Tooth Movements Adjacent to Single-Implant Restorations After More Than 15 Years of Follow-up

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Purpose: To analyze the prevalence and magnitude of tooth movements adjacent to single-implant crowns in a long-term study, and to discuss these changes in relation to changes in cephalometric measurements of a reference group after 10 years. ***Materials and Methods:*** Twenty-five of an original group of 39 patients, consecutively restored with single-implant crowns in the anterior maxilla, were included. The mean age was 25.4 years (SD: 10.0) at inclusion. Clinical photographs were taken at implant crown placement and at the final examination an average of 15.9 years (SD: 0.74) later. The reference group comprised 134 dental students with a mean age of 22.9 years (SD: 1.20) at inclusion. Cephalograms and study casts were made at inclusion and after 10 years. Study casts were also made after 20 years (n = 61). Tooth movements were assessed adjacent to the implant crowns according to a clinical index. For the reference group, cephalometric measurements were performed for anterior and posterior face height and gonion and nasion-sella line/mandibular line (NSL/ML) angles. Vertical overbite measurements were collected from the study casts. ***Results:*** Altogether, 28 implant crowns were included in the test group. Male patients presented a clinically stable situation without any signs of vertical tooth movement adjacent to the single-implant restorations in 11 of 20 implant sites, compared to none in female patients ($P < .05$). With regard to horizontal tooth movements, 55% of the sites showed palatal tooth movements, which were relatively more common in females. Both males and females presented a significant average increase of anterior and posterior face height ($P < .05$), but only females presented a significant increase of the NSL/ML angle. Average vertical overbite was basically stable for 20 years, but individual variations were obvious. ***Conclusions:*** A possible relationship between significantly higher incidence of tooth movements adjacent to implants in females in the study group and significantly greater increase of anterior face height and posterior rotation of the mandible in the female reference group was observed. *Int J Prosthodont 2007;20:626–632.*

Single-implant treatment introduces a new biomechanical situation in the dentate patient. The ankylotic abutment forces clinicians to modify the occlusal concept for the patient[1]; however, long-term changes of the dentition must also be considered. Ödman[2] showed that implants placed in young patients may show implant infraposition after several years due to craniofacial growth, which may continue in the young adult patient.[3–5] Eruption of the dentition in relation to implants has also been discussed by other authors, and signs of tooth movements in older adult patients have been reported.[6–9] Today, adult craniofacial growth[10] and craniofacial changes[11] are well documented and have been extensively discussed in the literature.[10–17] Therefore, the pattern of tooth eruption and implant infraposition is of minor interest to be discussed per se. Instead, levels of prevalence, magnitude and patterns of tooth movements, and identification of individual risk factors for implant infraposition are more important aspects to be investigated and discussed today.

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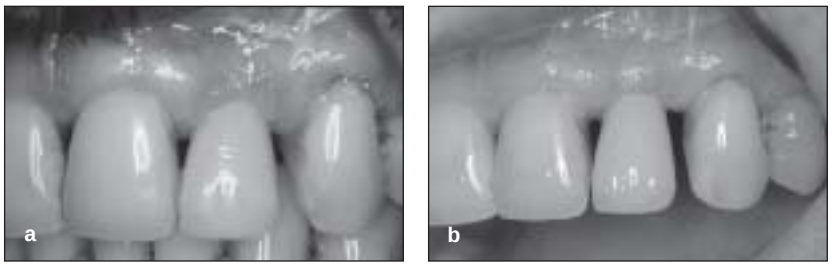
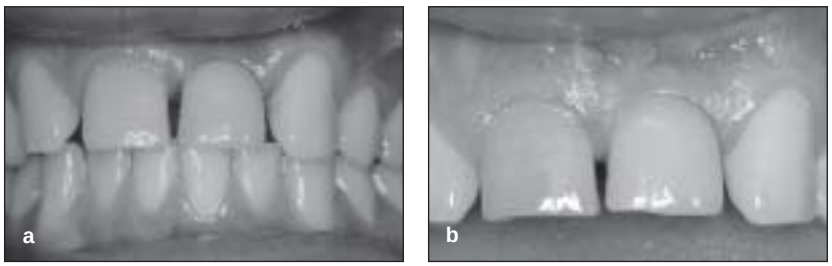


Figs 1a and 1b A 46-year-old male patient restored with a left lateral incisor implant crown after placement **(a)** and after 17 years of follow-up **(b)**. No obvious vertical tooth movements were observed in relation to the implant crown (score A).



Figs 2a and 2b A 21-year-old male patient restored with a left central incisor implant crown after placement **(a)** and after 16 years of follow-up **(b)**. Small vertical tooth movements (≤ 0.5 mm) were observed in relation to the implant crown (score B).

In a previous study by the current authors, it was shown that permanent anterior teeth adjacent to single-implant restorations showed a significant increase of clinical crown height compared to a population of dentate persons in a follow-up study of more than 15 years.[18] The data in this study indicated that "greater changes in clinical crown height may occur in patients provided with implant-supported crowns than in untreated control subjects, possibly more for women than men, and more for initially shorter teeth than for longer adjacent teeth."[18] However, the study strictly focused on clinical crown length, and accordingly, measurements of tooth movements and the degree of implant infraposition were not covered. The aim of the present study was to further analyze the results and reference groups of the previous material,[18] and to focus on prevalence and magnitude of tooth movements adjacent to single-implant crowns and relate these changes to cephalometric measurements of the reference group.

Materials and Methods

Study Group

The present study covers the original group of 39 patients as presented in the earlier publication, consecutively restored with single-implant restorations in the anterior maxilla (canine to canine) between December 1987 and June 1990.[18] The final follow-up examination was performed an average of 15.9 ± 0.7 years after crown placement. The 25 patients included in the present study (study group) were documented with clinical photographs at crown placement and at the final examination (Figs 1 to 4). Twenty-two of these patients were also documented with study casts. Compared to the earlier study,[18] 3 patients missing original master casts were included and 1 patient provided with 2 central incisors was excluded. The reason for the exclusion was difficulties judging the tooth movements adjacent to implant crowns at either side of the restoration. Seven of the present patients were female, and the mean age was 25.4 years (SD: 10.0) at the time of first surgery (Table 1).

The patients received a total of 28 turned Brånemark implants (Nobel Biocare) according to a 2-stage surgical procedure.[19] Standard or healing abutments (Nobel Biocare) were connected after a healing period of 6 to 8 months. Thereafter, permanent porcelain-fused-to-metal crowns were cemented to original single-implant abutments[1,20] or Cera-One abutment cylinders[21] (Nobel Biocare) by means of conventional zinc-phosphate cement (Table 1).[20,21]

With the implant crown as a reference, clinical tooth movements of the adjacent teeth were assessed from the clinical photographs taken at crown placement and at the final examination. Care was taken to take the follow-up photographs in a similar orientation as the initial photographs. Each implant site was evaluated and assigned an implant infraposition score by 3 of the authors individually. When the scores were not similar (3 cases), a discussion for consensus was carried out within the examiner group. The index score denotes the degree of vertical implant infraposition that had occurred since implant crown placement:

Figs 3a and 3b A 38-year-old male patient restored with a left central incisor implant crown after placement **(a)** and after 17 years of follow-up **(b)**. Vertical tooth movements (≤ 1.0 mm) were observed in relation to the implant crown (score C).

Figs 4a to 4c A 34-year-old female patient restored with a right central incisor implant crown after placement **(a)** and after 16 years of follow-up **(b and c)**. Obvious vertical **(b)** and palatal **(c)** tooth movements (vertical > 1.0 mm) were observed in relation to the implant crown (score D, P).

Table 1 Distribution of Patients and Single-Implant Crown Restorations in the Canine, Lateral Incisor, and Central Incisor Areas in the Study Group

	Patients			Restorations			
	No.	Mean age (y)	SD	Canine	Lateral incisor	Central incisor	Total
Males	18	26.9	12.7	–	10	10	20
Females	7	27.0	6.1	1	3	4	8
Total	25	26.9	11.1	1	13	14	28

- *Score A:* No obvious clinical vertical implant infraposition was identified in relation to the incisal edges of the adjacent teeth (Figs 1a and 1b).
- *Score B:* Small, insignificant, clinical vertical implant infraposition assessed to be less than half a millimeter (< 0.5 mm) was observed in relation to the adjacent teeth (Figs 2a and 2b).
- *Score C:* Obvious clinical vertical implant infraposition assessed not to exceed 1 mm (≤ 1.0 mm) in relation to the adjacent teeth was observed (Figs 3a and 3b).
- *Score D:* Clinically significant vertical implant infraposition assessed to be more than 1 mm (> 1.0 mm) was present (Figs 4a and 4b).

Assessments of buccal/lingual tooth movements were performed only when both photographs and final study casts were available. Sites showing the adjacent teeth to be palatal of the single-implant restorations at the final registration were denoted "P" (Fig 4c), while sites with a stable buccal/palatal situation were denoted "S." If the single-implant restoration was palatal to the adjacent teeth the situation was identified as "B."

Reference Group

Essentially, the same reference group as presented in the earlier publication was used in the present study, comprising 134 dental students at the Faculty of Odontology, Oslo University, first examined between 1972 and 1983.[15,18] Cephalograms and study casts were made at the first registration (R-0) in 57 women and 77 men who were recalled for another examination after 10 years (R-10). Thereafter, 61 subjects were also documented with study casts after 20 years of follow-up (R-20). None of the subjects had orthodontic treatment or retainers at the first registration or received any orthodontic or prosthetic treatment during the observation period in the anterior maxilla.[15,18]

Measurements

Descriptions of the radiographic technique and cephalographic analysis as well as an assessment of the reproducibility of cephalometric measurements are provided in more detail in an earlier publication.[15] Measurements

were made of anterior (nasion-gnathion [N-Gn]) and posterior (sella-gonion [S-Go]) face height and the angle between the base of the skull and base of the mandible (nasion-sella line/mandibular line [NSL/ML]).[15] The gonion angle (Ga) was also measured in the cephalograms from the first examination (R-0).

Using the study casts, vertical overbite was measured in the area of the right central incisors by means of a digital caliper to the closest 0.1 mm.[18] As accounted for in the earlier publication, clinical crown height was also measured in the reference group of the maxillary right canine, maxillary right central incisor, and maxillary left lateral incisor. The measurements were made from the most apical concavity of the gingival margin of the tooth to the incisal edge. Data on clinical crown height[18] were only used for calculation of correlations to the collected data in the present study.

Statistics

Distributions of vertical score index between genders were tested by means of chi-square tests with Yates correction for small samples.[22] The unpaired *t* test was used to assess differences in the cephalometric variables between male and female subjects, and the paired *t* test was used for assessments of changes of cephalometric data between the 2 registrations. The coefficient of correlation (*r*) was calculated for relationships between different cephalometric and study cast parameters. Significance was set at 5%.

Results

Study Group

Male patients presented a clinically stable situation without any signs of vertical tooth movements adjacent to the single-implant restorations (score A) at 11 of 20 implant sites (Table 2). In female patients, no implant site showed a clinically completely stable situation after 15 to 17 years of follow-up ($P < .05$). More implant sites showed tooth movements of more than half a millimeter in the female group compared to the male group; however, this difference did not reach statistical significance ($P > .05$).

Clinical photographs and/or study casts were available for 22 of 28 implant sites (79%) to allow assessments of adjacent tooth movements in a buccal/palatal direction. Altogether, 10 sites were recorded as clinically stable (S, 45%), and the remaining 12 sites presented palatal tooth movements (see Fig 4c) of adjacent teeth in relation to the implant crown (P, 55%). Eight and 4 of these recorded sites with palatal tooth movements were observed in males (47%) and females (80%), respectively.

Table 2 Distribution of Single-Implant Crowns with Regard to Gender and Vertical Implant Infraposition Index in the Study Group

	No. of implant sites		
Infraposition	Males*	Females**	Total
Score A	11 (55%)	0	11 (39%)
Score B	5 (25%)	5 (62%)	10 (36%)
Score C	2 (10%)	1 (13%)	3 (11%)
Score D	2 (10%)	2 (25%)	4 (14%)
Total	20	8	28

*Two males with 2 implants each were scored A/A and A/D.
**One female patient with 2 implants was scored C/B.

Reference Group

Mean values for the cephalometric measurements at the first registration (R-0) are given in Table 3. The mean values for all 4 cephalometric parameters showed a significant difference between the genders ($P < .05$).

A significant increase ($P < .05$) of mean anterior and posterior face height was observed for both genders after 10 years of follow-up (Table 4). Further, the NSL/ML angle increased significantly for females ($P < .05$) but not for men ($P > .05$) after 10 years. Anterior face height and NSL/ML angle increased significantly more in females ($P < .05$) than in males (Table 4), and significantly more women ($P < .05$) showed an increase of the NSL/ML angle compared to males (Table 4).

Mean vertical overbite was 2.3 mm (SD: 1.31) and 2.7 mm (SD: 1.68) for females and males at the first registration, respectively, and only small insignificant changes of mean values were observed at the follow-up registrations (Table 5). However, variations for individual subjects were obvious, ranging from 4.7 mm to –2.8 mm (Table 5), though no clear differences could be observed between the genders.

Correlations

For the entire reference group, the Ga measurements were significantly correlated to posterior face height (S-Go; $r = -0.213$), vertical overbite ($r = -0.327$), and NSL/ML angle ($r = -0.495$) measurements at the baseline registration (R-0). Vertical overbite measurements were also significantly correlated to NSL/ML measurements ($r = -0.251$) at the baseline registration, as well as the clinical length of the canine tooth to anterior (N-Gn; $r = 0.227$) and posterior (S-Go; $r = 0.264$) face heights.

For females, Ga measurements were significantly correlated to vertical overbite ($r = -0.399$) and NSL/ML angle ($r = 0.400$) at R-0, and vertical overbite measurements were significantly correlated to the NSL/ML

Table 3 Mean Anterior (N-Gn) and Posterior (S-Go) Face Height (mm) and Mean Mandibular Gonion Angle (Ga) and Angle Between Base of the Mandible and Base of the Skull (NSL/ML) (deg) at the First Registration in the Reference Group*

	Registration at baseline (R-0)							
	Males (n = 77)				Females (n = 57)			
	N-Gn	S-Go	Ga	NSL/ML	N-Gn	S-Go	Ga	NSL/ML
Mean	124.7	88.0	119.4	26.3	115.2	76.7	122.4	29.8
SD	5.78	4.90	6.30	4.51	5.95	4.78	5.50	5.23
Minimum	110.7	77.5	102.2	16.9	103.0	67.3	104.3	18.1
Maximum	140.9	102.0	143.0	38.7	127.4	86.0	137.2	44.7

*All 4 parameters showed significant differences between genders ($P < .05$).

Table 4 Mean Change of Anterior (N-Gn) and Posterior (S-Go) Face Height and Angle Between Base of the Mandible and Base of the Skull (NSL-ML) from Baseline to the 10-Year Follow-up in the Reference Group and Distribution of Changes of Individual Subjects

	Males (n = 77)			Females (n = 57)		
	N-Gn†	S-Go	NSL-ML†	N-Gn†	S-Go	NSL-ML†
Mean	0.7*	1.6*	0.0	1.4*	1.2*	0.9*
SD	1.72	2.38	1.60	1.65	2.13	1.35
Minimum	−2.4	−5.0	−4.4	−2.5	−3.2	−1.7
Maximum	5.2	6.6	5.4	4.7	6.5	4.9
Distribution: increase/decrease						
Increase	49	58	34	44	42	45
Decrease	27	19	42	12	15	12
Distribution: change (mm)						
< −3.0	–	2	2	–	2	–
−3.0 to −1.6	7	4	9	4	3	1
± 1.5	50	28	55	27	27	41
1.6–3.0	14	21	8	15	11	11
> 3.0	6 (7.8)	22 (28.6)	3 (3.9)	11 (19.3)	14 (24.6)	4 (7.0)

*Significant change from baseline to 10 years ($P < .05$).
†Significant difference between genders ($P < .05$).

Table 5 Mean Vertical Overbite at the First Registration (R-0), Change Between Baseline and Follow-up Situations (R-0 to R-10/R-0 to R-20) (mm) for Reference Subjects, and Distribution of Individual Observations in Relation to Vertical Overbite and Degree of Change

	Males			Females		
Vertical overbite*	R-0	R-0 to R-10	R-0 to R-20	R-0	R-0 to R-10	R-0 to R-20
No.	57	57	30	77	77	31
Mean (mm)	2.3	0.2	−0.2	2.7	−0.1	0.1
SD	1.31	1.04	0.90	1.68	0.89	0.77
Maximum (mm)	4.9	+4.7	+1.5	8.1	+1.6	+2.7
Minimum (mm)	−2.7	−2.8	−2.2	−2.7	−2.5	−1.1
Distribution (mm)						
> 6 / < −1.0		5 (9)	7 (23)	1	11 (14)	1 (3)
6.0–4.0 / < 0 to −1.0	3	19	8	15	30	11
3.9–3.0 / 0	15	4	3	10	8	7
2.9–2.0 / > 0–1.0	22	21	10	26	19	10
1.9–0.1 / > 1.0	15	8 (14)	2 (7)	21	9 (12)	2 (7)
0.0 to < 0	2			4		

*No correlation to tooth length ($P > .05$).

angle ($r = -0.395$) at baseline. Measurements of the clinical length of all 3 measured teeth showed a trend of correlation between change of clinical crown length and change of posterior face height (S-Go), reaching a significant level for lateral incisors only ($r = -0.260$).

For males, Ga measurements were significantly correlated to NSL/ML angle ($r = 0.521$), posterior face height ($r = 0.270$), and vertical overbite ($r = -0.259$) parameters at baseline. Change of vertical overbite after 10 years showed a significant correlation to anterior ($r = 0.237$) and posterior ($r = 0.357$) face height at the first registration.

Discussion

Within the limitation of the relatively small sample size, the present data indicate a different long-term pattern for males compared to females, with a higher risk for implant infraposition in female patients (Table 2). Signs of vertical and palatal tooth movements were observed, in accordance with earlier publications discussing continuous tooth eruption in the adult patient.[4–9] This difference between genders has not been discussed extensively in earlier follow-up studies on single-implant patients but has been frequently reported with regard to cephalometric parameters and craniofacial growth/changes.[10,11,14,15,17]

Certainly, a clinical score index to assess vertical tooth movements in relation to the implant crowns has its limitations. However, when it comes to patient complaints regarding esthetic situations and tooth movements, the patient relates his or her concerns in clinical terms, rather than objective, measurable parameters. Possibly, the index may be too refined as a clinical judgment; however, even if the only parameters used were "tooth movement" (scores B to D) and "no tooth movement" (score A), there would still be a trend of a more stable situation for male patients. Accordingly, in addition to open bite situations, females seem to be at a higher risk for single-implant infraposition caused by adult anterior face growth, as exemplified in a recent case report.[9]

The use of the present reference group is not optimal in the sense that the follow-up time for this group does not coincide with that of the test group. However, it was still considered valuable to allow for a comparison and discussion of implant infraposition in relation to a cephalometric long-term reference material from the same study, including individual observations, rather than mean values reported by others. Size of the reference group as well as age at inclusion, along with ethnic similarities, are favorable factors of importance for comparison and discussion, while the shorter follow-up time is compromising. However, as discussed in the previous publication,[18] most likely even greater cephalometric differences would have been reported if a longer follow-up period had been covered for the reference group.

It is reasonable to assume that patients with an increase of anterior face height (N-Gn) and/or posterior rotation of the mandible (increased NSL/ML angle) present a higher risk for implant infraposition when implants are placed in the anterior maxilla. In the present study, females showed a significantly greater increase ($P < .05$) and incidence (NSL/ML; $P < .05$) of these 2 cephalometric parameters after 10 years compared to males (Table 4). This pattern is well in accordance with other reports in adult persons, which also show obvious gender differences with regard to these parameters.[10,11,14,17]

Eighteen percent of measured single-implant sites presented an implant infraposition of 1 mm or more in relation to adjacent teeth in a previous radiographic study.[8] This coincides well with the prevalence of 14% of the sites with a similar level of infraposition in the present study (Table 2; score D). Single-implant sites with scores C and D present clinical situations that should initiate a discussion of new, longer implant crowns. These situations apply to 25% of the implant sites in this study, with a relationship of 1 to 1.9 for males to females (Table 2). Since there are few female patients in the test group, the estimation of distribution becomes uncertain, and this relationship does not coincide with the findings of Bernard et al[8]; however, the present study covers patients with a longer follow-up period. Furthermore, the relationship between genders in the present test group coincides with the relative distribution of males and females in the present reference group, considering obvious changes of anterior face height and change of NSL/ML angle (> 3.0 mm/degrees of change; Table 4). Thus, it is reasonable to assume that there is a higher risk for obvious vertical tooth movements in relation to anterior single implants in females compared to males in the long term, in accordance with a higher relative prevalence of obvious increased anterior face height and posterior rotation of the mandible in females, as also reported by others.[10,11,14,15,17]

It would be of great value if simple clinical parameters could be found to identify at-risk patients when single-implant treatment is planned. As discussed in the previous publication,[18] the present study further supports the assumption that females with long faces and posterior rotation of the mandible are potentially at risk. However, besides an open bite situation, no new obvious clinical predictor has been identified in the present study. In the previous study, clinical crown height at the first examination could possibly predict further changes of clinical crown height. A similar obvious clinical/radiographic predictor for facial anterior growth/change would be of great value to predict anterior facial growth in the adult patient. During the

planning stage of the present study, it was hypothesized that easily identified parameters such as vertical overbite or Ga measurements could be used as simple predictors of further facial growth/changes. However, no significant relationship could be established between these cephalometric and study cast parameters and a further increase of anterior facial height or posterior rotation of the mandible in this study. As an alternative, occlusal force measurements could be such a predicting factor, since many studies have reported more or less strong relationships between facial growth and occlusal force.[23–29] Thus, persons with long-face anatomy showing posterior mandibular rotation and increasing anterior face height may present lower occlusal force values compared to square-face persons—a relationship that would be of interest to future studies.

Conclusions

In conclusion, the present study shows that tooth movements occur in some patients adjacent to single implants in the anterior maxilla over the long term. The risk for major tooth movements seems to be higher in female patients. This may be associated with the significantly greater increase of anterior face height and posterior rotation of the mandible in females. Accordingly, it could be suggested that female patients with long-face anatomy are at risk for later tooth movements when single implants are placed in the anterior maxilla.

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