

The influence of oral health factors on the quality of life in older people: a systematic review

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Conflict of Interest

The authors declare that there are no conflicts of interest.

Abstract

Background and Objectives: The number of people aged 65 years or older is growing substantially. As a result of increased health burden and tooth retention, more oral health problems are expected in this age group. A poor Oral Health-related Quality of Life (OHQoL) can compromise a person's psychological state, social relationships, personal beliefs, and physical health. The aim of this systematic review is to identify oral health factors associated with OHQoL in people aged 65 years or older, and to give a comprehensive overview of the body of literature for each oral health factor separately.

Research Design and Methods: A comprehensive search was performed in 5 databases. The following terms were used as index terms or free-text words: "Oral Health", "Quality of Life", "Older People". Two researchers independently assessed studies for eligibility based on predefined criteria.

Results: Of 3,702 references retrieved from the databases, 68 studies were eligible and included (9 RCT's, 6 cohort studies, and 53 cross-sectional studies). All results were reported descriptively. OHQoL in people aged 65 years or older is positively associated with higher number of teeth, higher number of occluding pairs, implant-retained overdentures, and the Shortened Dental Arch concept; and negatively associated with xerostomia, orofacial pain, and poor chewing ability. In the current literature there is no consensus on the association between edentulism, caries, and periodontal conditions and OHQoL.

Discussion and Implications: Having a functional dentition (either natural or prosthetic) is important for a good OHQoL, whereas painful or functional complaints are associated with impaired OHQoL.

Keywords: oral health-related quality of life, dental status, dentition

Introduction

In 2017, the United Nations published a report about global ageing, showing that the older population is expected to increase substantially (United Nations, 2017).

Not only will the numbers of older people increase, but since older people are more likely to suffer from comorbid disease (Kassebaum et al., 2017), ageing of the world population will lead to an increased number of people with multiple comorbid diseases (Kassebaum et al., 2017). Nowadays, due to improved dental care during the lifespan, older people tend to retain more natural teeth (Petersen, 2003). Since impaired general health has a negative effect on oral health, and more older people have natural teeth, more oral health problems are expected in this population (Kassebaum et al., 2017).

Appropriate access to oral health care can improve the overall quality of life, even in older people with multimorbidity (Locker, Matear, Stephens, & Jokovic, 2002). The World Health Organization defines quality of life as ‘an individual’s perception of their position in life in the context of the culture and value systems in which they live and in relation to their goals, expectations, standards and concerns’ (Gift, Atchison, & Dayton, 1997). Impaired quality of life can compromise a person’s psychological wellbeing, social relationships, personal beliefs, and physical health (Gift et al., 1997). To focus on how to improve the quality of life of an older person in dental care, it is important to know which oral health factors contribute to improved quality of life. Only a few previous reviews have reported on oral health factors influencing quality of life in adults (Ferreira, Dias-Pereira, Branco-de-Almeida, Martins, & Paiva, 2017; Gerritsen, Allen, Witter, Bronkhorst, & Creugers, 2010; Ilhan, Cal, Dunder, Guneri, & Daghan, 2015; Tan, Peres, & Peres, 2016). Strikingly, with the exception of a single paper, there are no systematic reviews in the existing literature which comprehensively synthesise the associations of oral health factors with quality of life in older people (Cunha et

al., 2014). A person over 65 years old may have different values and perspectives than an 18-year-old adult.

The concept of Oral Health-related Quality of Life (OHQoL) is based on the perspective that oral health conditions and diseases can undermine someone's self-esteem and self-image, can cause other health problems, can discourage social interaction, and can lead to pain, stress or depression (Bennadi & Reddy, 2013). Furthermore, it could influence vital functions, such as swallowing, speaking, and breathing (Rozier & Pahel, 2008). The most widely used method to assess OHQoL is multiple items questionnaires (Bennadi & Reddy, 2013). They often contain questions regarding a person's perception on physical health, psychological status, and functional capacity (McGrath, Broder, & Wilson-Genderson, 2004).

One of the goals in dental care is to improve OHQoL of patients, which requires an understanding of which factors contribute to OHQoL (O'Boyle, 1997). In adults OHQoL is affected by impaired oral health (Ilhan et al., 2015), including the number of remaining natural teeth, the number of occluding pairs, and the location of remaining teeth (Gerritsen et al., 2010; Tan et al., 2016), and periodontal disease (Ferreira et al., 2017).

A systematic review conducted in 2013 on the influence of oral health and literacy on OHQoL, concluded that there is a negative impact of edentulism on OHQoL in people aged 65 years or older (Cunha et al., 2014). However, in this systematic review, the results of the 11 included studies were summarized separately, and the results were not systematically reported for each oral health factor. With the exception of this single paper, there are no other systematic reviews that describe the associations of oral health factors with OHQoL in older people. Due to global ageing, the proportion of people aged 65 years or older attending dental care clinics will increase substantially. For dental care professionals it is important to know which factors contribute to improved OHQoL, and what they should focus on when treating this specific population. Therefore, the aim of this systematic review is to identify oral health

factors associated with OHQoL in people aged 65 years or older, and to give a comprehensive overview of the body of literature for each oral health factor separately.

Research Design and Methods

Search strategy

A review protocol was developed based on the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA)-statement (www.prisma-statement.org). A comprehensive search was performed in the bibliographic databases PubMed, Embase, EBSCO/CINAHL, EBSCO/PsycINFO, and Wiley/Cochrane Library from inception up to April 3rd, 2019, in collaboration with a medical librarian. The following terms were used (including synonyms and closely related words) as index terms or free-text words: “Oral Health”, “Quality of Life”, “Older People”. The search was performed without date or language restriction. After deduplication, all titles were screened and appropriate abstracts reviewed. The full search strategies for all databases can be found in **Appendix 1** of the Supplementary Material.

Inclusion and exclusion criteria

The titles, abstracts, and full texts were reviewed according to the following inclusion and exclusion criteria. The inclusion criteria were:

- Randomised Clinical Trial (RCT) studies, cross-sectional studies, case-control studies, or cohort studies
- older people aged 65 years or above
- participants stratified for oral health factor (e.g., healthy vs. control)
- validated measurement tool for Quality of Life

Exclusion criteria were:

- age below 65 years old
- age not specified

- participants not stratified for oral health factors
- case report or review
- no usable data (e.g., qualitative studies)

Study selection

Titles, abstracts, and full texts were independently screened by a dentist (LR, MSc) and a dental master student (CS, BSc). Conflicts were resolved by consensus meetings between LR, CS, and RW (neurobiologist, PhD). Two papers were in other languages than English and were screened and assessed by a native speaker and dentist. The reference lists of all included studies were screened for additional relevant studies, but none were found.

Quality assessment

The quality of the included studies was assessed by one reviewer (LR). The quality of the included RCT studies was assessed by one reviewer with the Cochrane Risk of Bias Tool, which assesses RCT studies on selection bias, performance bias, detection bias, attrition bias, reporting bias, and other bias (Savović et al., 2014). The quality of the cohort studies was assessed with the Newcastle Ottawa Scale (NOS), which assesses cohort studies on selection, comparability, and outcome (Wells G, 2000). Furthermore, the quality of the included cross-sectional studies was assessed with the Appraisal tool for Cross-Sectional Studies (AXIS tool), which assesses cross-sectional studies on reliability and relevance (e.g., selection bias, response bias, and internal consistency) (Downes, Brennan, Williams, & Dean, 2016).

Data extraction

Two researchers extracted and reviewed the data from the eligible studies (LR, CS). The following characteristics were extracted from the included studies: (1) design; (2) country;

(3) age; (4) population; (5) oral health factor; and (6) outcome tool (validated instrument for quality of life).

The included studies were categorized according to the following oral health factors domains, which were pre-defined based on the literature (Gil-Montoya, de Mello, Barrios, Gonzalez-Moles, & Bravo, 2015; Turner & Ship, 2007; Ying Joanna & Thomson, 2015): (1) natural dentition; (2) caries; (3) periodontal conditions; (4) prosthetic status; and (5) other oral health-related factors.

Analysis

All results were reported descriptively and tabulated. Meta-analysis was considered. However, the studies and results were too heterogeneous (e.g., different study designs and populations, different assessments of the measurements, and different outcome tools) to conduct meaningful meta-analysis.

Results

Study selection and characteristics

Of the 3,702 references retrieved from the databases, 68 studies were eligible and included (**Figure 1**). From the 68 studies, 9 were RCT's, 6 were cohort studies, and 53 were cross-sectional studies. Of the included studies, one was in Korean and one was in Portuguese (M. S. Park & Ryu, 2010; Rodrigues Gomes, Teixeira, & Pimenta Paçô, 2015). Characteristics of included studies are described in **Table 1**. The included papers were published from 30 different countries with 49 conducted in community, 9 in institutional care, and 2 in both. Four studies included older people with dementia.

Quality ratings

Quality ratings are described separately for RCT's, cohort studies, and cross-sectional studies in **Appendix 2, 3, and 4**, respectively. In all RCT some sort of bias was present, five out of six cohort studies were of poor quality according to the NOS, and the quality of the cross-sectional studies ranged from 10 to 20 criteria of the AXIS tool.

Quality of life outcome tools

Of the 68 included papers, 38 papers used the OHIP, or a variety of the OHIP, to measure OHQoL (Allen & Locker, 1997). Nineteen papers used the GOHAI and nine papers used the Oral Impact on Daily Performance (OIDP) questionnaire to measure OHQoL (Adulyanon, 1997; Atchison & Dolan, 1990). Furthermore, four papers used the Euroqol 5 Dimension (EQ-5D) to measure general quality of life (Krabbe, Stouthard, Essink-Bot, & Bonsel, 1999).

Results categorized in domains

Natural dentition

All reported associations regarding edentulism, number of teeth, number of missing teeth, and number of occluding pairs are shown in **Table 2**. Five studies reported significantly lower OHQoL in edentulous participants than in dentate participants (Hoeksema et al., 2017; Hoeksema et al., 2018; Motallebnejad, Mehdizadeh, Najafi, & Sayyadi, 2015; Stromberg, Holmen, Hagman-Gustafsson, Gabre, & Wardh, 2013; Zuluaga, Montoya, Contreras, & Herrera, 2012), two studies demonstrated a positive association between edentate patients in comparison to dentate patients and OHQoL (Lee, Yang, Ho, & Lee, 2012; Souza, Costa Oliveira, & Martins, 2017), and seven studies reported no significant association between edentulism and OHQoL (Alshammari, Baseer, Ingle, Assery, & Al Khadhari, 2018; Cornejo, Perez, de Lima, Casals-Pedro, & Borrell, 2013; Dahl, Wang, Holst, & Ohrn, 2011; Kohli, Sehgal, Nelson, & Schwarz, 2017; Rebelo, Cardoso, Robinson, & Vettore, 2016; Sheiham et

al., 2001; Yu, Lee, Hong, Lau, & Leung, 2008). All studies regarding edentulism were cross-sectional studies. Only two studies, showing either no significant association or a negative association between edentulism and OHQoL, met all quality criteria of the AXIS tool (Hoeksema et al. 2018; Rebelo et al., 2016). One cohort study of poor quality showed that participants with permanent tooth loss were most likely to both worsen and improve OHQoL (Astrom, Ekback, Ordell, & Gulcan, 2018).

The number of natural teeth was found to be positively associated with OHQoL in twenty-one studies (Cornejo et al., 2013; Dahl et al., 2011; Eric et al., 2012; Ha, Heo, Jin, Paik, & Bae, 2012; Jensen, Saunders, Thierer, & Friedman, 2008; Jung & Shin, 2008; Kato et al., 2018; Klotz, Hassel, Schroder, Rammelsberg, & Zenthofer, 2017; Mihara et al., 2018; Satoshi Noguchi, Michiko Makino, Satoru Haresaku, Kaoru Shimada, & Toru Naito, 2017; Paredes-Rodriguez et al., 2016; Rodrigues Gomes et al., 2015; Saez-Prado, Haya-Fernandez, & Sanz-Garcia, 2016; Shao et al., 2018; Sheiham et al., 2001; Silva et al., 2011; Stromberg et al., 2013; Tsakos, Marcenes, & Sheiham, 2004; Wu, Cheung, Lam, & Gao, 2017; Yen et al., 2015; Zuluaga et al., 2012), with four studies finding no significant association between number of teeth and OHQoL (K.-J. Hsu et al., 2014; M. S. Park & Ryu, 2010; Santucci & Attard, 2015; Stenman, Ahlqwist, Bjorkelund, & Hakeberg, 2012). Regarding number of missing teeth, four studies found a significant negative association between number of missing teeth and OHQoL (Masood, Newton, Bakri, Khalid, & Masood, 2017; Saez-Prado et al., 2016; Santucci & Attard, 2015; Slade et al., 1996), while one study reported no significant association (Yoon et al., 2013). The study of Santucci et al. was conducted in institutionalised older people, while the other studies were conducted in community-dwelling older people.

One study reported a negative association between unfilled anterior spaces (gap between front teeth) and OHQoL (Stenman et al., 2012). With regards to occluding pairs (i.e., the

number of pairs of opposing lower and upper teeth), six out of eight studies concluded that there was a positive association between the number of occluding pairs and OHQoL (Eric et al., 2012; Shao et al., 2018; Tsakos et al., 2004; Wu et al., 2017; Yu et al., 2008; Zuluaga et al., 2012). The two studies that did not find an association between the number of occluding pairs and OHQoL, were of poor quality, meeting only 14 and 12 out of 20 criteria of the AXIS tool (Hsu et al., 2004; Santucci et al., 2015).

- **Summary:** There is no consensus on the influence of edentulism on OHQoL in people aged 65 years or older. However, there is overall agreement that a higher number of natural teeth and a higher number of occluding pairs are positively associated with OHQoL.

Caries

In **Table 3**, the associations between OHQoL and decayed teeth, Decayed Missing and Filled Teeth (DMFT), filled teeth, root caries, and retained roots are given. Seven studies found no significant association between decayed teeth and OHQoL (Dahl et al., 2011; Niesten et al., 2016; Noguchi et al., 2016; Rodrigues Gomes et al., 2015; Saez-Prado et al., 2016; Tsakos et al., 2004; Zuluaga et al., 2012), while four studies found a negative association between decayed teeth and OHQoL (Masood et al., 2017; Santucci et al., 2015; Strömberg et al., 2013; Wu et al., 2018). Four out of five studies reported a negative association between DMFT and OHQoL (Rebelo et al., 2016; Saez-Prado et al., 2016; Santucci et al., 2015; Shao et al., 2018). Regarding filled teeth, three studies reported a negative association with OHQoL (Noguchi et al., 2016; Saez-Prado et al., 2016; Tsakos et al., 2004), while one study reported no significant association (Santucci et al., 2015), and one study reported a positive association (Astrom et al., 2018).

The link between root caries (caries located on the root surface of a tooth) and OHQoL remains unclear: three studies reported a negative association between root caries and OHQoL (Ling et al., 2014; Shao et al., 2018; Slade et al., 1996), one study reported a positive association (Masood et al., 2017), and another one found no significant association between root caries and OHQoL (Tsakos et al., 2004). Retained roots (partial root structure that remains in the jaw following fracture or severely damage by caries) were negatively associated with OHQoL, according to two studies (Slade et al., 1996; Strömberg et al., 2013). One study found a negative association between presence of severely decayed teeth, ulceration caused by dislocated tooth fragments, fistula, and abscesses and OHQoL (Masood et al., 2017). All studies on the influence of caries on OHQoL were cross-sectional studies, varying with a quality rating from 12 to 20 on the AXIS tool. The different findings of the studies cannot be explained by the overall difference in quality.

- **Summary:** There is no consensus on the negative association between caries and OHQoL.

Periodontal conditions

Associations between pocket depth, mobility, bleeding, gingivitis, periodontitis, and abnormalities of the oral mucosa and OHQoL are given in **Table 4**. Three studies reported a negative association between pocket depth and OHQoL (Santucci et al., 2015; Shao et al., 2018; Slade et al., 1996), one study reported a negative association between mobility and bleeding and OHQoL (Porter et al., 2015), and one study reported a negative association between gingivitis and OHQoL (Yu et al., 2008). Two studies found a negative association between periodontitis and OHQoL (Göktürk & Uçan Yarkaç, 2018; Kato, Abrahamsson, Wide & Hakeberg, 2018). One study reported a positive association between a healthy periodontium and OHQoL (Cicciù et al., 2013).

On the other hand, more studies found no significant association between pocket depth (Masood et al., 2017; Noguchi et al., 2016; Wu et al., 2018), mobility (Tsakos et al., 2004), bleeding (Masood et al., 2017; Wu et al., 2018), gingivitis (Castrejon-Perez et al., 2017), or periodontitis (Castrejon-Perez et al., 2017; Rodrigues-Gomes et al., 2015) and OHQoL.

Additionally, two out of three studies found a negative association between abnormalities of the oral mucosa (e.g., ulcers, lichen planus, candidiasis) and OHQoL (da Silva et al., 2011; Shao et al., 2018).

Other studies found no significant association between periodontal inflammation (Yoon et al., 2013), and need for periodontal treatment and OHQoL (Cornejo et al., 2013). All studies regarding periodontal conditions were cross-sectional studies.

- **Summary:** There is no consensus on the negative association between periodontal conditions and OHQoL. From the 18 included studies, eight studies reported a negative association, one study reported a positive association, and nine studies reported no significant association.

Prosthetic status

Table 5 shows the associations between the prosthetic status and OHQoL. Four studies found a positive association between the use of removable dentures and OHQoL (da Silva et al., 2011; Klotz et al., 2017; Motallebnejad et al., 2015; Souza et al., 2017), six studies reported negative associations (Masood et al., 2017; Mihara et al., 2018; Stromberg et al., 2013; Yoon et al., 2013; Zhou, Zhang, Jiang, Wu, & Du, 2012; Zusman, Kushnir, Natapov, Goldsmith, & Dichtiar, 2016), and three other studies found no significant associations (Cornejo et al., 2013; Ha et al., 2012; K.-J. Hsu et al., 2014). Only one of these studies, reporting no significant association, was a cohort study (Ha et al., 2012). All other studies were cross-sectional studies. A negative significant association between OHQoL and non-functional dentures (dentures without stability, retention, and extension) was reported by two studies

(Castrejon-Perez et al., 2017; Klotz et al., 2017). Another cross-sectional study reported a negative association between OHQoL and dentures causing ulcers or bad breath (Alshammari et al., 2018).

One cohort study of good quality found an association between type of dental prosthesis and OHQoL, indicating a greater OHQoL in participants with a fixed dental prosthesis than those who wore removable dental prosthesis and conventional dentures (Klotz et al., 2018).

Moreover, after insertion of a new conventional denture, most studies, of which two RCT's, reported a positive association between new dentures and OHQoL (Campos, Ribeiro, & Rodrigues Garcia, 2017; Eric, Tihacek Sojic, Bjelovic, & Tsakos, 2017; Ha et al., 2012; Jabbour, Emami, de Grandmont, Rompre, & Feine, 2012; Komagamine et al., 2012; Pearson, Gibson, Davis, Gelbier, & Robinson, 2007), except for one RCT, which mentioned no significant association (Heydecke, Locker, Awad, Lund, & Feine, 2003).

Seven studies, of which five were RCT's, found statistically significant positive correlations between implant-retained overdentures in comparison with conventional dentures and OHQoL (Awad et al., 2003; Elham Emami, 2009; Emami, Allison, Grandmont, Rompré, & Feine, 2010; Geckili, Bilhan, & Bilgin, 2011; Heydecke et al., 2003; Hoeksema et al., 2017; Jabbour et al., 2012). Also, implant-retained overdentures compared with new conventional prostheses showed positive correlations with OHQoL, according to two RCTs (Emami et al., 2010; Müller et al., 2013). One cross-sectional study reported no significant differences in OHQoL between patients with implant-retained overdentures and dentate patients (Hoeksema et al., 2017).

Furthermore, only one study reported positive associations between OHQoL and characteristics of the removable partial denture (RPD), such as: aesthetics, retention, and fit (Hassel, Rolko, Grossmann, Ohlmann, & Rammelsberg, 2007). This is in contrast to fixed partial dentures, where no significant association between OHQoL and aesthetics was found

(Hassel et al., 2007). One study found positive associations between OHQoL and the aesthetics and speech function of the conventional denture (Komagamine et al., 2012). For maxillary denture retention and mandibular denture stability, positive associations were found with OHQoL as well (Chen et al., 2012). McKenna et al. conducted a RCT, showing that, regarding tooth replacement strategies for partially dentate people, treatment according to the Shortened Dental Arch (SDA) concept resulted in better OHQoL than treatment with RPD after 1-year and 2-year follow-up (McKenna et al., 2015; McKenna et al., 2018).

- **Summary:** There is no consensus of the influence of the use of dentures on OHQoL. Being satisfied with the dentures, proper function of the dentures, and no need for denture treatment, were positively associated with OHQoL. Several RCT's show a positive effect of implant-retained overdentures on OHQoL, and one RCT shows a positive correlation of the SDA concept compared to RPD.

Other oral-health related factors

The associations of other oral health factors that may have an influence on OHQoL are presented in **Table 6**. Most (8 out of 10) included studies found statistically significant negative associations between xerostomia and OHQoL scores (Castrejon-Perez et al., 2017; Gerdin, Einarson, Jonsson, Aronsson, & Johansson, 2005; Johansson et al., 2012; Paredes-Rodriguez et al., 2016; M. S. Park & Ryu, 2010; Porter et al., 2015; Rodrigues Gomes et al., 2015). There was no statistically significant association between hyposalivation and OHQoL (Gerdin et al., 2005). One study found a significant negative association between OHQoL and clinical symptoms of oral dryness (Skoskiewicz-Malinowska, Malicka, Zietek, & Kaczmarek, 2019).

One study reported no significant associations between OHQoL and orofacial pain, in contrast to four other studies that found negative associations (Alshammari et al., 2018; Jung

& Shin, 2008; Masood et al., 2017; Porter et al., 2015; Yen et al., 2015). The study that reported no significant association, had the lowest quality rating (14/20) (Yen et al., 2015). Furthermore, negative associations between OHQoL and the following oral health factors were reported by cross-sectional studies: presence of symptoms in the temporomandibular joint (Meneses-Gomez et al., 2016), sensitive teeth (Porter et al., 2015), halitosis (Yen et al., 2015), clinically assessed treatment need (Jensen et al., 2008; Motallebnejad et al., 2015; Niesten et al., 2016), and a poor opinion of their dental appearance (Cornejo et al., 2013; Meneses-Gomez et al., 2016; Östberg & Hall-Lord, 2011; Souza et al., 2017; Stenman et al., 2012). There was no association between OHQoL and burning mouth (Stenman et al., 2012). Moreover, three studies found positive associations between OHQoL and chewing ability (Cho & Kim, 2018; K.-J. Hsu et al., 2014; Östberg & Hall-Lord, 2011), but one study found no significant association (Lee et al., 2012). One study reported a significant positive association between occlusal force and OHQoL (Mihara et al., 2018).

- **Summary:** OHQoL is associated with xerostomia, but no association was found with hyposalivation. Furthermore, orofacial pain and poor chewing ability were negatively associated with OHQoL.

Discussion and Implications

The aim of this systematic review was to identify oral health factors associated with OHQoL in people aged 65 years or older, and to give a comprehensive overview of the body of literature for each oral health factor separately. We found higher number of natural teeth, higher number of occluding pairs, being satisfied with dentures, proper function of dentures, and not having a need for denture treatment were positively associated with OHQoL. Implant-retained overdentures compared to conventional dentures, and SDA concept compared to RPD, resulted in a better OHQoL in people aged 65 years or older. Xerostomia,

orofacial pain, and poor chewing ability were found to be negatively associated with OHQoL. There is no consensus in the current literature regarding the association between OHQoL and caries, periodontal conditions, and edentulism.

Natural dentition

Another systematic review concluded that edentulism in older people is associated with a poor quality of life (Cunha et al., 2014). However, they described the results of 11 papers separately, without clearly describing on what their final conclusion was based (Cunha et al., 2014). In our systematic search, it was found that most studies did not find a significant association between edentulism and OHQoL in people aged 65 years or older, and that there were two studies that reported a better OHQoL in edentate participants, due to the absence of dental problems that can only occur in natural teeth (Lee et al., 2012; Souza et al., 2017). The overall consensus on the negative effect of tooth loss has also been reported in the adult population (Gerritsen et al., 2010; Tan et al., 2016). A systematic review on qualitative studies shows that tooth loss is not only associated with diminished oral function, but is also associated with less self-esteem and loss of social status (Nordenram et al., 2013).

Caries

In the current literature, there is no consensus on the influence of caries on OHQoL in people aged 65 years or older. Impaired OHQoL due to caries may be caused by pain, poor aesthetics, or halitosis (Santucci & Attard, 2015). However, it is important to acknowledge that carious lesions do not always cause pain or may not be in the aesthetic zone, and as such, does not influence self-rated OHQoL.

Periodontal conditions

We found no consensus on the associations between periodontal conditions and OHQoL. Another systematic review found periodontal diseases have a negative impact on quality of life in adults, depending on the severity of the periodontal disease (Ferreira et al., 2017). However, periodontal disease is recognised as a “silent” disease, causing only a few or no symptoms, which could explain the results of the studies that did not find an association between periodontal conditions and OHQoL. Although periodontal disease may not directly lead to impaired OHQoL, it can ultimately lead to loss of teeth, and therefore have a negative impact on OHQoL in older people (Kato et al., 2018).

Prosthetic status

A previous review found a positive association between OHQoL and implant-retained overdentures compared to conventional dentures in the adult population (Strassburger, Kerschbaum, & Heydecke, 2006). We showed similar results for people aged 65 years or older. Implant-retained overdentures have better stability and retention, which supports patients’ satisfaction (Emami et al., 2010). This results in better chewing ability and improvement in aesthetics, speech, food choice, and social activity (Heydecke et al., 2003). Dissatisfaction with conventional dentures is the most common reason to fit implant-retained overdentures, which could also explain the better OHQoL of implant-retained overdentures compared to conventional dentures (Geckili et al., 2011).

Furthermore, regarding tooth replacement strategies for partially dentate people, the Shortened Dental Arch concept compared to Removable Partial Dentures resulted in a better OHQoL in people aged 65 years or older in this study. These results are in contrast with another review, which concluded that the SDA concept appears to be as feasible as RPD in terms of OHQoL in adults (Fueki & Baba, 2017). A recently conducted RCT showed no differences in chewing capacity between patients with SDA or RPD (Wallace et al., 2018).

Besides, patients often indicate that they do not want to have removable dentures (Cronin, Meaney, Jepson, & Allen, 2009). The shortened dental arch concept can therefore be a good strategy to prevent overtreatment and discomfort of removable dentures, while preserving a functional dentition (McKenna et al., 2015; McKenna et al., 2018).

Other oral-health related factors

Xerostomia is negatively associated with OHQoL, according to a few reviews (Gil-Montoya, et al. 2015). Xerostomia impacts on difficulties in swallowing and chewing, burning sensation, pain in salivary glands, and speech difficulties (Ying Joanna & Thomson, 2015). Furthermore, our review shows that orofacial pain has a negative influence on OHQoL in people aged 65 years or older. In adults, besides dental pain, negative associations were reported between temporomandibular disorders and OHQoL (Dahlstrom & Carlsson, 2010). Pain is known to have a negative impact on a person's physical and mental state, and social functioning (Sprangers et al., 2000).

Chewing ability has previously been reported as significantly related to lower OHQoL scores (Inukai, John, Igarashi, & Baba, 2010). In our review, poor chewing ability was also found to be negatively associated with OHQoL in people aged 65 years or older. This could be explained by diminished food intake and different food intake, which is caused by poor chewing ability (K. J. Hsu et al., 2014).

Quality assessment

From the 68 studies, 9 were RCT's, 6 were cohort studies, and 53 were cross-sectional studies. The RCT studies reported on the influence of implant-retained overdentures, conventional dentures, and the SDA concept on OHQoL, while the cohort studies reported on the influence of implant-retained overdentures, (new) conventional dentures, and fixed or

removable dentures on OHQoL. All other oral health factors were described in cross-sectional studies. It is important to acknowledge that results reported by cross-sectional studies cannot be used to determine cause and effect. However, cross-sectional studies are commonly used to determine factors that associate with a certain health related problem, in this case OHQoL. Most studies showed methodological flaws and some sort of bias. Performance and detection bias were often present in the RCT studies. According to the NOS, only one cohort study was of good quality and from the 53 cross-sectional studies, only three studies met all 20 criteria of the AXIS tool (Hoeksema et al., 2018; Porter et al., 2015; Rebelo et al., 2016).

Strengths & Limitations

This is the first systematic review on OHQoL for people aged 65 years or over including all oral health-related factors. Strengths include unrestricted literature searches, no language limitations, and study selection performed independently by two researchers.

Nonetheless, the sample size in each study varied greatly, from 32 participants in one study to a national survey (9,813 participants) study. Due to different study designs and populations, different assessments of the measurements, and different outcome tools, no meta-analysis could be performed. Furthermore, some studies did not adjust for confounders (e.g., age, gender, educational level, frailty, and general health) and the non-response rate was often not described, resulting in an increased risk for selection bias. In this review, we considered 65 years as the cut off point for older people. It is important to acknowledge, however, that in other countries younger individuals could be considered as older people.

Most of the included studies were cross-sectional. Future research with longer follow-ups and RCTs are needed to understand causal associations.

Clinical Implications

As people age, their perceptions and values with respect to quality of life may change (Stenman et al., 2012), and it is important to adjust the dental care accordingly. This review shows that to preserve a good OHQoL in dentate people aged 65 years or older, it is important to prevent tooth loss to preserve a good oral health-related quality of life. However, it should be acknowledged that more oral health problems can occur in dentate older people, due to impaired oral self-care and increased comorbid diseases (Kassebaum et al., 2017). This review shows that it remains unclear whether being dentate in people aged 65 years or older is preferable in terms of OHQoL than being edentate. People aged 65 years or older might benefit more from well-functioning dentures than from being dentate. More research is needed to determine at what point (e.g., number of teeth, missing front teeth) having well-functioning dentures is preferred over being dentate in terms of OHQoL. Furthermore, dental care in this population must focus on being free of pain and retain proper chewing ability. The results of the included studies are at population level, which should not mask the diversity on individual level. It is therefore recommended to evaluate each person's perceptions and wishes separately, to achieve the best possible treatment choice.

Conclusion

This is the first systematic review on OHQoL for people aged 65 years or over including all oral health-related factors. Having a functional dentition (either natural or prosthetic) is important for a good OHQoL, whereas painful or functional complaints are associated with impaired OHQoL.

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Table 1: Characteristics of included studies

Paper	Design	Country	N	Age mean (SD)	Population	Oral health factor(s)	Outcome (tool)
Alshammari et al. 2018	CS	Saudi Arabia	200	69.26 (SE 0.34)	elderly patients aged 65+ attending dental clinics	NT, prosthetic status, pain	GOHAI-Ar
Astrom et al. 2018	Cohort	Sweden	3585	70	Swedish people born in 1942	persistent tooth loss, FT	OIDP
Awad et al. 2003	RCT	Canada	60	65; 75	persons between the ages 65 and 75 who wished to replace their dentures	IOD	OHIP, OHIP-EDENT
Campos et al. 2017	Cohort	Brazil	32	76.7 (SD 6.3); 75.23 (SD 4.4)	partially or completely edentulous elderly individuals with AD and without AD	new CD	GOHAI
Castrejon-Perez et al. 2017	CS	Mexico	655	70+	home dwelling elders 70+	xerostomia, prosthetic status, periodontal conditions	OHIP-14-SP
Chen et al. 2012	CS	Taiwan	400	77	denture recipients under a new welfare and public health policy	complete dentures	OHIP-14
Cho et al. 2018	CS	Korea	3034	65+	elderly people	function	EQ-5D
Cicciù et al. 2013	CS	Italy	158	65-87	dentate older people with AD	periodontal conditions	OHIP-14
Cornejo et al. 2013	CS	Spain	194	65+	people aged 65 or older in long-stay centers	D vs ED, NT, DMFT, periodontal conditions, prosthetic status, dental appearance	GOHAI
da Silva et al. 2011	CS	Brazil	876	72.8	elderly people	NT, AOM, prosthetic status	GOHAI
Dahl et al. 2011	CS	Norway	151	72.1 (68-77)	adults of 68-77 years old	D vs ED, NT, DT	OHIP-14
Emami et al. 2009	RCT	Canada	255	70.0 (SD 4.8)	edentulous elders (65+)	IOD	OHIP-20
Emami et al. 2010	RCT	Canada	173	66-88	edentulous elders (65+)	IOD	OHIP-20
Eric et al. 2012	CS	Bosnia and Herzegovina	261	65+	community-dwelling adults 65+	NT, NOP	OIDP
Eric et al. 2017	CS	Bosnia and Herzegovina	120	65+	community-dwelling edentulous adults 65+	new CD	OIDP
Geckili et al. 2011	Cohort	Turkey	78	65-82	edentulous complete denture wearers seeking IOD	IOD	OHIP-14
Gerdin et al. 2005	CS	Sweden	41	83-91	old people living at service homes	xerostomia, hyposalivation	OHIP-14
Göktürk et al. 2018	CS	Turkey	110	72.1 (SD 4.33)	elderly patients from the periodontology department	periodontal conditions	GOHAI
Ha et al. 2012	Cohort	Korea	439	65-93	elderly, who were basic livelihood security recipients (65+)	prosthetic status	OHIP-14
Hassel et al. 2007	CS	Germany	36	75+	patients wearing FPD or RPD	prosthetic status	OHIP-SUM
Heydecke et al. 2003	RCT	Canada	55	69.4; 68.9	older people seeking denture replacement	IOD, new CD	OHIP-20
Hoeksema et al. 2017	CS	Netherlands	1026	80 (IQR 77-84)	community-living elderly participating in 'samen ouder' programme	dentate, CD, IOD	EQ-5D
Hoeksema et al. 2018	CS	Netherlands	103	79 (72-85)	community living older people	D vs ED	OHIP-14

Hsu et al. 2014	CS	Taiwan	332	76.0 (SD 0.4)	community-dwelling, independently living elderly adults	NT, NOP, prosthetic status, function	GOHAI-T
Jabbour et al. 2012	RCT	Canada	172	71 (SD 4.5)	edentulous females and males aged 65+	IOD, new CD	OHIP-20
Jensen et al. 2008	CS	USA	641	79.1	community-dwelling elderly persons with disabilities	NT, xerostomia, CTN	OHIP-14
Johansson et al. 2012	CS	Sweden	9813	65; 75	all 65 and 75 years of age	xerostomia	OIDP
Jung et al. 2008	CS	Korea	268	72.27 (SD 5.22)	community-dwelling older adults	NT, orofacial pain	OHIP-K
Kato et al. 2018	CS	Sweden	804	70, 78, 82, 86, 92	men aged 70, women aged 70, 78, 82, 86 and 92	NT, periodontal conditions	OHIP-14
Klotz et al. 2017	CS	Germany	169	82.9 (SD 8.9)	nursing home residents with or without dementia	NT, prosthetic status	GOHAI
Klotz et al. 2018	Cohort	Germany	152	73.9 (SD 0.9)	people born in 1930-1932	prosthetic status	GOHAI
Kohli et al. 2017	CS	USA	177	65+	institutionalized and community dwelling older adults	D vs ED	OHIP-14
Komagamine et al. 2012	Cohort	Japan	122	74.4	edentulous patients requiring new CD	new CD	OHIP-EDENT
Lee et al. 2012	CS	Taiwan	947	65+	all elderly over the age of 65	D vs ED, prosthetic status, function	OHIP
Ling et al. 2014	CS	New-Zealand	162	82.6 (SD 6.6)	older people admitted to older persons' hospital wards	D vs ED, root DT	OHIP-20
Masood et al. 2017	CS	UK	1277	65+	older people	NMT, DT, root DT, PUFA, periodontal conditions, orofacial pain, prosthetic status	OHIP-14
McKenna et al. 2015	RCT	Ireland	89	65+	partially dentate older patients	SDA, RPD	OHIP-14
McKenna et al. 2018	RCT	Ireland	89	65+	partially dentate older patients	SDA, RPD	OHIP-14
Meneses-Gómez et al. 2016	CS	Colombia	342	72.6 (SD 5.9)	elderly population receiving health care at the public hospital network	AOM, TMJ, prosthetic status	GOHAI
Mihara et al. 2018	CS	Japan	1969	69-71, 79-81	community-dwelling elderly residents	NT, function, prosthetic status	GOHAI
Motallebnejad et al. 2015	CS	Iran	300	71.4 (SD 5.6)	elderly population	D vs ED, prosthetic status, CTN	OHIP-14
Müller et al. 2013	RCT	Switzerland	34	85.0 (SD 6.19); 84.1 (SD 5.55)	very old edentulous patients who depend on help for activities of daily living	IOD	OHIP-EDENT
Niessen et al. 2016	CS	Netherlands	235	73.1 (SD 5.4); 85.4 (SD 7.1)	care-independent and care-dependent older population	DT, prosthetic status, CTN	GOHAI
Noguchi et al. 2017	CS	Japan	187	77.9 (SD 3.0)	elderly 75+ who have pain in general	NT, DT, FT, periodontal conditions	GOHAI
Östberg et al. 2010	CS	Sweden	186	80+	people with pain problems	function, dental appearance	OHIP-14
Paredes-Rodríguez et al. 2016	CS	Spain	30	80.50 (SD 8.93)	nursing home residents with or without dementia	NT, xerostomia	OHIP-14
Park et al. 2010	CS	Korea	156	77.4 (SD 6.53)	community-dwelling elders	NT, xerostomia, prosthetic status	OHIP-14
Pearson et al. 2007	RCT	UK	133	80.7; 79.5	older patients requiring CD	new CD	OIDP
Porter et al. 2015	CS	UK	179	65-100	older residents of nursing homes	periodontal conditions, sensitive teeth, orofacial pain, xerostomia	OIDP

Rebello et al. 2016	CS	Brazil	613	69.27 (SD 3.01)	elderly people	D vs ED, DMFT, prosthetic status	GOHAI
Rodrigues Gomes et al. 2015	CS	Portugal	207	65+	older adults with diabetes	NT, DT, periodontal conditions, xerostomia	OHIP-14
Sáez-Prado et al. 2016	CS	Spain	202	65+	elderly people aged 65 years or more	NT, NMT, DT, DMFT, FT	OHIP-14, EQ-5D
Santucci et al. 2015	CS	Malta	278	83.5 (SD 6.5)	state institutionalized older adults	NT, NMT, NOP, DT, DMFT, FT, periodontal conditions	OHIP-14, GOHAI
Shao et al. 2018	CS	China	744	69.3 (65-74)	elders	NT, DMFT, root DT, periodontal conditions, prosthetic status	GOHAI
Sheiham et al. 2001	CS	UK	202	65+	population aged 65 years and older	D vs ED, NT	OIDP
Skoskiewicz-Malinowska et al. 2019	CS	Poland	500	73 (65-99)	urban residents at the age of 65+	oral dryness	OHIP-14
Slade et al. 1996	CS	Australia, Canada, USA	1642	65+	people aged 65 and older	NMT, root DT, RR, periodontal conditions	OHIP
Souza et al. 2017	CS	Brazil	7619	69.09	older people	D vs ED, prosthetic status, dental appearance	OIDP
Stenman et al. 2012	CS	Sweden	561	70	elderly individuals	NT, burning mouth	OHIP-14
Strömberg et al. 2013	CS	Sweden	302	65-101	homebound elderly	D vs ED, NT, DT, RR, periodontal conditions, prosthetic status	GOHAI
Tsakos et al. 2004	CS	Greece	681	71.4 (SD 5.4); 74.5 (SD 6.9)	elderly population	NT, NOP, DT, root DT, periodontal conditions, prosthetic status	OIDP
Wu et al. 2018	CS	Hong Kong	195	75.3 (SD 6.7)	community dwelling elders	NT, NOP, DT, periodontal conditions	GOHAI
Yen et al. 2015	CS	Taiwan	277	76.0	elderly individuals	NT, AOM, orofacial pain, halitosis, xerostomia, prosthetic status	GOHAI-T
Yoon et al. 2013	CS	Korea	479	74.6	community-dwelling elders aged 65 years or above	NMT	OHIP-14
Yu et al. 2008	CS	China	155	80.0 (SD 7.2)	hospitalised geriatric patients	D vs ED, NOP, periodontal conditions, xerostomia	GOHAI
Zhou et al. 2012	CS	China	913	73 (SD 6)	older adults	prosthetic status	OHIP-14
Zuluaga et al. 2011	CS	Spain	215	82.9 (SD 7.6)	institutionalised elderly	D vs ED, NT, NOP, DT	GOHAI
Zusman et al. 2016	CS	Israel	987	65+	elderly	prosthetic status, dental appearance	OHIP-14

Note. RCT = randomized controlled trial, CS = cross-sectional, USA = United States of America, UK = United Kingdom, SD = standard deviation, IQR = interquartile range, AD = Alzheimer's Disease, IOD = implant overdenture, FPD = fixed partial denture, RPD = removable partial denture, CD = conventional denture, D = dentate, ED = edentate, NT = number of teeth, NMT = number of missing teeth, DMFT = decayed missing and filled teeth, DT = decayed teeth, NOP = number of occlusal pairs, CTN = clinically assessed treatment need, PUFA = Presence of severely decayed teeth with visible pulpal involvement, Ulceration caused by dislocated tooth fragments, Fistula and Abscess, SDA = shortened dental arch, AOM = abnormalities oral mucosa, TMJ = temporomandibular joint, FT = filled teeth, RR = retained roots, OHIP = Oral Health Impact Profile, GOHAI = Geriatric Oral Health Assessment Index, OIDP = Oral Impact on Daily Performance.

Table 2: Associations of oral health factors in the natural dentition domain with oral health-related quality of life

Paper	D vs. ED	NT	NMT	NOP
Alshammari et al. 2018	N.S.			
Cornejo et al. 2013	N.S.	+		
da Silva et al. 2011		+		
Dahl et al. 2011	N.S.	+		
Eric et al. 2012		+		+
Ha et al. 2012		+		
Lee et al. 2012	-			
Hoeksema et al. 2017	+			
Hoeksema et al. 2018	+			
Hsu et al. 2014		N.S.		N.S.
Jensen et al. 2008		+		
Jung et al. 2008		+		
Kato et al. 2018		+		
Klotz et al. 2017		+		
Kohli et al. 2017	N.S.			
Masood et al. 2017			-	
Mihara et al. 2018		+		
Motallebnejad et al. 2015	+			
Noguchi et al. 2016		+		
Paredes-Rodríguez et al. 2016		+		
Park et al. 2010		N.S.		
Rebelo et al. 2016	N.S.			
Rodrigues-Gomes et al. 2015		+		
Saez-Prado et al. 2016		+	-	
Santucci et al. 2015		N.S.	-	N.S.
Shao et al. 2018		+		+
Sheiham et al. 2001	N.S.	+		
Slade et al. 1996			-	
Souza et al. 2017	-			
Stenman et al. 2012		N.S.		
Strömberg et al. 2013	+	+		
Tsakos et al. 2004		+		+
Wu et al. 2018		+		+
Yen et al. 2015		+		
Yoon et al. 2013			N.S.	
Yu et al. 2008	N.S.			+
Zuluaga et al. 2012	+	+		+

Note. D = dentate, ED = edentate, NT = number of teeth, NMT = number of missing teeth, NOP = number of occluding pairs, + = positive association, - = negative association, N.S. = no significant association.

Table 3: Associations of oral health factors in the caries domain with oral health-related quality of life

Paper	DT	DMFT	FT	root caries	RR
Astrom et al. 2018			+		
Cornejo et al. 2013		N.S.			
Dahl et al. 2011	N.S.				
Ling et al. 2014				-	
Masood et al. 2017	-			+	
Nielsen et al. 2016	N.S.				
Noguchi et al. 2016	N.S.		-		
Rebello et al. 2016		-			
Rodrigues-Gomes et al. 2015	N.S.				
Saez-Prado et al. 2016	N.S.	-	-		
Santucci et al. 2015	-	-	N.S.		
Shao et al. 2018		-		-	
Slade et al. 1996				-	-
Strömberg et al. 2013	-				-
Tsakos et al. 2004	N.S.		-	N.S.	
Wu et al. 2018	-				
Zuluagu et al. 2012	N.S.				

Note. DT = Decayed Teeth, DMFT = Decayed Missing and Filled Teeth, FT = Filled Teeth, RR = retained roots, + = positive association, - = negative association, N.S. = no significant association.

Table 4: Associations of oral health factors in the periodontal conditions domain with oral health-related quality of life

Paper	pocket depth	mobility	bleeding	gingivitis	Periodontitis	AOM
Castrejon-Perez et al. 2017				N.S.	N.S.	
da Silva et al. 2011						-
Göktürk et al. 2018					-	
Kato et al. 2018					-	
Masood et al. 2017	N.S.		N.S.			
Meneses-Gomes et al. 2016						N.S.
Noguchi et al. 2016	N.S.					
Porter et al. 2015		-	-			
Rodrigues-Gomes et al. 2015					N.S.	
Santucci et al. 2015	-					
Shao et al. 2018	-					-
Slade et al. 1996	-					
Strömberg et al. 2013			+			
Tsakos et al. 2004		N.S.				
Wu et al. 2018	N.S.		N.S.			
Yu et al. 2008					-	

Note. AOM = abnormalities oral mucosa, + = positive association, - = negative association, N.S. = no significant association.

Table 5: Associations of oral health factors in the prosthetic domain with oral health-related quality of life

Paper	IOD vs CD	IOD vs new CD	Denture treatment need	PD vs CD	Using dentures	New CD
Awad et al. 2003	+					
Campos et al. 2017						+
Castrejon-Perez et al. 2017			-			
Cornejo et al. 2013			N.S./-		N.S.	
da Silva et al. 2011			-		+	
Emami et al. 2009	+					
Emami et al. 2010	+	+				
Eric et al. 2017						+
Geckili et al. 2011	+					
Ha et al. 2012				N.S.	N.S.	+
Heydecke et al. 2003	+					N.S.
Hoeksema et al. 2017	+					
Hsu et al. 2014					N.S.	
Jabbour et al. 2012	+					+
Klotz et al. 2017				N.S.	+	
Komagamine et al. 2012						+
Masood et al. 2017					-	
Mihara et al. 2018					-	
Meneses-Gomes et al. 2016			N.S.			
Motallebnejad et al. 2015					+	
Müller et al. 2013		+				
Nielsen et al. 2016				N.S.		
Park et al. 2010				N.S.		
Pearson et al. 2007						+
Rebelo et al. 2016			-			
Shao et al. 2018			-			
Souza et al. 2017					+	
Strömberg et al. 2013					-	
Tsakos et al. 2004			-			
Yen et al. 2015			-	N.S. / -		
Yoon et al. 2013					-	
Zhou et al. 2012					-	
Zusman et al. 2016					-	

Note. IOD = implant-retained overdenture, CD = conventional denture, PD = partial denture, + = positive association, - = negative association, N.S. = no significant association.

Table 6: Associations of remaining oral health factors with oral health-related quality of life

Paper	Xerostomia	Orofacial pain	Chewing function
Alshammari et al. 2018		-	
Castrejon-Perez et al. 2017	-		
Cho et al. 2018			+
Gerdin et al. 2005	-		
Hsu et al. 2014			+
Jensen et al. 2008	N.S.		
Johansson et al. 2012	-		
Jung et al. 2008		-	
Masood et al. 2017		-	N.S.
Östberg et al. 2011			+
Paredes-Rodríguez et al. 2016	-		
Park et al. 2010	-		
Porter et al. 2015	-	-	
Rodrigues-Gomes et al. 2015	-		
Yen et al. 2015	N.S.	N.S.	
Yu et al. 2008	-		

Note. + = positive association, - = negative association, N.S. = no significant association.

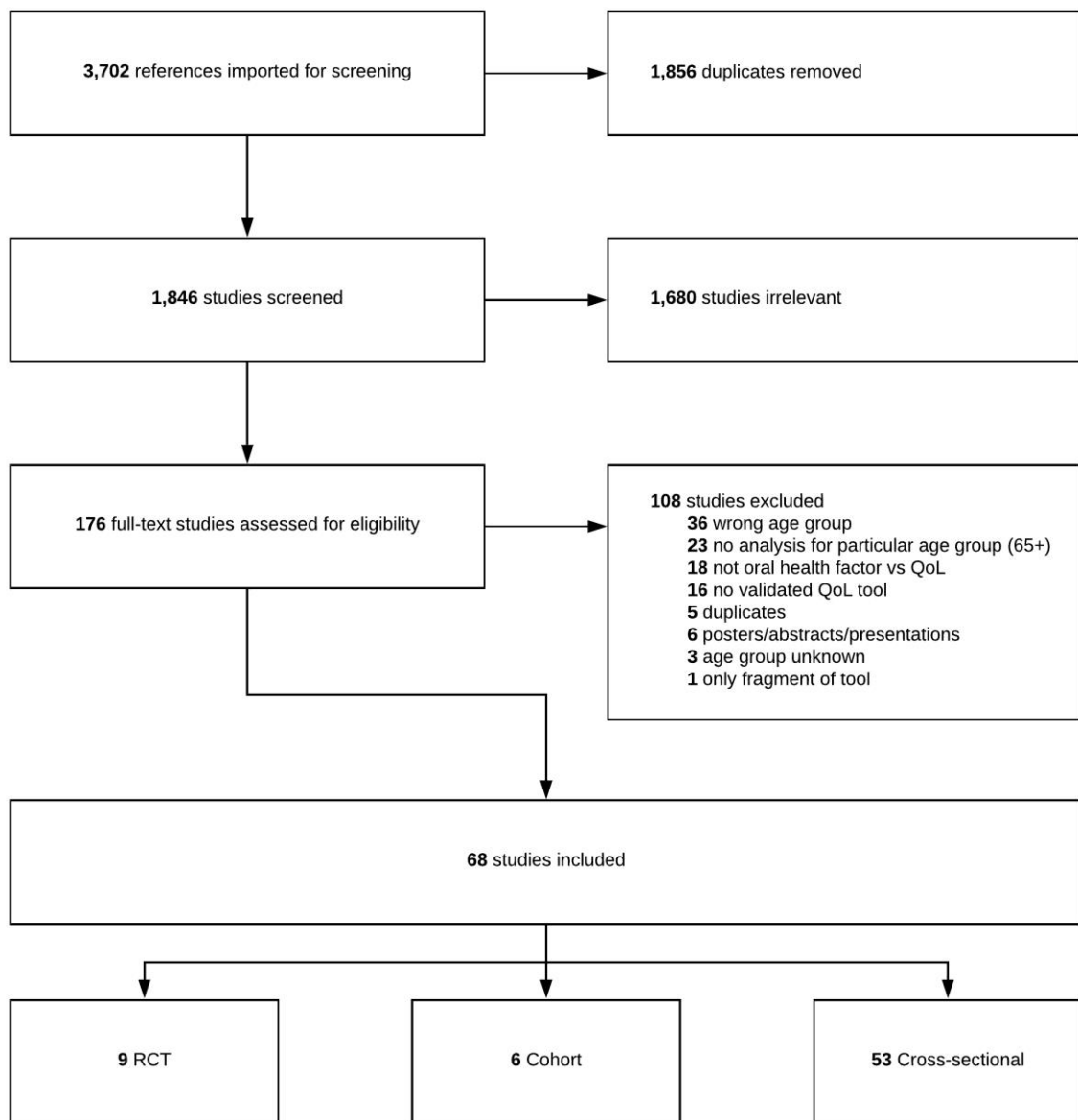


Figure 1. Flow diagram of study selection.

Supplementary Material

Appendix 1: full search strategies for all databases

PubMed Session Results (03 Apr 2019)

Search	Query	Items found
#4	#1 AND #2 AND #3	1,413
#3	"Aged"[Mesh] OR "Geriatric Dentistry"[Mesh] OR "Dental Care for Aged"[Mesh] OR elder*[tw] OR eldest[tw] OR frail*[tw] OR geriatri*[tw] OR old age*[tw] OR oldest old*[tw] OR senior*[tw] OR senium[tw] OR very old*[tw] OR septuagenarian*[tw] OR octagenarian*[tw] OR octogenarian*[tw] OR nonagenarian*[tw] OR centarian*[tw] OR centenarian*[tw] OR supercentenarian*[tw] OR older people[tw] OR older subject*[tw] OR older patient*[tw] OR older age*[tw] OR older adult*[tw] OR older man[tw] OR older men[tw] OR older male*[tw] OR older woman[tw] OR older women[tw] OR older female*[tw] OR older population*[tw] OR older person*[tw]	3,121,040
#2	"Quality of Life"[Mesh] OR life qualit*[tiab] OR "quality of life"[tiab] OR "qol"[tiab] OR "hrql"[tiab] OR "hrqol"[tiab] OR living qualit*[tiab] OR "quality of living"[tiab]	299,734
#1	"Oral Health"[Mesh] OR oral health[tiab] OR periodontal health[tiab] OR periodontal status[tiab]	32,625

Embase.com Session Results (03 Apr 2019)

Search	Query	Items found
#4	#1 AND #2 AND #3	1,420
#3	'aged'/exp OR elder*:ab,ti,kw OR eldest:ab,ti,kw OR frail*:ab,ti,kw OR geriatri*:ab,ti,kw OR 'old age*:ab,ti,kw OR 'oldest old*:ab,ti,kw OR senior*:ab,ti,kw OR senium:ab,ti,kw OR 'very old*:ab,ti,kw OR septuagenarian*:ab,ti,kw OR octagenarian*:ab,ti,kw OR octogenarian*:ab,ti,kw OR nonagenarian*:ab,ti,kw OR centarian*:ab,ti,kw OR centenarian*:ab,ti,kw OR supercentenarian*:ab,ti,kw OR 'older people':ab,ti,kw OR 'older subject*:ab,ti,kw OR 'older patient*:ab,ti,kw OR 'older age*:ab,ti,kw OR 'older adult*:ab,ti,kw OR 'older man':ab,ti,kw OR 'older men':ab,ti,kw OR 'older male*:ab,ti,kw OR 'older woman':ab,ti,kw OR 'older women':ab,ti,kw OR 'older female*:ab,ti,kw OR 'older population*:ab,ti,kw OR 'older person*:ab,ti,kw	3,142,637

Search	Query	Items found
#2	'quality of life'/exp OR ((life OR living) NEAR/3 qualit*):ab,ti,kw OR qol:ab,ti,kw OR hrql:ab,ti,kw OR hrqol:ab,ti,kw	535,127
#1	'dental health'/exp OR 'oral health':ab,ti,kw OR 'periodontal health':ab,ti,kw OR 'periodontal status':ab,ti,kw	29,748

Wiley / Cochrane Library Session Results (03 Apr 2019)

Search	Query	Items found
#4	#1 AND #2 AND #3	96
#3	(elder* or eldest or frail* or geriatri* or (old NEXT age*) or (oldest NEXT old*) or senior* or senium or (very NEXT old*) or septuagenarian* or octagenarian* or octogenarian* or nonagenarian* or centarian* or centenarian* or supercentenarian* or (older NEXT people) or (older NEXT subject*) or (older NEXT patient*) or (older NEXT age*) or (older NEXT adult*) or (older NEXT man) or (older NEXT men) or (older NEXT male*) or (older NEXT woman) or (older NEXT women) or (older NEXT female*) or (older NEXT population*) or (older NEXT person*)):ab,ti,kw	70,163
#2	(((life or living) near/3 qualit*) or qol or hrql or hrqol):ab,ti,kw	96,090
#1	((oral NEXT health) or (periodontal NEXT health) or (periodontal NEXT status)):ab,ti,kw	3,015

CINAHL (Ebsco) Session Results (03 Apr 2019)

Search	Query	Items found
S4	S1 AND S2 AND S3	693
S3	(MH "Aged+") OR (MH "Dental Care for Aged") OR TI (elder* OR eldest OR frail* OR geriatri* OR "old age*" OR "oldest old*" OR senior* OR senium OR "very old*" OR septuagenarian* OR octagenarian* OR octogenarian* OR nonagenarian* OR centarian* OR centenarian* OR supercentenarian* OR "older people" OR "older subject*" OR "older patient*" OR "older age*" OR "older adult*" OR "older man" OR "older men" OR "older male*" OR "older woman" OR "older women" OR "older female*" OR "older population*" OR "older person*") OR AB (elder* OR eldest OR frail* OR geriatri* OR "old age*" OR "oldest old*" OR senior* OR senium OR "very old*" OR septuagenarian* OR octagenarian* OR octogenarian* OR nonagenarian* OR centarian* OR centenarian* OR supercentenarian* OR "older people" OR "older subject*" OR "older patient*" OR "older age*" OR "older adult*" OR "older man" OR "older men" OR "older male*" OR "older woman" OR "older women" OR "older female*" OR "older population*" OR "older person*") OR SU (elder* OR eldest OR frail* OR geriatri* OR "old age*" OR "oldest old*" OR senior* OR senium OR "very old*" OR septuagenarian*	780,706

Search	Query	Items found
	OR octagenarian* OR octogenarian* OR nonagenarian* OR centarian* OR centenarian* OR supercentenarian* OR "older people" OR "older subject*" OR "older patient*" OR "older age*" OR "older adult*" OR "older man" OR "older men" OR "older male*" OR "older woman" OR "older women" OR "older female*" OR "older population*" OR "older person*")	
S2	(MH "Quality of Life") OR TI (((life OR living) N3 qualit*) OR qol OR hrql OR hrqol) OR AB (((life OR living) N3 qualit*) OR qol OR hrql OR hrqol) OR SU (((life OR living) N3 qualit*) OR qol OR hrql OR hrqol)	149,670
S1	(MH "Oral Health") OR TI ("oral health" OR "periodontal health" OR "periodontal status") OR AB ("oral health" OR "periodontal health" OR "periodontal status") OR SU ("oral health" OR "periodontal health" OR "periodontal status")	16,223

PsycINFO (Ebsco) Session Results (03 Apr 2019)

Search	Query	Items found
S4	S1 AND S2 AND S3	80
S3	TI (elder* OR eldest OR frail* OR geriatri* OR "old age*" OR "oldest old*" OR senior* OR senium OR "very old*" OR septuagenarian* OR octagenarian* OR octogenarian* OR nonagenarian* OR centarian* OR centenarian* OR supercentenarian* OR "older people" OR "older subject*" OR "older patient*" OR "older age*" OR "older adult*" OR "older man" OR "older men" OR "older male*" OR "older woman" OR "older women" OR "older female*" OR "older population*" OR "older person*") OR AB (elder* OR eldest OR frail* OR geriatri* OR "old age*" OR "oldest old*" OR senior* OR senium OR "very old*" OR septuagenarian* OR octagenarian* OR octogenarian* OR nonagenarian* OR centarian* OR centenarian* OR supercentenarian* OR "older people" OR "older subject*" OR "older patient*" OR "older age*" OR "older adult*" OR "older man" OR "older men" OR "older male*" OR "older woman" OR "older women" OR "older female*" OR "older population*" OR "older person*") OR KW (elder* OR eldest OR frail* OR geriatri* OR "old age*" OR "oldest old*" OR senior* OR senium OR "very old*" OR septuagenarian* OR octagenarian* OR octogenarian* OR nonagenarian* OR centarian* OR centenarian* OR supercentenarian* OR "older people" OR "older subject*" OR "older patient*" OR "older age*" OR "older adult*" OR "older man" OR "older men" OR "older male*" OR "older woman" OR "older women" OR "older female*" OR "older population*" OR "older person*")	171,270
S2	DE "Quality of Life" OR TI (((life OR living) N3 qualit*) OR qol OR hrql OR hrqol) OR AB (((life OR living) N3 qualit*) OR qol OR hrql OR hrqol) OR KW (((life OR living) N3 qualit*) OR qol OR hrql OR hrqol)	79,750

Search	Query	Items found
S1	DE "Oral Health" OR TI ("oral health" OR "periodontal health" OR "periodontal status") OR AB ("oral health" OR "periodontal health" OR "periodontal status") OR KW ("oral health" OR "periodontal health" OR "periodontal status")	1,556

Appendix 2: Methodological quality assessment of the included RCT studies with the Cochrane Risk of Bias tool

Paper	Selection bias	Performance bias	Detection bias	Attrition bias	Reporting bias	Other bias
Awad et al. 2003	-	+	+	-	-	+
Emami et al. 2010	-	+	+	-	-	+
Emami et al. 2009	-	+	+	-	-	+
Heydecke et al. 2003	-	+	+	-	-	+
Jabbour et al. 2012	-	+	+	-	-	+
McKenna et al. 2015	-	+	-	-	-	-
McKenna et al. 2018	-	+	+	-	-	-
Müller et al. 2013	-	+	+	+	-	-
Pearson et al. 2007	-	+	-	-	-	-

Note. RCT = randomized controlled trial, + = bias is present, - = bias is not present.

Appendix 3: Methodological quality assessment of the included cohort studies with the NOS

Paper	Selection				Comparability	Outcome			Total score	Quality rating
	1	2	3	4	5	6	7	8		
Astrom et al. 2018	a (1)	a (1)	c	a (1)	b (1)	c	a (1)	c	5	poor quality
Campos et al. 2017	b (1)	a (1)	a (1)	a (1)	c	c	a (1)	a (1)	6	poor quality
Geckili et al. 2011	b (1)	a (1)	a (1)	a (1)	c	c	a (1)	a (1)	6	poor quality
Ha et al. 2012	b (1)	a (1)	a (1)	b	a (1)	c	b	c	4	poor quality
Klotz et al. 2018	a (1)	a (1)	a (1)	a (1)	b (1)	c	a (1)	b (1)	7	good quality
Komagamine et al. 2012	b (1)	a (1)	a (1)	a (1)	b (1)	c	b	c	5	poor quality

Note. NOS = Newcastle-Ottawa Scale, () = number of stars

Good quality: 3 or 4 stars in selection domain AND 1 or 2 stars in comparability domain AND 2 or 3 stars in outcome domain

Fair quality: 2 stars in selection domain AND 1 or 2 stars in comparability domain AND 2 or 3 stars in outcome domain

Poor quality: 0 or 1 star in selection domain OR 0 stars in comparability domain OR 0 or 1 stars in outcome domain

Appendix 4: Methodological quality assessment of the cross-sectional studies with the Appraisal tool for Cross-Sectional Studies (AXIS tool)

Paper	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13 ^a	Q14	Q15	Q16	Q17	Q18	Q19 ^a	Q20	AXIS Score/20	
Alshammari et al. 2018	yes	yes	yes	yes	no	no	no	yes	yes	yes	yes	no	?	no	yes	yes	yes	yes	no	yes	14	
Castrejon-Perez et al. 2017	yes	yes	yes	yes	yes	yes	no	yes	yes	yes	yes	yes	no	no	yes	yes	yes	yes	no	yes	17	
Chen et al. 2012	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	no	yes	yes	yes	yes	yes	no	?	yes	18
Cho et al. 2018	yes	yes	yes	yes	yes	?	no	yes	yes	yes	yes	yes	?	no	yes	yes	yes	yes	yes	no	?	15
Cicciù et al. 2013	yes	yes	yes	yes	no	yes	yes	yes	yes	yes	yes	yes	no	yes	?	yes	yes	yes	no	yes	18	
Cornejo et al. 2013	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	no	yes	yes	yes	yes	no	yes	18	
Dahl et al. 2011	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	no	?	yes	17
da Silva et al. 2011	yes	yes	yes	yes	yes	yes	no	yes	yes	yes	yes	yes	?	no	yes	yes	yes	yes	yes	?	yes	16
Eric et al. 2012	yes	yes	yes	yes	no	yes	yes	yes	yes	yes	yes	yes	no	no	yes	yes	yes	yes	yes	?	yes	17
Eric et al. 2017	yes	yes	yes	yes	no	yes	no	yes	yes	yes	yes	yes	no	no	yes	yes	yes	yes	yes	?	yes	16
Gerdin et al. 2005	yes	yes	yes	yes	no	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	no	no	yes	17
Göktürk et al. 2018	yes	yes	yes	yes	no	no	no	yes	yes	yes	yes	yes	?	no	yes	yes	yes	yes	yes	no	yes	15
Hassel et al. 2007	yes	yes	yes	yes	no	yes	yes	yes	yes	yes	yes	yes	no	yes	yes	yes	yes	yes	yes	?	?	17
Hoeksema et al. 2017	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	18
Hoeksema et al. 2018	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	no	yes	yes	yes	yes	yes	yes	no	yes	20
Hsu et al. 2014	yes	yes	yes	yes	no	no	no	yes	yes	yes	yes	yes	?	no	yes	yes	yes	yes	yes	?	yes	14
Jensen et al. 2008	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	?	yes	yes	yes	yes	yes	yes	yes	yes	18
Johansson et al. 2012	yes	yes	yes	yes	no	yes	yes	yes	yes	yes	yes	yes	yes	no	yes	yes	yes	yes	no	?	yes	15
Jung et al. 2008	yes	yes	no	yes	no	yes	yes	yes	yes	yes	yes	yes	no	no	yes	yes	yes	yes	yes	?	?	15
Kato et al. 2018	yes	yes	yes	yes	yes	yes	no	yes	yes	yes	yes	yes	?	no	yes	yes	yes	yes	no	yes	17	
Klotz et al. 2017	yes	yes	yes	yes	no	yes	no	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	?	yes	16
Kohli et al. 2017	yes	yes	yes	yes	no	yes	no	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	no	yes	17
Lee et al. 2012	yes	yes	yes	yes	no	yes	yes	yes	yes	yes	yes	yes	yes	no	yes	yes	yes	yes	no	yes	?	14
Ling et al. 2014	yes	yes	no	yes	no	yes	no	yes	yes	yes	yes	yes	yes	no	yes	yes	yes	yes	yes	yes	yes	14
Masood et al. 2017	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	no	yes	yes	yes	yes	yes	no	no	?	18
Meneses-Gómez et al. 2016	yes	yes	no	yes	no	yes	no	yes	yes	yes	yes	yes	yes	no	yes	yes	yes	yes	yes	?	yes	14

Mihara et al. 2018	yes	yes	yes	yes	yes	no	no	yes	yes	yes	yes	no	no	no	yes	yes	yes	yes	no	yes	16
Motallebnejad et al. 2015	yes	yes	no	no	yes	yes	yes	yes	yes	yes	yes	yes	no	no	yes	yes	yes	no	?	?	14
Niستن et al. 2016	yes	yes	yes	yes	no	no	no	yes	yes	yes	yes	yes	no	no	yes	yes	yes	no	no	yes	15
Noguchi et al. 2016	yes	yes	yes	yes	no	no	no	yes	yes	yes	yes	yes	no	no	yes	yes	yes	yes	no	yes	16
Östberg et al. 2011	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	no	yes	yes	yes	yes	no	no	yes	19
Paredes-Rodríguez et al. 2016	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	?	no	yes	yes	no	no	no	yes	10
Park et al. 2010	yes	yes	yes	yes	no	no	yes	no	yes	yes	yes	yes	yes	no	yes	yes	yes	no	no	yes	14
Porter et al. 2015	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	no	yes	yes	yes	yes	yes	no	yes	20
Rebelo et al. 2016	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	no	yes	yes	yes	yes	yes	no	yes	20
Rodrigues Gomes et al. 2015	yes	yes	yes	yes	no	no	yes	yes	yes	yes	yes	yes	no	no	yes	yes	yes	yes	no	?	16
Sáez-Prado et al. 2016	yes	yes	yes	yes	yes	yes	no	yes	yes	yes	yes	yes	?	no	yes	yes	yes	no	no	yes	16
Santucci et al. 2015	yes	yes	yes	yes	no	no	no	yes	yes	yes	yes	no	?	no	yes	yes	yes	no	no	?	12
Shao et al. 2018	yes	yes	yes	yes	yes	yes	no	yes	yes	yes	yes	yes	no	no	yes	yes	no	yes	no	?	16
Sheiham et al. 2001	yes	yes	no	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	no	?	?	15
Skoskiewicz-Malinowska et al. 2019	yes	yes	yes	yes	no	yes	no	yes	yes	yes	yes	yes	?	no	yes	yes	yes	yes	?	yes	15
Slade et al. 1996	yes	yes	no	yes	yes	yes	no	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	?	?	15
Souza et al. 2017	yes	yes	yes	yes	yes	yes	no	yes	yes	yes	yes	yes	?	no	yes	yes	yes	yes	?	yes	16
Stenman et al. 2012	yes	yes	yes	yes	yes	yes	no	yes	yes	yes	yes	yes	no	no	yes	yes	yes	yes	?	yes	17
Strömberg et al. 2013	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	no	yes	yes	yes	yes	no	no	yes	19
Tsakos et al. 2004	yes	yes	no	yes	yes	yes	no	yes	yes	yes	yes	no	no	no	yes	yes	yes	no	no	?	14
Wu et al. 2018	yes	yes	yes	yes	no	no	no	yes	yes	yes	yes	yes	?	no	yes	yes	yes	yes	no	yes	15
Yen et al. 2015	yes	yes	no	yes	no	no	no	yes	yes	yes	yes	yes	?	no	yes	yes	yes	yes	no	yes	14
Yoon et al. 2013	yes	yes	no	yes	yes	no	yes	yes	yes	yes	yes	yes	no	yes	yes	yes	yes	yes	?	yes	17
Yu et al. 2008	yes	yes	yes	yes	no	no	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	?	yes	16
Zhou et al. 2012	yes	yes	no	yes	yes	yes	no	yes	yes	yes	yes	yes	no	no	yes	yes	yes	yes	?	yes	16
Zuluaga et al. 2011	yes	yes	yes	yes	yes	no	no	yes	yes	yes	yes	yes	?	no	yes	yes	yes	yes	?	yes	15
Zusman et al. 2016	yes	yes	yes	yes	yes	yes	yes	yes	yes	no	yes	yes	yes	no	yes	yes	yes	no	?	yes	15

Note. Q = question, ? = unclear. ^a = Item is reverse scored (i.e., no is a positive).

- Q1. Were the aims/objectives of the study clear?*
- Q2. Was the study design appropriate for the stated aim(s)?*
- Q3. Was the sample size justified?*
- Q4. Was the target/reference population clearly defined? (Is it clear who the research was about?)*
- Q5. Was the sample frame taken from an appropriate population base so that it closely represented the target/reference population under investigation?*
- Q6. Was the selection process likely to select subjects/participants that were representative of the target/reference population under investigation?*
- Q7. Were measures undertaken to address and categorise non-responders?*
- Q8. Were the risk factor and outcome variables measured appropriate to the aims of the study?*
- Q9. Were the risk factors and outcome variables measured correctly using instruments/measurements that had been trialled, piloted or published previously?*
- Q10. Is it clear what was used to determine statistical significance and/or precision estimates? (e.g. p-values, confidence intervals)*
- Q11. Were methods (including statistical methods) sufficiently described to enable them to be repeated?*
- Q12. Were the basic data adequately described?*
- Q13. Does the response rate raise concerns about non-response bias?*
- Q14. If appropriate, was information about non-responders described?*
- Q15. Were the results internally consistent?*
- Q16. Were the results presented for all the analyses described in the methods?*
- Q17. Were the authors' discussion and conclusions justified by the results?*
- Q18. Were the limitations of the study discussed?*
- Q19. Were there any funding sources or conflicts of interest that may affect the authors' interpretation of the results?*
- Q20. Was ethical approval or consent of participants attained?*