Longitudinal Changes in Tooth/Single-Implant Relationship and Bone Topography: An 8-Year Retrospective Analysis

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ABSTRACT

Purpose: To evaluate longitudinal changes in tooth/implant relationship and bone topography at single implants with a microthreaded, conical marginal portion (Astra Tech ST® implants, Astra Tech AB, Mölndal, Sweden).

Material and Methods: Thirty-one subjects with single implant–supported restorations in the esthetic zone were included. Radiographs obtained at crown installation and 1, 5, and 8 years of follow-up were analyzed with regard to changes in (1) bone level at the implant and adjacent teeth and (2) vertical position of adjacent teeth relative to the single implant.

Results: The mean marginal bone loss amounted to 0.1 mm at both implants and adjacent teeth during the 8 years of follow-up. Regression analysis failed to identify significant explanatory factors for observed variance in bone level change at the adjacent tooth surfaces. Vertical change in position of the teeth relative to the implants was more frequent and significantly greater in incisor compared with premolar tooth region but not associated with gender or age.

Conclusions: The marginal bone level at teeth adjacent to single implants with a microthreaded conical marginal part was not influenced by horizontal and vertical tooth-implant distances. Continuous eruption of adjacent teeth may result in infraocclusal positioning of a single-implant restoration.

KEY WORDS: bone loss, esthetics, implant-tooth distance, single implant, tooth eruption

INTRODUCTION

A high functional success rate of implant-supported single-tooth replacement has been documented in long-term prospective studies.[1] From an esthetic point of view, particularly when implants are placed in the anterior tooth region of the maxilla, the soft tissue topography around the implant-supported restoration, and its crown position in relation to adjacent teeth, are significant factors for treatment success.[2]

The height of the papillae between a single-implant restoration and adjacent teeth is claimed to be related to the bone level, or rather the connective attachment level, at the tooth surfaces facing the implant.[3,4] Radiographic evaluations of implants placed adjacent to teeth revealed that the inter-unit distance is a risk factor to consider with respect to marginal bone loss at the tooth.[5–9] Furthermore, an increased vertical implant-tooth distance was shown to cause increased marginal bone loss at the tooth surfaces facing the implant.[10]

The magnitude of bone loss around an implant may vary depending on its design and surface topography.[11–14] A conical implant-abutment interface was shown to more effectively counteract the stress concentration at the level of the marginal bone than a platform interface,[15,16] which in clinical studies was evidenced by a minimal bone resorption.[17–19] Other features of the marginal portion of the implant, for example surface modifications/roughness[13,20–22] and platform switching[14] may also be of significance for the maintenance of the peri-implant bone level. The Astra Tech ST® implant (Astra Tech AB, Mölndal, Sweden), which includes all these features, was in animal and

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human studies shown to cause minimal amount of peri-implant bone loss.[21,23–26] However, whether the reduced peri-implant bone resorption might lower the risk for bone loss at the adjacent tooth in case of a close relationship to the implant has not been addressed in previous studies.

Besides the soft tissue topography, disharmony in the position of the implant-supported crown in relation to neighboring teeth is of esthetic concern. Similar to ankylotic teeth, osseointegrated single implants face the risk to be positioned in infraocclusion by time because of continuous eruption of the adjacent teeth and/or facial bone growth.[27] In fact, longitudinal studies reported development of infraocclusal positioning of single implant–supported restorations in the anterior maxilla among both adolescents and adults.[8,28–30]

The aim of this study was to evaluate longitudinal changes in bone topography and tooth/implant relationship in patients with single implants with a microthreaded, conical marginal part (Astra Tech ST implants).

MATERIALS AND METHODS

Subject Sample

Subjects for the study were recruited from the pool of patients that had been treated with single implant–supported restorations at the Department of Periodontology, Institute of Odontology, The Sahlgrenska Academy at University of Gothenburg, Sweden. To be included in the study, the patient had to have the single implant placed in the esthetic zone of the maxillary jaw (tooth region 15–25) and functionally loaded for at least 5 years. Furthermore, radiographs of the implant site had to be available at crown cementation and at 1, 5, and preferably 8 years of follow-up. Thirty-one subjects (13 females/18 males) with 33 single implants qualified for the study. Ten implants were replacing central incisors, 9 lateral incisors, 11 first premolars, and 3 second premolars. Twenty-two of the subjects (24 single implants) were followed for 8 years. The mean age of the subjects at the time of implant surgery was 40 years (SD 12.6, range 19–71). The Ethics Committee at The Sahlgrenska Academy, University of Gothenburg, approved the study protocol.

Implant Treatment

All patients had been treated with Astra Tech ST implants with a body diameter of 3.5 mm and a marginal conical diameter of 4.5 mm inserted in a submerged procedure according to the manufacturer's manual. About 6 months after implant installation, standard ST-Abutments® varying in length from 0 and 1.5 mm, were connected to the implants. Immediately after abutment connection, an acrylic crown restoration was fabricated and inserted as a temporary prosthesis. The final porcelain fused to metal crown was cemented with a normal setting, zinc phosphate cement (De Trey Zinc cement, De Trey Division, Dentsply Ltd., Addlestone, UK) about 4 weeks after the abutment connection.

Standardized radiographs, with the film (Kodak Ektaspeed Plus, Eastman Kodak Co., Rochester, NY, USA) kept parallel and the X-ray beam (Heliodent MD, 60 kV, 7 mA, Siemens AG, Bensheim, Germany) perpendicular to the implant, were taken at crown placement and at 1, 5, and 8 years of follow-up using individually fabricated film holders (Have-Super-Bite, Hawe-Neos Dental, Genilino, Switzerland) attached to the occlusal surface of the suprastructure using an impression material (Optosil®P, Bayer Dental, Leverkussen, Germany).

Radiographic Measurements

Linear measurements were performed by the use of the software program NIH Image (Wayne Rasband, US National Institutes of Health, available electronically via Internet from the NIH Image website at http://rsb.info.nih.gov/nih-image[31]) on scanned images of the radiographs (resolution 500 dpi; PowerLook1000®, UMAX Technologies Inc., Dallas, TX, USA). The known implant diameter (4.5 mm) and length of the microthreaded portion (5.4 mm) were used for calibration of horizontal and vertical measurements in each radiograph. A line through the marginal corners of the implant shoulder (0.3 mm below the implant/abutment level) was used as a reference level for the measurements. The following variables were assessed to the nearest 0.1 mm at the mesial and distal sites of the implant and the adjacent tooth surfaces by a trained examiner (MC) (Figure 1).

Implant Position. Vertical implant-tooth distance is the distance between the location of the cement–enamel junction (CEJ) on the neighboring tooth and the reference level. Horizontal implant-tooth distance is the distance between implant and adjacent tooth at the reference level. Root apex position is the position of the apex of the adjacent tooth in relation to the thread

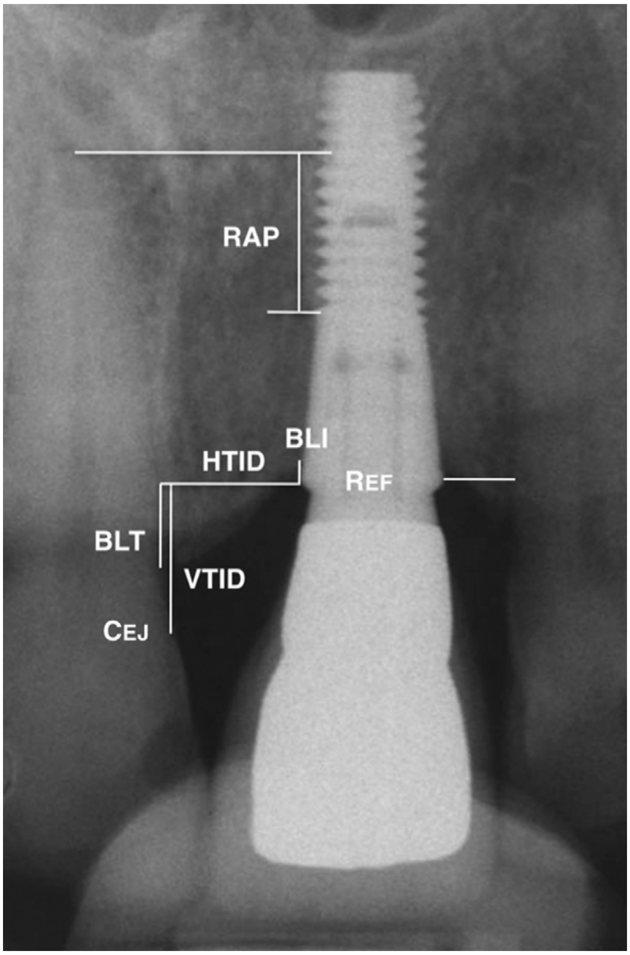

Figure 1 Radiographic assessments performed on the scanned image of radiograph (BLI = bone level at the implant; BLT = bone level at the tooth; CEJ = cement-enamel junction; HTID = horizontal tooth-implant distance; RAP = root apex position; REF = reference level; VTID = vertical tooth-implant distance).

level of the implant (lower half thread, i.e., 0.3 mm) assessed from the apical extension of the conical part of the implant. Two implants had to be excluded with regard to this assessment because the apex of the teeth was not reproduced in the radiographs.

Bone Topography. Bone level at tooth is the vertical distance between the reference level of the implant and the most coronal bone level at which the width of the periodontal ligament space was considered normal. Bone level at implant is the vertical distance between the reference level and the bone-to-implant contact.

Error of the Method

The measurement error was estimated by repeated assessments of 10 randomly selected images (20 mesial and distal sites) with a time interval of 2 weeks. The mean difference was 0.01 (SD 0.06) mm for the bone level at the adjacent teeth, 0.01(SD 0.03) mm for the bone level at the implants, 0.02 (SD 0.04) mm for the horizontal tooth-implant distance, and 0.04 (SD 0.05) mm for vertical tooth-implant distance. The assessments of the apex level of adjacent teeth in relation to the implant threads were identical in 89%, and no case showed a difference exceeding half a thread (0.3 mm).

Data Analysis

Mean values, standard deviations, and 95% confidence intervals were calculated for each variable with the implant as a statistical unit. To analyze the influence of various factors on the 5-year longitudinal marginal bone level change at the adjacent teeth, a multiple regression model was formulated including horizontal and vertical implant-tooth distances, longitudinal bone level change at the implant, and difference in marginal bone level between tooth and implant at baseline as explanatory variables. A potential relationship of age, gender, and implant position (incisor or premolar) to the presence of vertical change in position of the adjacent teeth relative to the implant was analyzed with the use of a logistic regression model. Data handling and statistical testing were performed with the use of SPSS 16 software package (SPSS Inc., Chicago, IL, USA).

RESULTS

Implant Position

The mean horizontal implant-tooth distance was 2.1 mm (range 0.4–6.4 mm), and the implants were positioned on average 4.1 mm below the CEJ of the adjacent tooth (range 0.2–7.1 mm).

Bone Topography

The data with regard to marginal bone level assessments are given in Table 1. At baseline (crown placement), the marginal bone level at the single implants was located on average 1.0 mm below the reference level, while the position of bone level at the adjacent teeth was 2.1 mm coronal to the reference line. The mean marginal bone loss at implants amounted to 0.1 mm at both 5- and 8-year follow-up. The corresponding figure at the adjacent teeth was 0.0 mm and 0.1 mm, respectively. Two implants showed marginal bone loss in excess of 2 mm after 5 and 8 years in function.

TABLE 1 Bone Level at Baseline (Crown Placement) and Changes at 1, 5, and 8 Years of Follow-Up at Single Implants and Adjacent Teeth

Bone Level	Implants	Adjacent Teeth
Baseline		
Mean (SD)	−1.0 (0.7)	2.1 (1.6)
Change from baseline to		
1 year ($n = 33$)		
Mean (SD)	0.0 (0.7)	0.0 (0.4)
Range	−1.7–1.9	0–0.4
5 years ($n = 33$)		
Mean (SD)	−0.1 (1.1)	0.0 (0.4)
Range	−4.1–1.9	−0.9–0.5
8 years ($n = 24$)		
Mean (SD)	−0.1 (1.3)	−0.1 (0.5)
Range	−4.5–1.9	−0.8–0.4

Mean (SD) and range in millimeters.

TABLE 2 Vertical Change of the Adjacent Tooth in Relation to the Single Implant According to Implant Position (Incisors/Premolars)

	Incisors*	Premolars†	All
Vertical change from crown installation to			
1 year			
Mean	0.14	0.06	0.11
95% CI	0.03/0.25	−0.07/0.18	0.03/0.19
5 years			
Mean	0.37	0.19	0.29
95% CI	0.22/0.52	−0.01/0.37	0.18/0.41
8 years			
Mean	0.53	0.15	0.38
95% CI	0.20/0.85	−0.12/0.42	0.15/0.60

Mean values and 95% confidence interval in millimeters.
*$n = 18$ (1 and 5 years), 13 (8 years).
†$n = 13$ (1 and 5 years), 9 (8 years).

Multiple regression analysis with bone level change at the tooth as dependent variable revealed no statistically significant influence of any of the included explanatory variables (horizontal and vertical implant-tooth distances, peri-implant bone level change) ($p = .074$ for the model).

Change in Vertical Relationship between the Single Implant and Adjacent Teeth

In relation to the single implant, the vertical position of adjacent teeth had changed coronally on average 0.1 mm (95% confidence interval 0.03/0.19) at 1 year, 0.3 mm (0.18/0.41) at 5 years, and 0.4 mm (0.15/0.60) at 8 years (Table 2). The percent frequency of cases showing a coronal shift in position was 29, 55, and 58% at 1, 5 and 8 years, respectively. The mean vertical change in incisor position amounted to 0.4 mm at 5 years and 0.5 mm at 8 years ($p < .05$), whereas in premolar position the assessed relative change was 0.2 mm at both intervals.

The binary logistic regression analyses of factors with potential relationship to the presence of a vertical change of adjacent tooth at 5 years relative the single implant revealed that presence of infraposition of the implant restoration was more common in incisor than premolar position (odds ratio = 8.7; $p = .025$), while gender and age showed no significant association (Table 3).

Figure 2 describes the longitudinal vertical change in position of the teeth relative the single implants for those cases that were followed for 8 years. The single-implant restorations particularly in incisor position revealed a mean continuous increase of the degree of infraposition relative to the adjacent tooth. The greatest difference observed among the cases with an implant-supported crown in the incisor jaw region was 1.2 mm.

DISCUSSION

The results of the present study revealed an insignificant mean marginal bone loss of 0.1 mm at the single

TABLE 3 Binary Logistic Regression Analysis with Vertical Change in Tooth/Implant Relationship at 5 Years as Dependent Variable

Variables	Coefficient	SE	*P* Value	Odds Ratio	95% CI
Implant position (incisor)	2.163	0.965	0.025	8.70	1.31/57.69
Gender (female)	1.349	0.950	0.156	3.86	0.60/24.82
Age	−0.022	0.038	0.558	0.98	0.91/1.05

CI = confidence interval; SE = standard error.

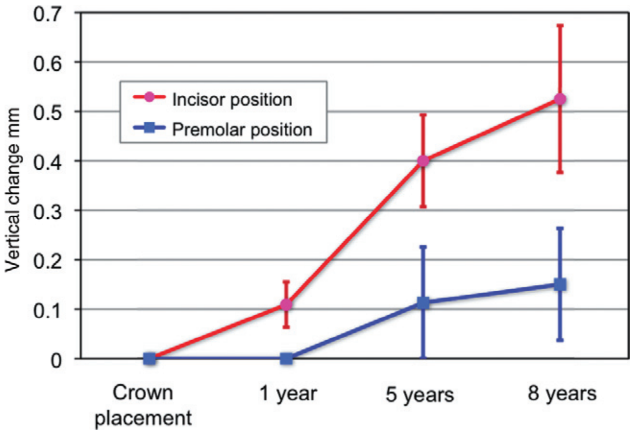

Figure 2 Mean longitudinal vertical change of adjacent tooth in relation to the single implant in patients with 8 years of follow-up, according to implant position (incisor position $n = 13$, premolar position $n = 9$). The bars indicate standard error of the means.

implants and neighboring teeth over the 8 years of follow-up. In a previous publication,[23] describing the overall outcome of the single-implant treatment after 5 years in the subject sample from which the current patient material was generated, it was reported that 48% of the implants had not experienced any bone loss during the observation period, whereas less than 13% showed a peri-implant bone level reduction of >1 mm. These figures with respect to peri-implant bone alterations are well in agreement with data from other longitudinal studies[21,32–34] on the use of Astra Tech ST implants for single-tooth replacement, and demonstrate an excellent long-term performance of the implant with regard to maintenance of the marginal bone level.

At the tooth sites adjacent to the implants, the mean bone loss recorded at 8 years of follow-up was minimal (0.1 mm). Furthermore, neither the horizontal nor the vertical tooth-implant distance was identified as a significant factor influencing the degree of bone loss at the tooth surface. These findings are important in relation to the esthetic outcome of implant-supported single-tooth replacements because loss of marginal bone and periodontal support at the adjacent teeth may cause recession of the proximal soft tissue. Other single implant studies reported increased degree of bone loss at the adjacent tooth when the horizontal implant-tooth distance decreased.[5–10] In these studies it was reported that the bone loss showed large variation between subjects and that the recorded bone loss differed significantly between the anterior (mean 1.6 mm) and posterior tooth regions (mean 0.4 mm).[9] Furthermore, from radiographic examinations of young individuals who received their single-implant therapy during adolescent, Thilander et al.[8] reported 1.4–2.2 mm bone loss between crown cementation and 10-year follow-up at adjacent teeth to single implants placed in incisors position. Esposito et al.[5] on the other hand found that the increased bone loss at adjacent teeth was confined to the time period before loading and that no increase in bone loss was detected during the period of functioning loading. The latter finding is supported by data from a 3-year retrospective study of adult subjects[35] and the current study showing lack of a relationship between the inter-unit distance and longitudinal marginal bone loss at the proximal tooth surface next to an implant.

Infraocclusion positioning of the single implant in relation to adjacent teeth has been observed in longitudinal studies of adolescents and young adults[8,28] but also in mature adults.[29] Similar to ankylotic teeth, the osseointegrated single implant faces the risk to be positioned in infraocclusion by time because of continuous eruption of the adjacent teeth and/or facial bone growth.[27,36,37] In the current study, it was observed that the vertical position of adjacent teeth in relation to the single implant in the incisor tooth region had changed on average 0.1 mm at 1 year, 0.4 mm at 5 years, and 0.5 mm at 8 years. Eighteen of 31 single implants (58%) showed vertical change in position relative to the implant, with a maximum change of 1.2 mm. Jemt et al.[30] reported that all females and 45% of the males included in a 15-year follow-up study showed vertical change of the teeth adjacent to a single implant. Bernard et al.[29] found that in all examined subjects the adjacent teeth to single implants showed a change in vertical position ranging from 0.12 mm to 1.86 mm during a mean follow-up period of 4.2 years. Thilander et al.[28] observed a mean vertical difference of 0.46 mm after 4 years and 0.95 mm after 8 years in 10 adolescents with single implants in incisor position. The reason for the less frequent and smaller magnitude of vertical change of the teeth observed in the current study may be because of the fact that single implants in premolar positions were included, while the studies referred to were limited to single implants in the anterior region, that is canine to canine[29,30] or only incisors.[28] In fact, in the current study, more pronounced vertical change of adjacent teeth was observed in incisor than premolar position (0.4 mm vs 0.2 mm at 5-year follow-up, 0.5 mm vs 0.2 mm at 8-year follow-up; Table 3).

In the present study, gender was not identified as significant factor for the development of infraposition of the single-implant restorations. On the other hand, Jemt et al.[30] observed a higher incidence of infraposition of single implants in females than males and suggested that this might be related to a greater increase of anterior face height and posterior rotation of the mandible in females. However, a longitudinal study of individuals from the age of 5–31 years[38] revealed that the increase in face height and posterior rotation of mandible was constantly larger in males than in females and hence does not support such a hypothesis. Because of a higher age of our patient material at time of implant placement (mean 40 years), increase of anterior face height and posterior rotation of the mandible affecting the vertical change might be less likely, and may explain the difference in incidence and magnitude of vertical change in the current study in comparison to studies including adolescents or young adults.[28–30]

In conclusion, the marginal bone level at teeth adjacent to single implants with a microthreaded, conical portion was not influenced by the horizontal or the vertical tooth-implant distances. Continuous eruption of adjacent teeth may result in infraocclusal positioning of a single-implant restoration.

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