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Radiological evaluation of single implants in maxillary anterior sites with special emphasis on their relation to adjacent teeth – a 3-year follow-up study

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Abstract – *Aim*: The aim of this study was to measure, in adults, changes in crest bone level around single dental implants in the anterior maxilla and continuous eruption of adjacent teeth. *Material and methods*: In this prospective study, 50 patients received single-implant-supported crowns in the maxillary anterior region. Enrolled patients lacked maxillary anterior teeth as a sequel to trauma or agenesis in the maxillary anterior region. Participants were followed during a 3-year period. Baseline radiographs were taken at the time of loading and then repeated at one- and 3-year recalls. Radiographic parameters were recorded to assess changes in the skeletal bone structure and crest bone level. *Results*: Twenty-six patients attended for all recalls. Three patients were excluded owing to difficulties related to identifying the same radiographic landmark on the radiographs throughout the recall period. All implants were successfully integrated with no sign of peri-implantitis. The mean crest bone loss was 0.45 mm at the mesial aspect of the implant and 0.56 mm at the distal aspect. In smokers, there was significant bone loss on the distal aspect. Mean change between reference points on implant and adjacent tooth (continuous eruption of adjacent tooth) over the 3-year period was 0.67 mm. In women, mean change (0.79 mm) was statistically insignificantly higher, compared with men (0.59 mm). *Conclusions*: Radiographic evaluation of crest bone level showed slight bone loss after 3 years of functional loading. Some changes in the eruption of neighbouring teeth were seen. Being a smoker was associated with significant negative changes related to the crest bone level.

Introduction

Missing teeth as a consequence of traumatic dental injuries (TDI) in the maxillary anterior region, often referred as the aesthetic zone, can entail permanent damage with fibrotic scar formation and reduction of the maxillary alveolar bone ridge and its quality (1). Uncontrollable periapical lesions, vertical root fractures and traumatized alveolar bone can all lead to bone resorption, deformation and permanent loss of the alveolar bone structure and soft tissue. Consequences of tooth avulsion and replantation can be replacement resorption and ankylosis, with teeth in infra-position and arrested alveolar bone growth in both horizontal and vertical directions with subsequent unfavourable aesthetic results (2–4). Further, surgical removal of the ankylotic tooth may lead to permanent bone loss and the need for surgical bone augmentation to secure the quality and quantity of the surrounding bone and mucosa, which are of importance for successful replacement by implant-supported crowns.

Studies related to the incidence of TDI in children and adolescents indicate a cumulative incidence between 1 and 3%, with peak incidence in the age range 8–10 years (5–7). Other studies show that boys are more prone to TDI, often related to physical activity and sports engagement. The maxillary central incisors are the tooth group most often involved in TDI (8, 9).

Dental implants have, over recent decades, been accepted as the least invasive method for prosthetic restoration of anterior single teeth absent owing to trauma or agenesis. Studies show a 5-year survival rate for implant therapy exceeding 95% (10–12).

Important criteria for long-term success of dental implants are stabile bone support, a moderate degree of inflammation around the implant site, good aesthetic appearance and a fully functional implant-supported crown (13). Studies have shown that the major loss of bone related to implants occurs within the first year after placement, and there is far less annual bone loss thereafter (14–17). Without international standardized criteria for success regarding bone loss, some investigators propose that bone loss <1.5 mm in the first year in function and followed by <0.2 mm yearly bone loss thereafter indicate success (13, 18). Previous studies have shown that single-implant osseointegrations have similar behaviour to ankylotic teeth and therefore the long-term dento-alveolar changes that occur around the adjacent teeth will not follow (19–21). This phenomenon occurs not only in young patients but also in mature patients (22) and may result in an implant in infra-position, even in adult patients, compromising the implant's function and aesthetic appearance.

The aim of this study was (i) to evaluate radiographically changes in peri-implant bone height related to single-implant crown replacing teeth absent due to TDI or agenesis in the maxillary anterior region and (ii) to measure changes between fixed reference points on the implants and adjacent teeth (continued eruption of adjacent teeth), over a 3-year period.

Material and methods

A total of 50 patients with 56 implants prosthetically rehabilitated using single-implant-anchored crowns to replace teeth absent as sequel to TDI or agenesis in the maxillary anterior region (canine to canine) were included. All subjects had received implant-anchored crown at the Dental Hospital, University of Bergen (UoB) or the Department of Maxillo-facial Surgery, Haukeland University Hospital (HUS) during the year 2006. After being informed about the aim of the study, written consent was obtained from all participants. Radiographs were taken at the time of loading the implant with a crown and repeated at the 1- and 3-year recall visits. Participants residing outside Bergen had their travelling expenses for the recalls reimbursed. Participants present at the 3-year recall included 26 patients with 28 implants. Of the 28 implants, 26 were Brånemark (Nobel Biocare, Göteborg, Sweden) and 2 were Astra (Astra Tech, Mödalen, Sweden). The implants surfaces in this study were modified by the manufacture, Brånemark implants had the same oxidized layer (TiUnite®) and Astra implants had the same fluoride-modified surface layer (OssoSpeed®). For the present paper, when a participant had more than one implant, only the one with the most anterior position was analysed, giving 26 participants and implants. The mean age of the patients was 34.8 years (range 20–56 years) with 11 women (42.3%) and 15 men (57.7%). All surgical treatments were carried out by oral surgery specialists following the implant manufacturers' instructions. The prosthodontic treatment was carried out by prosthodontic specialists and a dentist with special training in implantology.

Radiographic examination

The initial radiographs were taken at the time of functional loading of the implants and used as a baseline. They were repeated at the 1- and 3-year recalls using the same long-cone parallel technique and an Eggen-system holder (Eggen, Lillehammer, Norway), maintaining the implant in the centre. Radiographs were taken either using film F-speed (Kodak Insight, Eastman Kodak Co., Rochester, NY, USA) or digital film Digora® Optime phosphor image plate system (Soredex Corporation, Helsinki, Finland). The two different types of radiographic films used in this study were because of a transitional phase regarding renewing radiographic equipment at the institutions involved. Radiographic examinations were conducted by the main investigator (VHV), who was not involved in the surgical or prosthetic parts of the treatment. All radiographs were processed and analysed using NIS-elements BR 2.30, SP4 computer software (Nikon Instruments Inc., Tokyo, Japan).

For each radiograph, three separate measures were taken for all relevant variables (mesial and distal bone height and further eruption of adjacent teeth). The mean of the three measures was the expression of the relevant variable in each case.

Measuring changes in marginal bone level

Both mesial and distal peri-implant crest bone levels were measured on radiographs according to Bragger et al. (23) (Fig. 1) by using both the implant shoulder, fixture-abutment junction (FAJ) and the most apical part of the implant as reference points for reaching linear measuring values. To compensate for radiographic length distortion, all length measurements were corrected by a factor given by the ratio between the measured length of implant on each radiograph and the original length of the implant type given by the manufacturer.

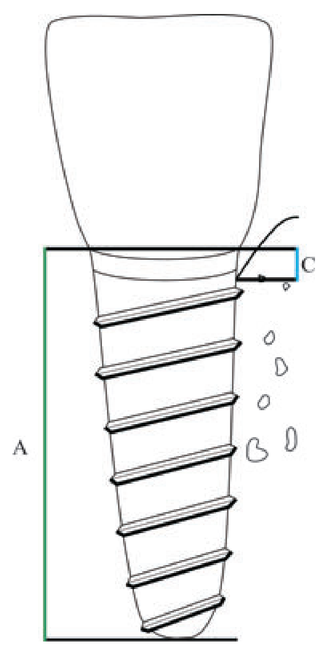

Fig. 1. Drawing showing the relevant measures related to marginal bone changes. Evaluation of the image distortion by measuring the length of the implant (A). Marginal bone level was measured as the distance between the fixture-abutment junction and bone level related to the relevant side of the implant (C).

Measuring differences between reference points on implant and adjacent tooth (eruption)

For measuring changes between fixed reference points of the implants and their adjacent teeth, the implant fixture-abutment junction (FAJ) facing the adjacent tooth was used as a reference point owing to the implant's osseointegration. The reference point chosen on the neighbouring tooth was a carefully chosen landmark easy to reproduce on all the radiographs throughout the study period, being a filling or the angle between the axial and incisal edge of the tooth. The same reference points were used on both the implant and the adjacent tooth on all radiographs for each case. The same corrections for possible distortion on the radiograph were carried out as for the measuring of marginal bone level. The collected data were used to compare any changes between the same reference points according to Bernard et al. (19) (Fig. 2).

Statistical analyses

Data processing and analysis were carried out using the Statistical Package for Social Sciences (SPSS), version 15.0 (SPSS Inc., Chicago, IL, USA).

Frequency distributions were produced and the intraclass correlation coefficient was used for the test-retest calculations. Cross-tabulation and the Pearson chi-square test were used for identifying associations between relevant variables and gender. Pearson chi-square test was also used for dropout analysis. The general linear model for repeated measures was used for identifying differences between the baseline, 1-year and 3-year recall (Wilks' Lambda). If a significant difference was revealed, the multiple comparisons were used to determine amongst which groups the difference was significant (Bonferroni). The between-subjects factor was used to test for the effect of variables given in Table 1 on the outcome. The level of significance was set at 5%.

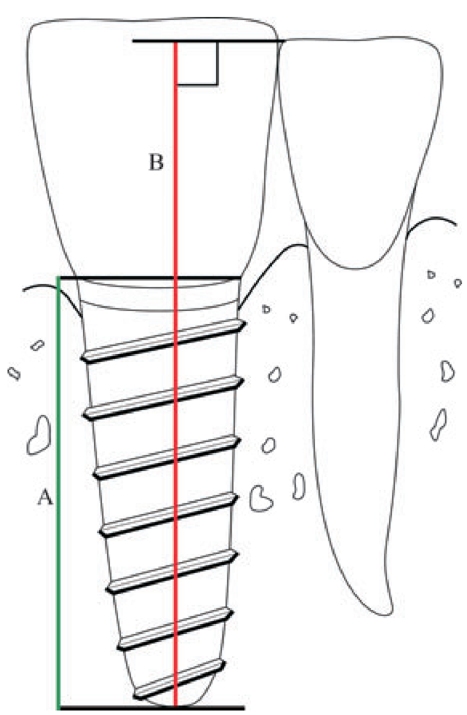

Fig. 2. Drawing showing the relevant measures related to fixed points on implant and neighbouring teeth. The evaluation of the image distortion was by measuring A; length of the implant. Differences in measures between T_0 and T_1 were measured as changes in length on the longitudinal axis of the implant between the apical part of the implant and the line perpendicular to the fixed point of the neighbouring tooth (B).

Reliability

For calibration purposes, three separate measures were conducted on the relevant variables on each radiograph, 2–4 weeks after the original measures. A mean value was calculated based on these three measures on all radiographs taken at the 1- and 3-year recalls.

The two mean values obtained were correlated to check for reliability of the data collected. For the repeated measures of the bone level of the implants, the intra-class correlation coefficients were 0.98 and 0.99 for the mesial side and 0.92 and 0.99 for the distal side. For the measurement of the distance between the fixed reference points on implant and adjacent tooth (eruption), the two intra-class correlation coefficients were 0.64 (24).

Results

The study group consisted of 26 patients and implants (11 women and 15 men) at the 3-year recall. All implants were stable and no signs of peri-implantitis or loosening of implants during the 3-year observation period. However, as three radiographs at baseline were difficult to identify reference points for neighbouring teeth, the total number of individuals analysed in this

Table 1. Distribution of relevant variables according to sex (n = 23)

	Sex			
Variable	Male (14)	Female (9)	Total	Pearson χ^2 (2-sided asymp.)
Reason for treatment				
Trauma	13	9	21	0.72
Agenesis	1	1	2	
Preoperative bone augmentation				
Yes	7	5	12	0.80
No	7	4	11	
Type of implant				
Brånemark	12	9	24	0.50
Astra	2	0	2	
Age (years)				
20–35	8	5	13	0.94
36–56	6	4	10	
Smoking				
Yes	4	4	8	0.44
No	10	5	15	
CPI				
0–2	12	8	20	0.83
3–4	2	1	3	

study was 23. There was no significant effect of gender ($P < 0.05$) on any of the variables given in Table 1.

A dropout analysis was carried out. No statistic significant differences were found between the dropout group and the 3-year recall group regarding smoking, gender, income or education. The only variable showing statistical significance ($P = 0.026$) was age (dichotomized according to Table 1), indicating higher dropout amongst younger patients.

A total of 14 implants replaced central incisors (10 for tooth 11), 7 replaced lateral incisors and 2 replaced canines. The main causal variable for missing teeth was trauma (21 implants, 91.3%), while the remaining two implants were required because of agenesis (8.7%).

Details of radiographic measurements for the evaluation on bone marginal level changes from baseline, 1-year recall and 3-year recall are presented in Table 2. There was a gradual increase in bone loss from baseline to the 1- and 3-year recalls. The mean bone loss difference between baseline and the 3-year recall was 0.45 mm on the mesial side of the implants, ranging from an increase in the bone level of 1.60 mm to a loss of 2.63 mm. For the distal side, the mean bone loss over the 3-year period was 0.56 mm, ranging from an increase of 1.35 mm to a loss of 3.97 mm.

The between-subjects factor revealed a significant effect of smoking on the distal crest bone level ($P < 0.05$). However, smoking was not significant for the mesial crest bone level ($P < 0.10$). None of the other variables shown in Table 1 had an effect on the change in crest bone level.

For the measurement of the difference between the fixed references points of the implant and the adjacent tooth (eruption of adjacent tooth), a vertical change could be observed already at the 1-year recall (Table 3). There were significant changes between baseline and the 3-year recall and between the 1- and 3-year recalls. The mean change in eruption of neighbouring teeth over the 3-year period was 0.67 mm, ranging from 0.13 to 1.75 mm.

There was no effect on the mean difference between the fixed reference point on the implant and the adjacent tooth for any of the variables included in Table 1. However, women showed a higher, but statistically not significant, mean change (0.79 mm) compared with men (0.59 mm) over the 3-year observation period.

Table 2. Mean distances between reference point on implants and alveolar crest bone levels on mesial and distal aspects of the implant-supported crown. Statistically significant values with multiple comparisons in bold face

Side of tooth	*n*	Mean value (mm) *	SD	Pair-wise comparison	Sign. Multiple comparison (Bonferroni)
Baseline					
Mesial	23	1.17	0.70	1-year recall	1.00
				3-year recall	0.26
Distal	23	1.17	0.61	1-year recall	0.50
				3-year recall	**0.04**
1-year recall					
Mesial	23	1.29	0.84	Baseline	1.00
				3-year recall	**0.03**
Distal	23	1.48	0.98	Baseline	0.50
				3-year recall	**0.01**
3-year recall					
Mesial	23	1.62	1.08	Baseline	0.26
				1-year recall	**0.03**
Distal	23	1.77	1.11	Baseline	**0.04**
				1-year recall	**0.01**

*Wilks' Lambda showed a significant overall effect of for the mesial aspect ($P < 0.04$) and for the distal aspect ($P < 0.01$).

Discussion

Trauma was the main reason for the absence of teeth amongst the participants in this study (88. 5%) and predominated in men (57.7%). This, as well as the distribution of teeth exposed to trauma amongst our participants, corresponds well with established facts related to the occurrence of TDI (5, 7, 25–27).

Dropouts occur in most clinical prospective investigation, and it is important to discuss its implications owing to possible bias. The rather high dropout rate in this study did not influence any of the variables with effect on the results (smoking with effect on bone level). The only significant difference between dropouts and the 3-year recall group was age. An important reason for dropout amongst young people is likely to be lifestyle changes.

The radiographs in this study were either taken by conventional radiographic film or by phosphor image system. At the time when the study started, the use of digital radiographs was not fully implemented at the institutions involved. However, after a transitional phase, the phosphor indirect image system is now used routinely. Although digital films show higher density values and narrower density ranges, studies show similar levels of reproducibility of structures such as alveolar crest bone level and high relative inter-observer agreement when comparing digitalized and conversational films (28–30). The reliability of measuring marginal bone level radiographically depends on reproducible methods for such measurements, including standardized radiographic tools, image resolution, parallel standardized film holders, and accurate analytical and measuring devices such as data programs and computer equipment (31, 32). One study concluded that

Table 3. Mean distance between reference points on the implants and adjacent teeth (eruption). Statistically significant values with multiple comparisons in bold face

	n	Mean value (mm)*	SD	Pair-wise comparison	Sign. Multiple comparison (Bonferroni)
Baseline	23	21.82	3.15	1-year recall	0.36
				3-year recall	**0.00**
1-year recall	23	22.04	3.19	Baseline	0.36
				3-year recall	**0.01**
3-year recall	23	22.48	3.12	Baseline	**0.00**
				1-year recall	**0.13**

*Wilks' Lambda showed a significant overall effect ($P < 0.001$).

reliable methods for detecting true bone loss cannot be established until at least 1mm marginal bone loss between the tooth CEJ and its adjacent bone has occurred (33). Clearly, there are differences in radiographic detail between the tooth reference point using the CEJ and more distinct metallic landmarks on the implant. Further developments in tools for data analysis and better image quality can be expected to improve accuracy and radiographic diagnostic reliability (34). Two-dimensional intraoral radiographs are easy to use, a low dose of radiation is needed and the images are reliable but there are limitations in evaluating the buccal and palatal bone levels and some intra-osseous defects (35, 36). Newer radiographic instruments such as cone beam computer tomography allow for three-dimensional detailed images of the bone tissue surrounding the implant and are able to monitor accurately the changes in bone levels pattern over time (37). This is an expensive technique, and complexity and higher radiation doses required will limit its use. The results of this 3-year follow up of single implants in the maxillary anterior region indicate a mean alveolar crest bone height loss of 0.45 mm on the mesial side and 0.56 mm on the distal aspect, measured from the time of prosthetic loading (baseline). Although there is loss of crest bone, the amount of loss presented in this study is well within the criteria for success proposed by some authors (13, 18), and comparable with the findings of other studies which reported bone losses of between 0.5 and 0.8 mm over a 5-year period (14, 38). Implant studies that measure marginal bone losses report wide-ranging values, possibly owing to differences in study designs, variations in image quality, variations between observers interpreting the different variables and the use of products from different implant manufacturers and types, and comparisons of results of the different studies are therefore difficult (39, 40). Using radiographic evaluation with regular intervals is a non-invasive way of recording changes in bone structure surrounding the single implant. Even minimal changes can now be recorded, although limitations persist relating to registering a three-dimensional object on two-dimensional images, with missing measurements on the buccal and palatal sides of the single implant. The need for consensus parameters for monitoring marginal bone losses with radiographic evaluation is essential because of the need to define widely accepted criteria for success.

In this study, smoking was the only factor (distal aspect) negatively affecting peri-implant bone loss. This is in agreement with other studies, verifying that not only does smoking contribute to more bone loss, but it has far more negative effect on crest bone loss in the maxilla than in the mandibular region (41, 42). A low number of participants at the 3-year follow up might explain the fact that the relation of bone loss and smoking was significant only for the distal aspect.

Delaying the insertion of dental implants until the patient has completed skeletal height growth, estimated to be 15 years of age for girls and 17 years for boys, is recommended though great variations between individuals occur (22, 43). This estimation is based on radiographic observations of the closure of growth plates of the hand-wrist region (44, 45). Chronologic age is not suitable for estimating cranio-skeletal growth cessation. There are studies that confirm continuous growth in the anterior craniofacial region well into the fourth decade of life (46, 47). The ankylotic behaviour of osseointegrated dental implants puts a stop to continuous skeletal bone growth in both horizontal and vertical directions for tissues surrounding the implant, and could result in infra-position of the osseointegrated implant-supported crown compared with natural neighbouring teeth. Anterior teeth in infra-position create aesthetically unfavourable situations over time (20).

The finding in our study confirms continuous eruption of teeth adjacent to osseointegrated dental implants in adult patients, with mean changes of 0.67 mm (Table 3) over a 3-year period. This is in agreement with other studies comparing patients at similar ages (19, 20). These findings clearly anticipate the effect of small changes over time in a critical aesthetic zone which can compromise oral rehabilitation by creating aesthetical disharmony and compromising the function of the implant crown. For patients who have lost teeth following trauma at young age, treatment with implant-supported crowns is often undertaken in the early twenties, so the long-term consequences of continuing eruption of adjacent teeth and marginal bone loss must be considered.

Even though no statistically significant differences were found between gender and eruption of teeth adjacent to implants in this study, there was a trend for women to have higher mean values of continuous eruption of teeth adjacent to implants compared with the male group. This is in accordance with findings from earlier reports which indicate different long-term craniofacial growth patterns between men and women; men appear to have a more passive continuous eruption pattern (21, 22).

The muco-gingival conditions surrounding the implant are an important factor linked to a successful aesthetic outcome, providing harmony with the adjacent teeth on the facial aspect and at interproximal sites. Interproximal and facial marginal mucosal heights around the implant site depend on the marginal bone level and the contact point between the implant crown and the adjacent teeth. Studies have indicated the relationship between the soft tissue thickness and the marginal crest level to be approximately 5 mm. This indicates that marginal bone loss over time will lead to muco-gingival regression in the facial region with, as a consequence, the uncovering of the implant's screw structure, leading to black areas which will jeopardize the aesthetics and cause discomfort to the patient. Slow marginal bone loss will have similar effects in the proximal area regarding the gingival papillae (48–50). The long-term effects of crestal bone loss around an implant in the proximal area should have lesser impact on the papillary height compared with the facial aspect because of the crest bone height is determined by its contact point with the adjacent tooth. Hence, continuous eruption of teeth adjacent to the osseointegrated implant could compensate for the long-term natural crest bone loss near to the single implant, thus avoiding later papilla loss. Another factor affecting the long-term outcome is the fact that the teeth most commonly affected by tooth wear are the incisors; wear on these teeth increases with age as a part of the ageing process (51, 52), while porcelain crowns show less wear than natural teeth (53). In cases where natural teeth are adjacent to a single-implant crown, this might contribute to arresting unfavourable long-term aesthetic changes regarding changes in incisal height in the aesthetic zone.

Conclusions

Using radiographs to analyse and investigate marginal bone loss and continuous eruption of teeth adjacent to implants is a simple and accurate way of measuring long-term changes in the hard tissue around the implants. This study shows that adult patients with implant-supported crowns in the maxillary anterior region display long-term changes, such as continuous cranio-skeletal growth and marginal bone level changes. These changes may jeopardize the aesthetic and long-term function of the implant. Smoking was the only variable with a significant effect on negative changes related to the marginal bone level.

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