					1.61 ± 1.21[†]					
Tirtania et al. 1986	Preop						39					0		4	7		
	6-36 mo postop						29					4		0	0		
Upton et al. 1984	Preop	27	22		19		26					27					
Westermark et al. 2001	Preop	24	24	24	11				9						10	9	5
	2 y postop	20	20	20	6				4						3	4	2
White and Dolwick, 1992	Preop[‡]	34	4	8	29			21				13			12		
Wolford et al. 2003	Preop				3.7*							4.5*	4.5*	4.5*			
	Longest follow-up				6.8*							4.8*	4.8*	4.8*			
Zhou et al. 2001	Postop						83									71	

Preop, Before surgery; *postop*, after surgery; *preortho*, before orthodontic treatment; *N/R*, not reported.
*Visual analog scale rating; †oral health status questionnaire 11, mild; 7, extreme; ‡unclear whether findings reported are from clinical examination or patient questionnaire.

Table III. Clinical findings of TMD signs

		Joint sounds			*Pain*						*Range of jaw movement*						
												Lateral excursions (mm)					
Author, year	*Time interval*	*Click (%)*	*Pop (%)*	*Crepitus (%)*	*TMJ (%)*	*Muscle (%)*	*Jaw (%)*	*Face (%)*	*Movement (%)*	*Ear (%)*	*MIO (mm)*	*Right*	*Left*	*NS*	*Limited opening (%)*	*Jaw locking*	*Deviation*
Aoyama et al. 2005	Preop		14		3	14									3		
	1 y postop		11		11	19									8		
Athanasiou and Melsen, 1992	Preop	36*			8	11					46.5	7.1	9		53		36*
	6 mo postop	11*			0	11					41.1	7.8	8.1		64		11*
Athanasiou and Yücel-Eroğlu, 1994	Preop		32*		10	16										32*	
	6 mo postop		17*		2	7										17*	
Athanasiou et al. 1996	Preop										$Mn^{\dagger}$ 46.2	$Mn^{\dagger}$ 8.2	$Mn^{\dagger}$ 8.3				
											Ms 45.5	Ms 9.1	Ms 8.1				
	6 mo postop										$Mn^{\dagger}$ 40.7	$Mn^{\dagger}$ 7.6	$Mn^{\dagger}$ 7.4				
											Ms 43.6	Ms 8.2	Ms 8.1				
Austa et al. 2004[‡]	Preop	27			4												
	Predistraction	0			8												
	After distraction removal	12			19												
Bonellap et al. 2004	Preop	33			16						46.4			10.1			
	3 mo postop	22			17						37.6			6.6			
	6 mo postop	25			14						41.8			7.5			
	24 mo postop	28			10						45.6			8.5			
Bonellap et al. 2004	3 mo postop	25			24												
	6 mo postop	12			30												
	24 mo postop	17			26												
Cutbirth et al. 1998	Preop	39			13												
	Postop	18			5												
Dahlberg et al. 1995	Preop	50		4	53	53											
De Boever et al. 1996	Preop	36				8											
Dervis and Tuncer, 2002	Preop	38		24	20	70					49.5				10		28
	2 y postop	28		30	14	40					48.3				10		16
Egermark et al. 2000	5 y postop	25				23					52			8.4			17
Feinerman and Piecuch, 1995	Preop	52			20	55					DIF	Authors report that results are incomplete					
											48.6						
											RF						
											49.7						
	3-9 y postop	49			14	29					DIF	DIF	DIF				
											48.6	8.2	8.6				
											RF	RF	RF				
											47.6	9.7	9.3				
Flynn et al. 1999	1-5 y postop	30		10	13	28					43.5						8
Gaggl et al. 1999	Preop	88		36		28					47.5						88
	5 mo postop	52		16		12					39.5						96

Table III. Continued

Author, year	Time interval	Joint sounds: Click (%)	Joint sounds: Pop (%)	Joint sounds: Crepitus (%)	Pain: TMJ (%)	Pain: Muscle (%)	Pain: Jaw (%)	Pain: Face (%)	Pain: Movement (%)	Pain: Ear (%)	Range of jaw movement: MID (mm)	Lateral excursions (mm): Right	Lateral excursions (mm): Left	Lateral excursions (mm): N/S	Limited opening (%)	Jaw locking	Deviation
Hackney et al. 1989	Preop	22			17						>40						0
	6-12 mo postop	17			11						>40						0
Herbosa et al. 1990	Preop	28	4	4		28								10.2-10.3			
	6-18 mo postop	13	0	4		↑								9.4-9.8			
Hoppenreijs et al. 1998	Preortho	RHS 38 LHS 40									N/A						
	Latest follow-up	RHS 31 LHS 32									45						
Hu et al. 2000	Preop										46.2[*]						
											45.9						
	6 mo postop										42.1[†]						
											44.5						
Kallela et al. 2005	Preop	25		23	13	13					44.7						
	1 y postop	13		3	8	5					44.7						
	Latest follow-up	8		5	13	0					45.9						
Kasahara and Maruo, 1985	Preop	41			29										4		30
	6 mo postop	6			4										3		5
Landes, 2004	3 mo postop										47%[‡]			66%			
	6 mo postop										76[‡]			86%			
	1 y postop										90%[‡]			100%			
Link and Heckmann, 1992	Preop										50						
	Postop										44						
Little et al., 1986	Preop	30				6					42.0	4.8	4.6		18		
Milošević and Samardžić, 2000	Preop																
Nemeth et al. 2000	Preop	47		4													
	1 y postop	29		11													
Onizawa et al. 1995	Preop	50			Nb						50.1	II 8.0	II 7.4				40
	3 mo										II 39.4	II 5.4	II 5.2				
											III 37.3	III 6.5	III 5.8				
	6 mo										II 40.6	II 6.7	II 6.5				
											III 41.3	III 6.9	III 6.5				
Pihlaja and Heiser, 2004	Pre-Rx	35		8	21	32											28
	~2 y postop	13		32	10	22											26
Pinals et al. 2000	Preop	42		22	45	50									0		
	1 y postop	42		20	12	20									13		
	Latest follow-up	48		30	16	16									30		
Raveh et al. 1988	Preop	6		3	6												
	1-6 y postop	4		2	1												
Rodriguez-Garcia et al. 1998	Preop	49	14	5													
	2 y postop	24	8	15													
Schaerlaeck et al. 1994	Preop										46.8						
	1 y postop	6				13					45.8					2	

Table III. Continued

Author, year	Time interval	Joint sounds: Click (%)	Joint sounds: Pop (%)	Joint sounds: Crepitus (%)	Pain: TMJ (%)	Pain: Muscle (%)	Pain: Jaw (%)	Pain: Face (%)	Pain: Movement (%)	Pain: Ear (%)	Range of jaw movement: MID (mm)	Lateral excursions (mm): Right	Lateral excursions (mm): Left	Lateral excursions (mm): N/S	Limited opening (%)	Jaw locking	Deviation
Scott et al. 1997	8 wk postop	R 3		R 0	R 0										R N/R		
		CE 17		CT 2	CE 48										CE 90		
	6 mo postop	R 3		R 0	R 2										R N/R		
		CE 43		CE 3	CE 48										CE 65		
	1 y postop	R 3		R 0	R 2										R 0		
		CE 33		CE 12	CE 45										CE 33		
	2 y postop	R 7		R 2	R 3										R 3		
		CE 50		CE 10	CE 29										CE 21		
Smith et al. 1992	Preop	50		8							49.7	9.9	8.9				
	6-7 mo postop	64		9							44.8	8.6	8.5				
Timms et al. 1986	Preop	54			4	18											25
	6-36 mo postop	36			4	14											18
Ueki et al. 2001	Preop	62		7							SP 44.4						
											BP 49.6						
	1 y postop	19		7							SP 40.7						
											BP 45.8						
Westermark et al. 2001	Preop	74													N/R		
	2 y postop	N/R													10		
White and Dubrick, 1992	Preop	35	4	8	20	21									13		
Wolford et al. 2005	Preop	64			16						48.6			8.5			
	Longest follow-up	16			24						48.7			6.7			

MID, Maximal incisal opening (mean, unless a range is given). *Preop*, before surgery; *postop*, after surgery; *preortho*, before orthodontic treatment; *pre-Rx*, pretreatment; *N/S*, not specified; *N/R*, not reported; *N/A*, not applicable; *IMF*, intermaxillary fixation surgical group; *RF*, rigid fixation group; *SP*, straight plate; *BP*, bent plate; *R*, records; *CE*, clinical examination; *RHS*, right-hand side; *LHS*, left-hand side; *II*, skeletal Class II; *III* skeletal Class III. *Results for both clicks and deviations were combined; †Study looked at number of joints affected, not patients.; ‡Results are subdivided according to surgical groups (mandibular and maxillary osteotomies).; §Range of motion on mouth opening was reduced to the following percentages.

presurgery and 35.5 mm 3 months postsurgery, but studies with a longer follow-up, such as that of Borstlap et al,[30] showed a more modest reduction from 46.4 mm before surgery to 45.6 mm 2 years after surgery.

The percentages of patients with confirmed TMD at various time intervals are shown in Table IV. A positive diagnosis of TMD in presurgery patients varied between 7% and 78%.[12,34] In the 18 longitudinal studies with follow-up data, the postoperative prevalence of TMD varied. The percentages of patients affected by TMD decreased in most (n = 12) studies. This decrease in TMD was marked in some studies: from 43% to 28%[13] and from 73% to 48%,[18] and less in others—from 66% to 62%.[10] TMD prevalence remained the same in 1 study[33] and actually increased in 6 studies.[3,14,15,20,27,31] This increase was marked in some studies: from 36% to 84%[3] but less in others—40% to 45%.[20]

Change in TMD signs and symptoms are given in Table V. Thirty-five studies reported changes in TMD. There was, however, great variability in the signs and symptoms investigated in the studies. The initial time point for most studies was presurgery, although in 2 studies it was before orthodontic treatment.[11,35] Subsequent follow-up time intervals ranged from 6 months after surgery to more than 9 years.[36] There was little consistency in the changes in TMD signs and symptoms during the follow-up intervals. Only 13 studies reported whether patients who were asymptomatic before surgery developed new signs and symptoms after surgery; this ranged from 4%[37] to 35%.[14]

The percentages of patients who had improvements in signs or symptoms ranged from 6%[21] to 89%,[4] and 5%[38] to 41%[14] had worse TMD signs and symptoms. In most studies that reported whether symptoms got better, worse, or remained the same, the percentages of patients whose symptoms improved (18 studies of 23) outweighed those whose symptoms worsened (4 of 23). In patients who had TMD signs and symptoms in the initial time period, the percentages whose symptoms remained the same ranged from 3%[4] to 67%.[9]

TMD findings in studies that used the Helkimo index are shown in Table I. Twelve studies classified TMD according to the Helkimo or the modified Helkimo, index. The percentages of patients with no dysfunction preoperatively ranged from 4%[11] to 43%.[13] After surgery, these changed to 8% and 58%, respectively. In 4 studies where a before-and-after comparison was possible, the percentage of patients with no dysfunction increased after surgery. It remained the same in 1 study[33] and decreased in 2 studies.[9,15]

When mild dysfunction was considered, the percentages of patients affected ranged from 13%[11] to 58%[33] before surgery, and between 38%[11,13] and 68%[9] after surgery. The percentages of moderate dysfunction ranged from 7%[13] to 75%[11] before surgery, and 5% and 54% after surgery, respectively. Few studies reported patients with severe dysfunction (n = 3). In 4 studies, the percentage of patients with mild dysfunction increased after surgery, whereas the percentages of patients with moderate or severe dysfunction showed a tendency to decrease after surgery (n = 5).

Only 4 studies also recorded the anamnestic index.[9,11,13,14] The results for this component of the Helkimo index varied between studies, but the percentages of patients with severe symptoms decreased after surgery in those 4 studies.

Meta-analyses

As stated in the methodology, because of the few studies included and the high variability of their estimates, random-effects meta-analyses were used in this study.

The percentages of orthognathic patients with TMD before surgery are shown in Table VI. The random-effects pooled estimate of TMD prevalence before surgery for the studies was 74% (95% CI, 57%-92%) (Table VI, Fig 1). The forest plot[7] shows statistically significant between-study variations in the percentages of patients affected by TMD before surgery (Fig 1). The greatest weight was given to the study of Panula et al,[11] with an estimate of 97% (95% CI, 92%-100%).

Information on patients with skeletal Class II deformity having BSSO advancement procedures is presented in Table VII. There were significant between-study variations in the reported percentages of presurgery patients affected by TMD in the 3 Class II mandibular advancement studies.[9,10,13] Significant between-study variations were also found for the percentages of TMD postsurgery and overall changes after treatment. The forest plots of the percentages of patients with TMD before and after surgery are shown in Figure 2, *A* and *B*. The change in the percentage of patients affected by TMD is shown in Figure 2, *C*. Figure 2, *A*, shows that the pooled meta-analysis effect corresponds to a preoperative TMD percentage of 59% (95% CI, 35%-84%), and Figure 2, *B*, shows a pooled postsurgery percentage of 72% (95% CI, 40%-100%). Figure 2, *C*, indicates a pooled change in the percentage of patients affected by TMD of 16% (95% CI, −9%-41%). This point estimate corresponds to an increased prevalence of the condition but was not statistically significant ($P = 0.216$).

Information on patients with VME undergoing LeFort 1 maxillary impaction procedures is given in Table VIII. Only 2 studies were included in this meta-analysis. The meta-analysis for the postsurgical data is shown, and the pooled estimate for the studies was 68% (95% CI, 52%-84%). It was not possible to carry out a meta-analysis on the preoperative data or to estimate the change after treatment because the preoperative results in the study of Little et al[14] were not reported. Figure 3 shows that the estimates for both studies (71% and 65%) were similar to the pooled meta-analysis estimate of 68% (95% CI, 52%-84%). However, only 2 studies contributed to these results.

Table IV. Patients with confirmed TMD at various time intervals (percentages were rounded up)

Author, year	*Preortho (%)*	*Presurgery (%)*	*<6 mo postop (%)*	*≥6 mo postop (%)*	*≥1 y postop (%)*	*≥2 y postop (%)*
Aghabeigi et al, 2001	40					45
Aoyama et al, 2005		30				38
Athanasiou and Melsen, 1992		67		67		
Athanasiou and Yücel-Eroğlu, 1994		66		62		
Athanasiou et al, 1996*		Mn 62		Mn 77		
		Mx 88		Mx 71		
Borstlap et al, 2004		39		31		31
Cuthirth et al, 1998		7				
Dahlberg et al, 1995		53				
De Boever et al, 1996		58				
De Clercq et al, 1995		26		18		
Dervis and Tuncer, 2002		60				38
Herbosa et al, 1990		38			21	
Hu et al, 2000		44				
Kallela et al, 2005		73				48
Karaboutu and Martis, 1985		41		11	11	11
Kerstens et al, 1989		16				
Lai et al, 2002		26		4	4	4
Landes, 2004†		II 64			II 7	
		III 21			III 0	
Little et al, 1986		47	59	59	59	59
Milosevic and Samuels, 2000				43		
Motamedi, 1996		69				
Nurminen et al, 1999	32					
Onizawa et al, 1995		67				
Pahkala and Heino, 2004		78				
Panula et al, 2000	73					60
Raveh et al, 1988		28				
Rodrigues-Garcia et al, 1998		46				74
Schearlinck et al.1994		46				
Smith et al, 1992‡		A 73				
		C 82				
Ueki et al, 2001		43				
Ueki et al, 2002		74				
Upton et al, 1984		53				
Westermark et al, 2001		43				28
White and Dolwick, 1992		49				
Wolford et al, 2003		36				84

Preortho, Before orthodontic treatment; *Postop*, after surgery.
*Results were divided into 2 groups by surgery type: *Mn*, mandibular osteotomy group; *Mx*, maxillary osteotomy group; †Results were presented according to skeletal classification: *II*, Class II; *III*, Class III; ‡A, TMD diagnosis based on anamnestic evaluation; *C*, TMD diagnosis based on clinical evaluation.

DISCUSSION

There was great variability in the percentages of patients who noted improvement in joint sounds after surgery in their self-reports, and no conclusive trend was observed with regard to these symptoms.

The patients' perception was that pain tended to improve after surgery. For almost all types of pain reported (TMJ, jaw, muscles, face), there was a tendency for the percentages of patients with reported pain to decrease after surgery. This was also true for headaches. It is unclear whether this is a genuine effect caused by changes in the joint as a result of the surgery or a placebo effect because of the patients' altered outlook. Although a placebo effect in patients undergoing orthognathic interventions has not been

Table V. Change in TMD signs and symptoms

Author, year	Sign/symptom	Initial time interval	Affected (%)	Follow-up time interval	Affected (%)	Same (%)	Better (%)	Worse (%)	New symptoms/signs (%)
Aghabeigi et al, 2001	Pain	Preop	40	1 y postop	45	30	N/R	8	N/R
	Dysfunction		N/R		43	32	N/R	11	N/R
Aoyama et al, 2005	TMD	Preop	29	1 y postop	38	60	16		24
Athanasiou and Melsen, 1992	Muscular pain	Preop	11	6 mo postop	11				
	Mandibular mobility		53		67				
	TMJ function		39		11				
	TMJ pain		8		0				
Athanasiou and Yucel-Eroğlu, 1994	TMD	Preop	66	6 mo postop	62	n = 1	n = 11	n = 8	
Athanasiou et al, 1996	TMD in mandibular osteotomy group	Preop	62	6 mo postop	77			15	
	TMD in maxillary osteotomy group	Preop	88	6 mo postop	71		18		
Azami et al, 2004	TMJ symptoms	Preop	n = 6 N = 13	Postop	n = 7	n = 1	n = 6	n = 7	
Borstlap et al, 2004	TMD	Preop	39	24 mo postop	30	64			22
Corbett et al, 1998	Click	Preop	39	Postop			21	10	
	Pain		13				8	10	
De Clercq et al, 1995	TMD	Preop	27	6 mo postop	18		n = 34	n = 17	
De Clercq et al, 1998				1-2.5 y postop		49	40	11	
Derrick and Turner, 2002	TMD	Preop	60	2 y postop	38				10
Egermark et al, 2000	TMD			2.2-9.5 y postop		37	51	12	
	Headache					33	67	—	
	Chewing ability					17	81	—	
Feinerman and Piecuch, 1995	Click	Preop	52	2.5-9 y postop	49	n = 7	n = 23	n = 4	
	TMJ pain		20		14	n = 2	n = 10	n = 1	
	Muscle pain		33		29	n = 5	n = 16	n = 1	
Hackney et al, 1989	Click	Preop	22	6-12 mo postop	17	6	17	11	
	TMJ pain		17			11	6		
Hu et al, 2000	TMD	Preop	22	6 mo postop		41	55	10	
Hwang et al, 2004	TMJ sounds	Preop	59	2 y postop	46		26		26
	TMJ pain		21		28				
Kalfelz et al, 2005	1 or more signs or symptoms of TMD	Preop	73	Latest follow-up 1-5 y postop	48		41	18	
Karaiwora and Martis, 1985	1 or more signs or symptoms of TMD	Preop	41 n = 114	Postop	11.3 n = 12				4 n = 6
			N = 280		N = 114				N = 166
Kerstens et al, 1989	TMJ pain and dysfunction	Preop	16	1.4-4.7 y postop			66	12	
Lai et al, 2002	Clicking ± pain	Preop	26 n = 6 N = 23	>6 mo postop	4	n = 0	n = 6		n = 1
Little et al, 1986	TMD	Preop	47 n = 8 N = 17	1.4-4.7 y postop	59 n = 10 N = 17	6 n = 1	35 n = 6	41 n = 7	35 n = 6

Table V. Continued

Author, year	Sign/symptom	Initial time interval	Affected (%)	Follow-up time interval	Affected (%)	Same (%)	Better (%)	Worse (%)	New symptoms/signs (%)
Onizawa et al, 1995	1 or more subjective findings	Preop	67	6 mo postop		33	30	17	
Pahkala and Heinonen, 2004	TMD	Preop	78 n = 56 N = 72	1.9 y postop	67 n = 48 N = 72		51 n = 37 N = 72	14 n = 10 N = 72	
	TMJ pain					n = 4	n = 11		n = 3
	Clicking					n = 5	n = 20		n = 4
	Crepitation					n = 5	n = 1		n = 4
	Locking					n = 0	n = 4		n = 1
	Muscle pain					n = 10	n = 13		n = 6
	Deviation					n = 5	n = 15		n = 14
	Headache					n = 6	n = 27		n = 3
Pantaleo et al, 2000	1 or more signs or symptoms of TMD	Preortho	73	29 mo postop	60				7
Ravesh et al, 1988	TMD-eg, pain, subluxation and clicking	Preop	28	1-4 y postop		26	64	7	
Rodrigues-Garcia et al,1998	Pain	Preop	46	2 y postop	31	19	27	13	
Schoenlaub et al, 1994	TMD	Preop	46 n = 47 N = 103	Postop		20	68	12	11 n = 11 N = 103
Scott et al,1997	NR*								
Smith et al, 1992	TMD anamnestic evaluation	Preop	73	6-7 mo postop		50	32	18	
	TMD clinical evaluation		82			64	18	18	
	Clicks					67	13	20	
Ueki et al, 2001	TMD	Preop	67 n = 28 N = 42	1 y postop			64 n = 18 N = 28		
Ueki et al, 2002	TMD-based on radiographic examination	Preop	74 n = 32 N = 43	6 mo postop			n = 21		
Upton et al, 1984	TMJ pain and dysfunction symptoms	Preop	53	Postop		16	78	5	8.5
Westermark, 2001	1 or more signs or symptoms of TMD	Preop	43	2 y postop	28				21
White and Dolwick, 1992	TMD	Preop	49	Postop		3	89	8	8
Zhou et al, 2001	Pain	Preortho	54	Postop			51		
	Clicking		55				67		

Preop, Before surgery; *postop*, after surgery; *preortho*, before orthodontic treatment; *NR*, not reported.*When possible, percentages were reported; otherwise, *n*, number of patients affected; *N*, total patients in group.

Table VI. Heterogeneity test and meta-analysis for the overall proportion of TMD presurgery

Study/method	Study estimate/ pooled estimate	95% CI	
		Lower	Upper
Athanasiou and Yucel-Eroglu, 1994	0.66	0.56	0.76
Kallela et al, 2005	0.57	0.42	0.73
Smith et al, 1992	0.82	0.66	0.98
Pahkala and Heino, 2004	0.67	0.57	0.77
Panula et al, 2000	0.97	0.92	1.01
Pooled (random)	0.74	0.57	0.92

Test for heterogeneity: Q = 65.384 on 4 degrees of freedom (P <0.001).

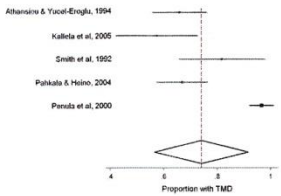

Fig 1. Forest plot of the overall proportion of patients with TMD preoperatively.

Table VII. Heterogeneity test and meta-analysis for patients with skeletal Class II deformity having BSSO

Study/method	Proportion of skeletal Class II patients with TMD presurgery			Proportion of skeletal Class II patients with TMD postsurgery			Change in proportion of TMD pre- and postsurgery in skeletal Class II patients			
	Study estimate/pooled estimate	95% CI		Study estimate/pooled estimate	95% CI		Study estimate/pooled estimate*	95% CI		P value
		Lower	Upper		Lower	Upper		Lower	Upper	
Athanasiou and Yucel-Eroglu, 1994	0.33	0.07	0.60	0.83	0.62	1.04	0.50	0.16	0.84	N/A
Kallela et al, 2005	0.57	0.42	0.73	0.43	0.27	0.58	−0.01	−0.23	0.20	N/A
Smith et al, 1992	0.82	0.66	0.98	0.91	0.79	1.03	0.09	−0.11	0.29	N/A
Pooled (random)	0.59	0.35	0.84	0.72	0.40	1.04	0.16	−0.09	0.41	0.22
Test for heterogeneity	Q = 10.500 on 2 degrees of freedom (P = 0.005)			Q = 24.721 on 2 degrees of freedom (P <0.001)			Q = 6.378 on 2 degrees of freedom (P = 0.041)			

*A positively signed change estimate indicates that the proportion of patients with TMD is increasing.
N/A, Not applicable.

explored, it has been studied in medicine. Turner et al[39] reviewed the literature to investigate the importance and implications of placebo effects in pain treatment. They found that placebo response rates vary greatly and are frequently much higher than the often-cited one third, and, as with medication, surgery can also produce substantial placebo effects. They concluded that placebo effects influence patient outcomes after any treatment, including surgery, which the clinician and the patient believe is effective.

In contrast to the patients' self-reported symptoms, the clinical findings seemed to advocate a reduction in clicking after surgery. The improvement in clicking might be related to repositioning of the condylar disc complex especially during BSSO surgery for correction of Class II skeletal relationships.[23] It must be acknowledged that a reduction in clicking might not necessarily relate to recapturing the disc but, rather, to the progression of the patient to a worse condition of disc displacement without reduction. This condition is often accompanied by a reduction in mouth opening, but this was difficult to assess from the articles with the level of detail that they provided. Magnetic resonance imaging would address this conflict, but unfortunately only 2 studies used this.[23,40] Encouragingly, the results from these studies indicated that the joints with displaced discs were more likely to show no change or an improvement. Twenty-two of 24 studies found that clicking improved after surgery; therefore, one can guardedly advise patients of this. The results for crepitus were more varied, with some studies reporting an increase and others a decrease after surgery. Crepitus is closely associated with pathology or resorption of the condylar head, and the exact influence of surgery on this is unclear. The incidence of condylar resorption, however, was about 7.5%.[13]

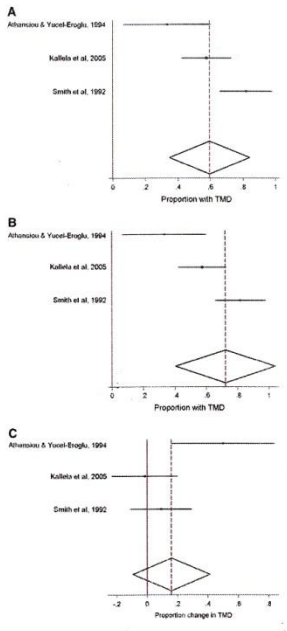

Fig 2. Forest plots: **A,** proportion of TMD before surgery in skeletal Class II patients having BSSO; **B,** proportion of TMD after surgery in skeletal Class II patients having BSSO; **C,** change in proportion of TMD before and after surgery in skeletal Class II patients having BSSO.

Clinically diagnosed pain on palpation was similar to the patients' self-reported findings, and all types of pain had a tendency to improve after surgery. Clinicians can be cautiously optimistic when discussing pain with patients suffering from TMD, since there appears to be a strong indication for less TMJ-related pain after surgery.

Almost all studies reported average increases in limitation in mouth opening after surgery, but this is most likely due to inflammation and scar tissue formed as a direct result of the surgery. It is not uncommon for patients to have reduced mouth opening immediately after surgery, and this often continues to improve up to 24 months after surgery.[41] Borstlap et al[30] found an average reduction in opening of 1 mm at 2 years postsurgery; this is unlikely to be clinically relevant.

It is difficult to determine the true prevalence of TMD among orthognathic patients as a whole. There was great variability among the studies with regard to the percentages reported (7%-78%), and this might be explained by the different criteria used when assessing and classifying TMD. It could also depend on the characteristics of the study participants (ie, their skeletal relationships, ages, and so on). However, TMD is seen frequently in orthognathic patients, and clinicians should have a thorough understanding of the likely effects of surgery on the prevalence and severity of TMD when they explain informed consent to their patients.

Table VIII. Heterogeneity test and meta-analysis of VME patients

Study/method	Study estimate/ pooled estimate	95% CI	
		Lower	Upper
Athanasiou et al, 1996	0.71	0.49	0.92
Little et al, 1986	0.65	0.42	0.87
Pooled (random)	0.68	0.52	0.84

Test for heterogeneity: Q = 0.135 on 1 degree of freedom (P = 0.713).

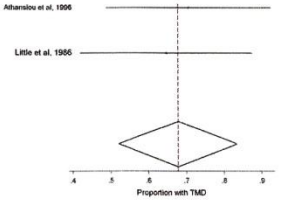

Fig 3. Forest plot of the postoperative proportion of TMD in patients with VME having LeFort 1 maxillary impaction.

Meta-analyses

As previously stated, it was only possible and appropriate to conduct meta-analyses with a few studies. The meta-analysis pooled estimate for the preoperative percentage of orthognathic patients with TMD was 74% (95% CI, 57%-92%). However, the wide 95% CI highlights the lack of precision of this estimate. This estimate was toward the higher end of the range reported in the narrative findings and was influenced by the great weight given to the study of Panula et al[11] (Fig 1). Those authors discussed the high prevalence reported in their study and reiterated that other studies also found a high prevalence of TMD in orthognathic patients.[42,43] They attributed the differing prevalences of TMD reported in the literature to different criteria for reporting symptoms, different characteristics of the patient samples, and varying patterns of referrals.

Patterns of referrals can vary by country and culture, and this might impact the prevalence of TMD in orthognathic patients. Studies finding that most orthognathic patients have normal TMJ function suggest a cosmetic motive for seeking treatment.[44] In contrast, certain cultures advocate orthognathic surgery for persons with functional impairments, and these studies are likely to report a greater percentage of patients affected by TMD.

Given the clinical and statistical heterogeneity associated with TMD in patients referred for orthognathic treatment, one must question whether obtaining a single estimate for the percentage of TMD is appropriate. There might be several different estimates based on differing patient characteristics (skeletal relationship) or interventions (type of surgery).

The presurgery percentage of skeletal Class II patients with TMD was 59% (95% CI, 35%-84%), and the postsurgery percentage was 72% (95% CI, 40%-100%). The wide 95% CIs associated with the estimates indicate lack of precision. The point estimate for the change in the percentage of patients with TMD when comparing pretreatment and posttreatment suggests a 16% increase in TMD prevalence (95% CI, −9%-41%), but this was not statistically significant, and the wide 95% CI again indicates lack of precision. Thus, the meta-analysis results provide no definitive findings; this can be attributed to the small number of pooled studies and the heterogeneity among them.

The final meta-analysis concerned the percentage of patients with VME affected by TMD after surgery. The pooled estimate of TMD prevalence at postsurgery was 68% (95% CI, 52%-84%). Unfortunately, the lack of presurgery data prevented an estimate of its prevalence and also an estimate of the presurgery-to-postsurgery change. Nonetheless, a postsurgical TMD prevalence of 68% is relatively high. The negative effects of LeFort I impactions might be related to autorotation of the mandible, which reduces the anatomic distance between the condyle and the fossa, potentially squeezing the disc.[45] Alternatively, it could be the result of postsurgical condylar displacements, attributed to reprogramming muscular environments or the remodeling process.[15,46]

The findings from all meta-analyses in this review were subject to considerable variations, so that it was not possible to draw strong inferences. It is important to explain sources of heterogeneity in these results; in most cases, the study design (cohort) meant that there was considerable potential for selection bias to have affected the results. Additionally, one can hypothesize that, in studies of this type, clinicians are alert to the importance of identifying patients with TMD, and this is a potential source of measurement bias. Other sources of heterogeneity involving patient characteristics, interventions, and outcomes were discussed in Part 1 of this study.

CONCLUSIONS

The conclusions that can be drawn from this systematic review have several clinical implications that might be useful for orthodontists and surgeons when advising patients and obtaining informed consent.

1. Patients having orthognathic treatment for correcting dentofacial deformities and also suffering from TMD are more likely to see improvements in their signs and symptoms than deterioration. This trend can be included in the information given to prospective patients, but it should be stressed that no guarantees can be made.
2. Clicking is more likely to improve than deteriorate after surgery. In contrast, crepitus does not seem to be affected by surgery.
3. Most patients experience restriction in mouth opening and lateral excursions after surgery. This, however, continues to improve, and most patients regain the full range of movement 2 years after surgery.

In addition, clinicians should study the routine radiographs (lateral cephalometric and panoramic radiographs) taken before treatment for any signs of condylar resorption and perhaps look for risk factors associated with resorption.

The major limitation in conducting a literature review relating to TMD was the heterogeneity of the studies. Many researchers noted this shortcoming; thus, the following recommendations can be made.

1. Set criteria should be used for diagnosing and classifying TMD that are valid, reproducible, and simple to carry out.
2. Future research in TMD should adhere to an internationally recognized set of criteria and a universal scale.
3. More prospective longitudinal studies are needed with strict quality-assurance protocols to minimize bias, thus increasing their standing in the evidence-based hierarchy.
4. Research should focus on categorizing participants homogenously to reduce the effects of confounding factors and enable adequate comparisons to be made between studies.

By heeding these recommendations, it should be possible to conduct good-quality studies that are adequately homogenous to allow comparisons and enable statistical analyses, further strengthening conclusions about TMD and orthognathic surgery.

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