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Three-Dimensional Positional Changes of Teeth Adjacent to Posterior Edentulous Spaces in Relation to Age at Time of Tooth Loss and Elapsed Time

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Abstract - *The purpose of this study was to study the stability of teeth adjacent to posterior edentulous spaces and correlate it with patient age and time lapse since tooth loss. Dental casts, panoramic radiographs, and questionnaires of patients treated in a University setting were employed. Teeth adjacent and opposing posterior edentulous spaces were examined for the following parameters: Supraeruption, rotation, space closure, and axial inclination. One hundred twenty three patients with 229 edentulous spaces were analyzed. Statistical analysis showed that the effects of "jaw", "gender", and "age group at the time of tooth loss" were not significant for any of the variables tested. The effect of time lapse since tooth loss was significant regarding the "amount of distal tooth inclination" ($P<0.001$), the "amount of distal tooth rotation" ($P=0.004$), and "space closure" ($P=0.038$). Post-hoc analysis of the "amount of distal tooth inclination" revealed a marked increase in inclination 5 years after tooth loss. Within the limitations of this study, it was concluded that in the group of patients studied, minor positional changes in teeth opposing or adjacent to posterior edentulous spaces had occurred. The greatest changes in position were recorded for mandibular teeth distal to edentulous spaces.*

KEY WORDS: **Age, tooth movement, supraeruption, edentulous, space, extraction.**

INTRODUCTION

The stability of dental arches in humans has been the subject of several investigations. Movement of teeth adjacent to, or opposing edentulous spaces may often complicate planned prosthetic restorations or create occlusal interferences[1,2]. Some theories[3-6] support the concept that dental supraeruption is a continuous process compensating for tooth wear. Nevertheless, there is no adequate scientific documentation regarding dental arch stability following tooth loss. There is a general belief among dentists that teeth without antagonists are most likely to supraerupt[7]; this theory has also been supported by animal studies[8]. Human studies have produced conflicting results. One survey[9] of military dentists concluded that mesial inclination of teeth distal to edentulous areas was not inevitable, but rather seemed to depend on the age tooth loss had occurred. Similar conclusions were reached in a study of dental casts and radiographs of patients with unopposed molars[10]. A retrospective study[11] compared bite-wing radiographs in patients 24-90 years of age for changes in the position and periodontal health of teeth next to edentulous spaces. The time elapsed since tooth loss averaged between 1 and 9.6 years. The study concluded that in the vast majority of patients no significant changes had occurred. No attempt was made by the authors to correlate change with the timing of tooth loss. A similar study[12] of an adult patient sample found that limited space closure had occurred 6 years after single posterior tooth extractions.

In contrast to the above studies, Compagnon and Woda[13] found marked molar supraeruption in a group of patients with an age range of 18-45 years who had lost the antagonist tooth 5-20 years before. Another study[14] found supraeruption of all second molars studied in a group of young (mean age 22 years) patients whose antagonist molars had been removed in the previous 10 years for orthodontic reasons. A further study[1] examined 120 patients and concluded that supraeruption of unopposed teeth was present in 83% of the subjects. The same group of investigators in a study[15,16] of dental casts and radiographs reported that 92% of unopposed posterior teeth presented with some form of supraeruption, and teeth adjacent to extraction sites presented with some form of tipping or rotation. No correlation with age, or time since tooth loss was attempted in the above studies. A recent study[17] showed tooth deviations 5 years after adjacent tooth loss.

Research on jaw development has shown that between the ages of 13 and 18 years the lower mandibular molars move, on average, 2 to 3 mm mesially and supraerupt another 2 to 4 mm[18]. Another similar study[19] showed mesial and downward movements in first upper molars of 3 and 8 mm respectively between the ages of 9 and 25 years. The study concluded that jaw development continues, at a slower rate, even during early adulthood. A number of prospective clinical studies[20-25] have demonstrated that changes in jaw morphology and tooth relations may occur even at the beginning of the fourth decade of life.

The studies mentioned imply a possible correlation between the age and time of tooth loss and subsequent dental arch stability. It would be helpful to be able to identify

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patients who are prone to tooth movement following tooth loss. Such knowledge would determine the need for prosthodontic intervention and the risk associated with lack of intervention. The purpose of this study was to study the stability of teeth adjacent to posterior edentulous spaces and correlate it with patient age and time lapse since tooth loss had occurred.

MATERIAL AND METHODS

The study utilized dental diagnostic casts and panoramic radiographs of patients treated at the undergraduate clinic of the department of Fixed Prosthesis and Implant Prosthodontics in the dental school of Aristotle University in Thessaloniki, Greece. Casts and radiographs were made as part of the routine examination protocol of the clinic. All patients examined during the academic years 2002-2003, 2003-2004 and 2004-2005 (3 years) were considered for inclusion in the study. All patients had been asked to fill out a questionnaire during treatment pertaining to information regarding the age at which tooth loss had occurred (10-18y, 19-25y, 26-45y, >45y) and time lapse since then (0-5y, 6-10y, 11-20y, >20y), reason for tooth loss and possible history of orthodontic treatment. Consent was obtained from all subjects following a verbal explanation of the purpose and methods of the study. Permission was granted from the ethics committee of the Aristotle University dental school.

The inclusion criteria for the patient sample and edentulous spaces were: (1) Patients with at least one posterior (premolar or molar) tooth missing, (2) intact casts in patient records, (3) completed patient questionnaire, and (4) no history of orthodontic movement.

Each edentulous space was treated as a separate unit for analysis purposes. Third molars were excluded from measurements, as were teeth with broken or restored clinical crowns, and teeth with prosthodontic interventions. Canines were included as teeth mesial to edentulous spaces. In instances where residual roots were present in the edentulous spaces only supraeruption of opposing teeth was measured. Data were gathered from measurements made on the dental casts and the panoramic radiographs, as well as the patient questionnaire. The measurements were made by one examiner after interexaminer and intraexaminer reliability had been tested.

The following parameters were measured:

The supraeruption of teeth opposing the edentulous space.

The measurements were made on the dental casts between the marginal ridges of the teeth under investigation and those of neighboring teeth. All unopposed teeth were measured on both marginal ridges. If part of the tooth was in contact with the opposing dentition, or it had been prosthetically restored, the measurement was not made. The highest value was recorded in millimeters and the following categories were considered: no sign of supraeruption, minor supraeruption <= 2mm, major supraeruption > 2mm.

The rotation of the teeth mesial and distal to the edentulous spaces.

Imprints were made from the occlusal surfaces of the arch. Two lines were drawn: One through the mid-point of the marginal ridges of the teeth, and the other through either the middle of the marginal ridges of the neighboring teeth or along the direction of the marginal ridge. The angle formed between the two lines was measured with a protractor and the following categories were considered: No sign of rotation 0-10 degrees, minor rotation 11-30 degrees, major rotation = > 31 degrees.

The inclination of the teeth distal of edentulous spaces in the mandible.

Mesiodistal tooth angulation was measured on panoramic radiographs[26-31]. All radiographs were performed by an experienced operator using one unit (Planmeca PM2002; Planmeca Inc, Helsinki, Finland). Two lines were drawn on the panoramic radiograph: one parallel to the long axis of the tooth, and the other in the midline, vertical to the tangent of the lower border of the mandible. The angle formed between the two lines was measured with a protractor and the following categories were considered: no sign of inclination <20 degrees, minor inclination 20-40 degrees, major inclination > 40 degrees. Twenty degrees were set as a cutoff point after pilot measurements performed on the casts and radiographs of patients with intact casts and no edentulous spaces revealed that "straight" teeth presented with a measured angle of 15-20 degrees on the radiographs.

Space closure.

Each edentulous space was measured and compared with the contra lateral side. The measurement was performed only if the teeth on the contra lateral side were intact and the difference recorded in millimeters.

The four parameters measured were statistically analyzed and compared with regard to the factors included in the questionnaire. The influence of the presence of a third molar was also analyzed regarding distal tooth rotation, inclination and space closure.

Statistical analysis was performed using Intraclass Correlation Coefficient test for inter/intra examiner variability, and one-sample Kolmogorov-Smirnov test for normality of data distribution. Depending on the data distribution, statistical analysis was performed by using either One-way ANOVA, or the Kruskal-Wallis test. The level of statistical significance was set at $\alpha<.05$ (SPSS, PC, version 14.0; SPSS, Inc, Chicago, Ill).

RESULTS

Clinical records indicated that 488 patients had been recorded during the 3 academic years. A total of 365 patient records did not conform to the inclusion criteria and were excluded, leaving 123 patients with 229 edentulous spaces for analysis (105 maxillary and 124 mandibular spaces). The group comprised 53 males and 70 females with a mean age of 44.5 years (S.D. 12.7y, range 21-72y). Statistical analysis revealed a normal distribution of age groups within the cohort, and no significant difference in mean age between males and females (*t* test 2-tailed, $t=-1.090$, $P=0.287$).

Both inter- and intra-examiner variability of all the measurements were very low with the intraclass correlation coefficient ranging from 0.90-1.00.

Analysis of normality of data led to parametric tests (1-way ANOVA) for the variables "tooth inclination" and "space closure" and non-parametric tests (Kruskal-Wallis) for "amount of supraeruption", and "tooth rotation". Descriptive statistics of the questionnaire data are shown in Tables 1 through 3. Descriptive statistics of all the variables studied are shown in Table 6.

Statistical analysis showed that the effect of "jaw" or "gender" was not significant for any of the variables tested, neither was the effect of the presence of third molar teeth statistically significant for the parameters measured. Statistical analysis of the effect of age group at the time of tooth loss on different measurements revealed no statistical significance. The effect of time lapse since tooth loss was statistically significant only regarding the "amount of distal tooth inclination" (df of 3, F of 6.462, P=0.001), the "amount of distal tooth rotation" (X^2=13.548, df of 3, P=0.004), and "space closure" (df of 3, F of 3.118, P=0.038). Post-hoc analysis (Gabriel test) of the "amount of distal tooth inclination" revealed a marked increase in degrees of inclination after 5 years of tooth loss (Table 5). Post-hoc analysis (Gabriel test) of the "amount of distal tooth rotation" revealed an increase in rotation after between 11-20 years of tooth loss and regression thereafter (Table 6). Post hoc analysis for space closure was not possible due to the small number of cases.

DISCUSSION

The positional stability of teeth opposing or adjacent to an edentulous space may not critically influence the oral function of a patient unless occlusal interferences occur. However, when prosthetic restoration of the edentulous space becomes necessary, difficulties may arise due to supraeruption, rotation or tilting of teeth[2]. It would therefore be helpful in treatment planning to try to establish prognostic models related to dental arch stability following tooth loss.

The present cross-sectional study tried to correlate events such as supraeruption, rotation and tilting of teeth with age and time lapse since tooth loss. The average values of tooth position measurements in this group of patients showed that, with the exception of "distal tooth inclination", only minor positional changes had occurred. In fact, a significant percentage of the teeth studied retained a stable position. Median value for supraeruption of unopposed teeth was 2mm which can be considered as a minor supraeruption. This is in agreement with a previous study[10] that measured supraeruption of unopposed molars, and two studies[11,15] of unopposed posterior teeth. Median values measured in this study for mesial and distal tooth rotation were 7 degrees and 10 degrees respectively, while mean distal tooth inclination was 30 degrees. A recent study[16] reported mean values of 15 degrees and 11 degrees for mesial and distal tooth rotation respectively, and 18 degrees for distal tooth inclination. Although the results of the two studies are not strictly comparable due to differences in measuring techniques, they both report values within similar ranges. The mean value for space closure was 2mm, which is in agreement with a 6-year prospective study[12] and a retrospective study[11] of posterior bounded edentulous spaces. When analyzing the average values reported in this study it is important to also consider the maximum values in the descriptive statistics and the fact that outlier values existed in almost all categories studied. The implication of this finding is that some patients do not conform to the average population values and no prognostic factor for this particular group of patients could be identified in the present study. This indicates that each individual patient with loss of posterior teeth should be monitored through a recall system in order to prevent major changes in tooth position.

The results of the present study showed that age at the time of tooth loss did not have a significant effect on tooth stability. This is in agreement with a prospective study[25] which measured vertical changes of anterior maxillary teeth and found no significant differences between young and mature adults. Different results were reported in a retrospective study[10] of unopposed molars where less supraeruption was reported for patients who had lost their antagonist teeth after the age of 26 years.

Table 1. Reported reason for tooth loss

Reason	*Frequency*	*Percent*
Decay	128	55.9
Periodontitis	6	2.6
Other	67	29.3
No recall	28	12.2
Total	229	100

Table 2. Age group when tooth was lost

Age group (years)	*Frequency*	*Percent*
10-18	21	9.2
19-25	60	26.2
26-45	107	46.7
Over 45	35	15.3
No recall	6	2.6
Total	229	100

Table 3. Elapsed time since tooth loss

Time (years)	*Frequency*	*Percent*
0-5	74	32.3
6-10	54	23.6
11-20	67	29.3
Over 20	32	14.0
No recall	2	0.8
Total	229	100

Table 4. Descriptive statistics of studied variables

Variable	*N*	*N with no change*	*Mean*	*SD*	*Median*	*(25th, 75th quartile)*	*Min*	*Max*
Supraeruption (mm)	43	10	N/A	N/A	1	(1,2)	0	
Mesial tooth rotation (degrees)	206	112	N/A	N/A		(5,17)	0	89
Distal tooth rotation (degrees)	196	142	N/A	N/A	7	(4,12)	0	70
Distal tooth inclination (degrees)	100	16	30	10	N/A	N/A	0	58
Space closure	41	12	2	1.9	N/A	N/A	0	6

N: Number of cases, SD: Standard deviation, N/A: not applicable

Table 5. Elapsed time since tooth loss and amount of distal tooth inclination

Time (years)	*N*	*Mean (degrees)*	*SD*
0-5	29	24.0[a]	5.8
6-10	27	32.1[b]	7.8
11-20	27	31.3[b]	10.8
Over 20	15	35.6[b]	13.3
Total	98	30.1	10.0

[a] Statistically different from [b] (P=0.01)

Table 6. Elapsed time since tooth loss and amount of distal tooth rotation

Time (years)	*N*	*Median degrees (25th, 75th quartile)*
0-5	64	6 (4,9)[a]
6-10	46	7 (4,10)[a]
11-20	61	10 (6,16)[b]
Over 20	24	7 (4,10)[a]
Total	195	7 (4,12)

[a] Statistically different from [b] (P=0.004)

The results of the present study showed that in the group of patients studied the effect of time lapse since tooth loss was statistically significant only regarding the "amount of distal tooth inclination", the "amount of distal tooth rotation", and "space closure". Further analysis revealed that the position of the tooth distal to the edentulous space is compromised after 5 years with a mean increase in inclination of 8 degrees. Obviously, these changes occur gradually over the 5-year period. This result is in agreement with a recent study[17] which showed tooth deviations 5 years after tooth loss. An unexpected finding was the fact that distal tooth rotation measurements reached their maximum values between 11-20 years after tooth loss and then returned to normal values. There is no clear explanation for this finding. Space closure seemed to reach a high 5 years following tooth loss but due to the small sample size available for this particular measurement it should be interpreted with caution. A previous prospective study[12] concluded that space closure mainly occurs during the first 2 years following tooth loss.

There are certain limitations that should be taken into account when interpreting the results of this study. Panoramic radiographs were used for measurements of mesiodistal tooth inclinations of posterior mandibular teeth. This technique has some limitations since panoramic radiographs are extremely technique and operator sensitive and the resulting images are distorted and magnified to a certain extend. The radiographs for this study were made on the same machine by an experienced operator. Studies[26-28] have shown that measurements of mesiodistal tooth inclinations on panoramic radiographs differ from true patient measurements. Nevertheless the distortion is greater in the anterior portion of the mouth and the difference for posterior teeth is less than 5 degrees, which is not clinically significant. Taking into account that measuring discrepancies in the posterior region were not clinically significant, and that panoramic radiographs were utilized routinely for all patients as part of the examination protocol, it was decided to use them for measurements of tooth inclination as other studies[29-31] have indicated. The arbitrary angle of 20 degrees was chosen as a cutoff point of tooth inclination for two reasons: First, mesial inclinations of mandibular teeth are often exaggerated in panoramic radiographs.[28] Second, pilot measurements of patients with intact casts and no edentulous spaces revealed that "straight" teeth presented with a measured angle of 15-20 degrees on the radiographs. One more limitation of the study was that the cross-sectional rotation measurements made on dental casts may not accurately reflect the longitudinal events because no information was provided to the authors about the position of the teeth before the extractions.

The periodontal condition of the patients was not recorded in this study. One recent study[32] showed that unopposed periodontally affected molars erupted more than healthy molars. The group of patients treated in the undergraduate clinic do not present with generalized chronic periodontitis, since these patients are referred to the postgraduate clinics for treatment. The cohort of patients studied may therefore not be representative of the general population.

In this study the variables "age at time of tooth loss" and "time since tooth loss" were based on subjective patient answers which may have had an impact on the accuracy of information given, although the large sample size of this study probably minimized any possible error.

Cross-sectional studies of this kind present with difficulties in establishing objective and repeatable reference points of measurements. Other similar studies[10,15,17] studying dental arch stability have presented subjective and difficult to replicate reference points, such as an imaginary curve of Spee or occlusal curve/plane. The high inter- and intra-examiner agreement obtained in this study confirmed the validity of the reference points used. In order to fully comprehend the mechanisms involved in dental arch stability following tooth loss long-term prospective studies should be conducted.

CONCLUSIONS

Within the limitations of this study, it was concluded that in the group of patients studied minor positional changes of teeth opposing or adjacent to posterior edentulous spaces had occurred. The greatest changes in position were recorded for mandibular teeth distal to edentulous spaces; these changes became significant 5 years after adjacent tooth loss.

ADDRESS FOR CORRESPONDENCE

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