
Original Article

Radiographic Investigation of the Marginal Bone Loss on Dental Implants: A Retrospective Cohort Study

Gantumur CHIMEDDULAM¹⁾, Keisuke NISHIGAWA^{1,2)}, Yoshihito NAITO³⁾,
Junhel DALANON¹⁾, Shaista AFROZ¹⁾, Rika HAYAMA¹⁾, Masamitsu OSHIMA¹⁾,
Yoritoki TOMOTAKE³⁾, Tetsuo ICHIKAWA⁴⁾, Yoshizo MATSUKA¹⁾

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Abstract : Background: During functional loading, the design of the dental implant may have an effect on the response of marginal bone.

Objectives: The purpose of this study was to report the prevalence of peri-implantitis, and to compare radiographic parameters around Brånemark and Replace Select dental implants and evaluate whether disparities in the morphologic features of these two indistinct implant systems, particularly their abutment-implant attachment, had an influence on the health of surrounding tissues and marginal bone loss (MBL).

Materials and Methods: Collection of data was done at the Department of Fixed Prosthodontics, the Department of Maxillo-Facial Prosthodontics, and Oral Implant Center of Tokushima University Hospital, in Tokushima, Japan; between March 2003 and followed until January 2017. Patients who have been treated with the Replace Select internal type implant and the Brånemark variety were selected as cohort. Marginal bone level measurements were evaluated via periapical and panoramic radiographs taken at regular follow-up visit. These dimensions were calculated, starting from the orientation mark at the implant abutment interface to the bottommost perceived contact area of marginal bone with the aforementioned implant system. The change in the level of bone was estimated by calculating the variation involving an initial reference value and the follow-up values.

Results: An average loss of bone at 0.65 ± 1.51 mm (range 0.36 to 7.89 mm) in the Replace Select group was observed, while in the Brånemark group 0.7 ± 1.32 mm (range 0.62 to 8.64 mm) was observed. Spearman rank correlation exhibited a statistically significant positive correlation between progress of bone loss around implant body and interval from implantation in the Brånemark group, whereas in the Replace Select group it was not significant. The Brånemark group exhibited significant ($P = 0.0269$) negative correlation of MBL and its diameters, whereas the Replace Select group did not exhibit such correlation.

Conclusion: Within the limits of this study, it can be concluded that deviations in the morphologic attributes of these two diverse implant systems had an influence on the health of surrounding tissues and MBL. The Brånemark implants showed a significant increase in MBL (> 1.8 mm) as the time of placement elapses. This marked MBL was greater in females than males, in posterior than in anterior,

¹⁾ Department of Stomatognathic Function and Occlusal Reconstruction, Graduate School of Biomedical Sciences, Tokushima University

²⁾ Department of Oral Health Sciences, Faculty of Health and Welfare, Tokushima Bunri University

³⁾ Oral Implant Center, Tokushima University Hospital

⁴⁾ Department of Oral and Maxillofacial Prosthodontics, Graduate School of Biomedical Sciences, Tokushima University

and in the narrow platform implants than the regular platform implants or the wide platform implants. On the other hand, results suggested that this bone loss was greater in the mandible than the maxilla, in single-unit implant crowns than multiple implant restorations in the Replace Select group.

Introduction

In 1977, Brånemark et al. published a 10-year follow-up of osseointegration of dental implants in the treatment of the edentulous jaw¹. It was a considerable scientific breakthrough in the implant dentistry field. An established and likely treatment modality is the installation of dental implants as prosthetic substitute for missing dentitions, although biological and mechanical problems still ensue². Biological complications refer to disturbances in the function of the dental implant, characterized by biological processes that affect the tissues supporting the dental implant. Implant body loss is classified as a biological complication and can be distinguished into early and late losses. Sufficient x-ray and clinical examination methods are compulsory in the detection of biological complications, which include reactions in the hard and soft tissues surrounding the implant body³.

Marginal bone loss (MBL) surrounding these dental implants have been mentioned in most clinical longitudinal studies. In these clinical studies, MBL is a pathologic progression most noticeable during the first year after installation⁴. A fusion of mechanical, biological, and factors such as surgical distress to the bone and periosteum⁵, micro gap size between the abutment and implant body, proliferation of bacteria at the sulcus of the dental implant⁶, the biological width⁷, and the loading-related biomechanical factors⁸ are the theorized instigators of MBL. The dental implant-associated MBL seems to be unavoidable, specifically after attachment of the abutment. Reflected to be a mark of the enduring implant installation success is the absence or least MBL after an implant-abutment connection. Post-operative remodeling or adaptation during loading is reflected by the various degrees of MBL that are normally seen around the dental implants. Prior to a time of least yearly bone loss is a period during the first 12 months in function where MBL up to 1.5 mm occurs⁹. Throughout clinical function some dental implants may show widespread and occasionally unremitting loss of bone. The primary cause for this is not well understood. It may be caused by ongoing atrophy after tooth loss or a noninfectious reaction to surgery, prostheses load, local bone morphology, or due to the other factors¹⁰. MBL as assessed over a period of time on intraoral radiographs, has been regarded as a critical examination variable in many long-term studies¹¹. Within a year after placement, obtaining tissue stability is expected,

while > 0.2 mm MBL per year is regarded as undesirable according to some authors¹². In concurrence, an MBL of 1.5 mm¹³, 1.8 mm¹⁴, or 1.5 - 2 mm¹⁵ during the first year of installation represents a suitable result according to some authors. Despite the inconsistency in inter-thread distances among different implant systems, less than three threads of MBL has also been proposed as a success criterion^{16, 17}. For either implant systems or individual implants, a certain magnitude of annual bone loss has been suggested to be acceptable¹⁸. Through a proposal in a consensus report, a revision of radiographic measures with regards to acceptable levels of MBL at the implant site was made¹⁹. An absence of movement, < 1.5 mm average radiographic MBL during the first year of function and < 0.2 mm annually thereafter, and paresthesia or absence of pain were to be considered success measures for osseointegrated implants as agreed at the first European Workshop on Periodontology²⁰. It was further stated that presentation of radiographic data on bone-level changes, should include the frequency distribution in addition to the mean values²¹.

It is highly probable that infection may be a chief reason for the loss of bone. Similarly, after bone loss has ensued for other causes, the site of implant may be infected. Peri-implantitis is unremitting loss of bone with clinical indications of infection, regardless of the order of events such as suppuration and bleeding. Modification of both the macro and the microstructures have been done by the manufacturers due to the increase in demand and recent clinical purposes of contemporary implant dentistry²² (e.g. implant morphology, implant-abutment attachment type, implant thread, implant thread design and implant surface treatment)²³. Approximation with bone of the smooth neck portion and the implant surface characteristics were most significant among the features suggested as likely grounds for bone resorption²⁴. Based on the findings of some studies, the geometry of the coronal collar is just one facet of implant design that may contribute to bone loss^{25, 26}, although other results conveyed that retention components like micro threads within the collar of the implant body and adding a biomechanically secure joint will prevent such bone loss²⁷.

The objectives of the current investigation were to evaluate the MBL around the implant body during the osseointegration period, through radiographic parameters comparison, and

assess the different implant systems' impact on peri-implant tissue health.

Materials and Methods

Radiographic and electronic file enquiry

This retrospective clinical study was performed at Tokushima University Hospital. Data through radiographs and electronic file were taken from the patients of the Department of Fixed Prosthodontics, the Department of Maxillo-Facial Prosthodontics and Oral Implant Center of Tokushima University Hospital, Tokushima, Japan, between March 2003 and followed until January 2017. These data sources did not contain the names or any distinguishing marks that could unravel the anonymity of the patients. Hence, patient confidentiality has been maintained in the data gathering. This retrospective cohort study was done in compliance to the moral ideologies of the World Medical Association Declaration of Helsinki and the research procedures strictly adhered with the guidelines for epidemiological studies as provided for by the Ministry of Health, Labor and Welfare of Japan. The Ethical Committee of Tokushima University Hospital permitted this research construct (Reference number: No.2170). Holistically healthy patients, in need of an implant-sustained, a single crown or a fixed partial denture were the inclusion criteria. Exclusion criteria encompassed, the patients who didn't have an appointment with a doctor after placing superstructure within a year, the patients who weren't diagnosed via subsequent x-ray examinations, non-identified patients in electronic patient chart, patients who had undergone implant surgery in the Tokushima University Hospitals but the prosthetic suprastructure was installed in another clinic, and patients who did not agree to participate in the research. Patients who have been treated with the Replace Select internal type implant and the Brånemark external type implant systems were chosen in the study (Figure 1).

Marginal bone loss measurements

The Brånemark and Replace Select implants, both utilize a unique implant surface called TiUnite, that enhances osseointegration. A flat top with an external hexagon butt-joint connection is a distinguishing feature of the Brånemark implant-abutment interface, whereas, an internal conical seal is an attribute of the Replace Select implants. The following basic implant data were collected from the patient's chart: implantation site, date of initial implant placement, date of second surgery, date of prosthetic loading, length and diameter of implant fixture, and surgical technique utilized. Marginal bone level was evaluated via periapical and panoramic radiographs taken at regular follow-up visits. To the lowest observed mark of connection between the marginal bone

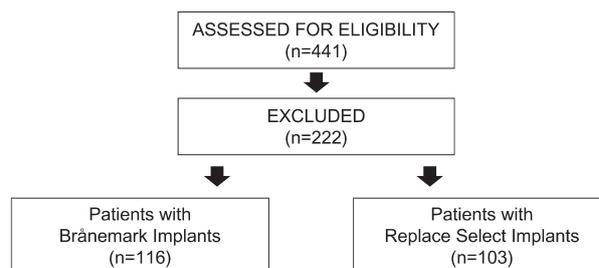


Fig. 1 Flow of data collection according to the CONSORT statement (2010).

and the dental implant, from the reference mark, were the landmarks in measuring the MBL. The variation in the level of bone was projected by calculating the change amidst the benchmarked scores and follow-up scores, using the implant abutment interface as the reference mark. The vertical MBL was logged to the closest 0.01 mm by measuring the implant threads pitch. In estimating the level of marginal bone, the gain in marginal bone was not accounted for, in which a gain in bone was deliberated to be a 0 mm bone loss. This is a result to the reference mark being the implant-abutment connection. Bone loss was measured on the mesial and distal aspects of the implant fixture, and the mean value was used. Each radiograph was calibrated by using the known implant thread pitch distances in the image as the reference (for Brånemark Mk III, and Replace Select, the thread pitch distance)

Statistical analyses

Patient data were charted in a Microsoft Excel spreadsheet and subsequently analyzed through the utilization of SPSS version 15 (SPSS Inc., Chicago, IL, USA). Ordinal and dichotomous variables were presented as percentages, whereas, the distributions of continuous variables were given as mean \pm standard deviation, median and a confidence interval (CI) of 95 %. Spearman rank correlation was utilized to compare between each time point and the baseline measurements, while Wilcoxon test was done to detect the changes in marginal bone levels around the implant body. All statistical comparisons were conducted at $P = 0.05$ level of significance. All of the variables associated with implant failure were introduced into a multiple logistic regression model.

Results

Four hundred and forty-one patients were considered for admissibility. Those who did not qualify the inclusion criteria were two hundred and twenty patients. A total of two patients did not give their approval. Consequently, a

total of 219 patients were successively registered into this study. The pool of patients consisted of 155 females (70.5 %) and 64 males (29.5 %). From 19 to 82 years, with an average score of 58.5 ± 8.35 years, were the patients' age during implant installation. A total of 905 implant bodies were installed. A TiUnite exterior and a length range between 8 and 16 mm were features of the Replace Select implants that were installed. This implant group consisted mostly of dental implants with a diameter of 4.3 mm, while a few had a diameter of 5 mm. Overall, 408 Replace Select implants were inserted: 169 (41.4 %) in the maxilla and 239 (58.6 %) in the mandible. Lengths extending from 8.5 to 18 mm and a TiUnite finish were features of the Mark III variety of the Brånemark implants used. Excluding sites of implantation where 4 mm implant bodies were used for major stability, the diameter of the implant body was usually 3.75 mm. Altogether, 497 Brånemark implants were placed: 204 (41.1 %) in the maxilla and 293 (58.9 %) in the mandible (Table 1).

With a total of 905 implant bodies placed, there was an average of 4 ± 2.4 Brånemark implant placed per patient, while 3 ± 2.7 was the average for the Replace Select implant. The functional time was 8.8 ± 1.8 years in Brånemark group, 9.5 ± 2.8 years in Replace Select group (Table 2). Throughout the follow-up time, there was no patient that backed out. The dental implant survival at 14 years of follow-up was 98.6 %. There were 12 late failures (1.3 %) after loading that were recorded, while no early failures (0.0 %) before loading was observed. The letdown was due to infection of the tissue around the implant body with erratic levels of suppuration and developing bone loss in each of these cases. During follow-up, a mean bone loss of 0.7 ± 1.5 mm (range 7.9 to 2.2 mm) in the Replace Select group was observed, while in the Brånemark group 0.7 ± 1.3 mm (range 8.6 to 2.6 mm) was observed (Table 3). In the Replace Select group, osseointegration was achieved in 355 implant bodies (87.1 %), while bone loss was recorded in 53 (12.9 %) cases. In the Brånemark group, osseointegration was achieved in 373 implant bodies (75.1 %), bone loss was recorded in 124 (24.9 %) cases. In 24 (5.8 %) of the Replace Select implants and 59 (11.9 %) in the Brånemark implants, a bone loss of more than 3 threads (1.8 mm) occurred (Figure 2a, b).

In the original population of 219 patients, the number of known failed implant bodies from the installation of implant bodies to the final checkup were 12 implants in 8 patients of the Brånemark group and 5 implants in 4 patients of the Replace Select group. From the examination period of 5 - 15 years, five of these implant bodies were lost.

The multiple regression analysis of bone loss and other parameters showed gender and implant placement location were significant predictive parameters for the Brånemark

group, while implant body placement location and implant body length were predictors for the Replace Select group (Table 4).

Spearman rank correlation exhibited a statistically significant positive correlation between progress of bone loss around the implant body and interval from implantation in the Brånemark group. Moreover, this conveys that MBL was greater as the time of placement elapses. In the Replace Select group it was not found to be significant (Figure 3).

The comparison analysis regarding bone loss and gender yielded significance in the Brånemark group. The analysis showed that there was marked increase in bone loss with cases involving female than male in the aforementioned group. Although there was a difference in the bone loss trend between males and females in the Replace Select group, the disparity was not great to be of significant correlation. Since these comparisons were done between two groups, Wilcoxon test verified the result of the one-way ANOVA (Figure 4).

With implant body placement location pertaining the maxilla or mandible, there was a difference in the peri-implant MBL involving both groups. It was found out that there were more cases of bone loss in the mandible than the maxilla. Although, the difference was only evident and significant in the Replace Select group (Figure 5).

The Brånemark group exhibited significant ($P = 0.0269$) negative correlation of MBL and its diameters, whereas the Replace Select group did not exhibit such correlation. This means that marked bone loss was more evident posteriorly placed implant bodies than their anterior counterparts (Figure 6).

Comparison analysis of the MBL and implant body length shows significant negative correlation with the Replace Select group. There were more cases of bone loss with single-unit implant crowns than multiple implant restorations. The same significance was not exhibited in the Brånemark group (Figure 7).

A significant correlation was observed with the Brånemark group, as more bone loss existed with the narrow platform implants than the regular platform implants and the wide platform implants. In contrast, there was no marked difference between the different platforms of the Replace Select group in terms of MBL (Figure 8).

Discussion

This retrospective cohort study made a radiological evaluation of the external and internal types of dental implants that replace missing dentition in the mandibular and maxillary regions. The purpose of the analysis was to evaluate crestal bone loss around the implant body during the osseointegration period, comparing external and internal type connection implants with butt-joint and conical type connections. The

Table 1 Distribution of dental implants according to gender and implant body location

	Brånemark		Replace Select		Total implant (n)
	n	%	n	%	
Gender					
Male	36	31.03	28	27.18	64
Female	80	68.97	75	72.82	155
Implant location					
Maxilla	204	41.10	169	41.40	373
Mandible	293	58.90	239	58.60	532

n- Number
% - Percentage

Table 2 Distribution of dental implants according to age, average insertions, and survival rate

	Brånemark		Replace Select	
	n	SD	n	SD
Age (year)	58.6	8.93	58.3	9.28
Average insertions (n)	4	2.4	3	2.7
Functional time (year)	8.8	1.84	9.5	2.8

n- Number
SD – Standard deviation

Table 3 Distribution of dental implants according to marginal bone loss (mm) in the mesial and distal aspect

	Brånemark		Replace Select	
	Mean	SD	Mean	SD
Mesial	0.7	1.29	0.6	1.45
Distal	0.7	1.32	0.7	1.51

SD – Standard deviation

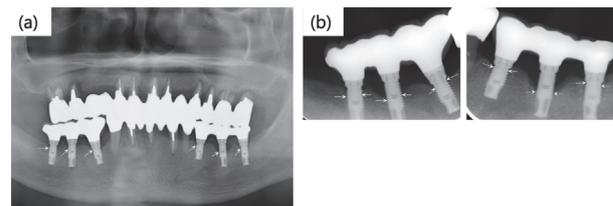


Fig. 2 Radiograph showing MBL was greater as the time of placement elapses.

(a) MBL after 3 years functional loading.

(b) MBL after 7 years functional loading. Arrows exhibit MBL level on the X-ray images.

Table 4 Multiple regression analysis of bone loss and other parameters

	Independent variables	Regression coefficients	Standard error	P value
Brånemark	Male vs. female	0.2628359	0.059019	<.0001*
	Maxilla vs. mandible	0.1150708	0.057458	0.0458*
	Anterior vs. posterior	-0.013709	0.070557	0.846
	Single vs. multiple	-0.057696	0.137063	0.674
	Implant diameter	-0.330279	0.17441	0.0589
	Implant length	-0.019164	0.032345	0.5538
Replace select	Male vs. female	-0.093197	0.076087	0.2213
	Maxilla vs. mandible	0.192827	0.077763	0.0136*
	Anterior vs. posterior	0.0051791	0.096732	0.9573
	Single vs. multiple	-0.229646	0.118917	0.0542
	Implant diameter	0.3572845	0.214687	0.0969
	Implant length	-0.129544	0.042901	0.0027*

Brånemark, n=489, Multiple R2=0.05697, P<0.0001.
Replace select, n=406, Multiple R2=0.076048, P<0.0001.

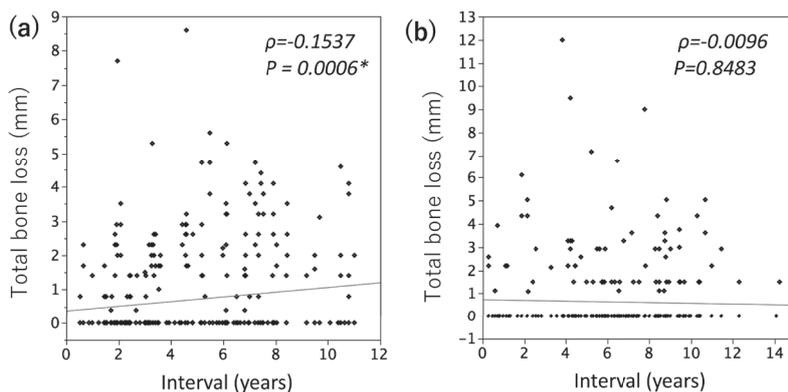


Fig. 3 The relationship between progress of bone loss around dental implant and interval from implant body placement.

(a) Spearman rank correlation between progress of bone loss around Brånemark dental implant and interval from implant body placement.

(b) Spearman rank correlation between progress of bone loss around Replace Select dental implant and interval from implant body placement.

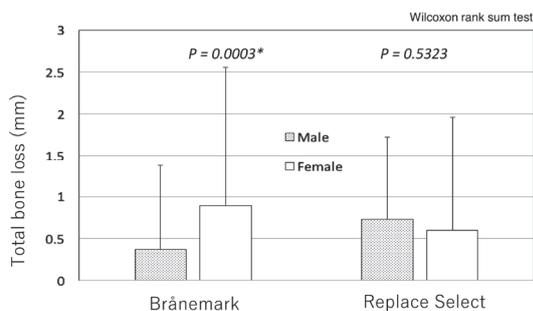


Fig. 4 The relationship between progress of bone loss around dental implant and gender.

Wilcoxon comparison analysis between progress of bone loss around Brånemark and Replace Select dental implant with gender.

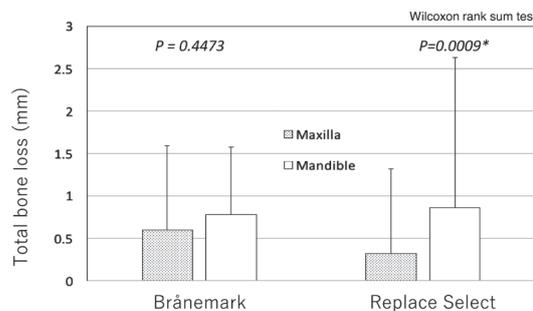


Fig. 5 The relationship between progress of bone loss around dental implant and placement location (mandible vs. maxilla).

Wilcoxon comparison analysis between progress of bone loss around Brånemark and Replace Select dental implant with placement location (mandible vs. maxilla).

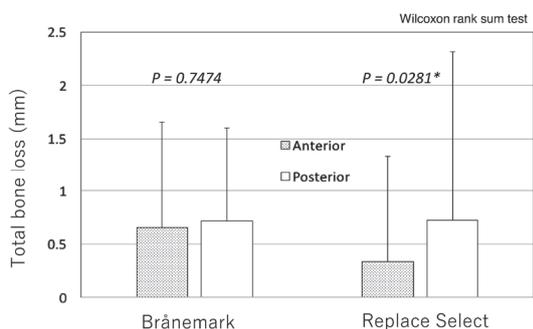


Fig. 6 The relationship between progress of bone loss around dental implant and placement location (anterior vs. posterior).

Wilcoxon comparison analysis between progress of bone loss around Brånemark and Replace Select dental implant with placement location (anterior vs. posterior).

study took peri-implant crestal bone loss as its main clinical parameter, as this is one of the most important clinical criteria for implant success⁸⁾. Loss of marginal bone is a great importance in both the medium and long-term dental implant survivability, as reduction in the bone level that exceeds physiological limits can lead to the loss of the implant's bone anchorage. This report suggested that the calculation of change in marginal bone around the implant body is of clinical significance and is not just a theoretical predictor of implant success. Moreover, the results of this study showed that consideration of MBL rate, rather than straightforward MBL data may enhance the clinicians' expectations of the diseases involving the tissues surrounding the implant body.

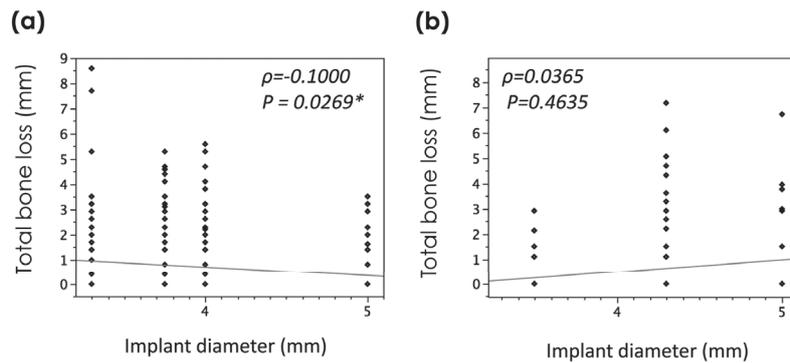


Fig. 7 The relationship between progress of bone loss around dental implant and implant body diameter.
 (a) Spearman rank correlation between progress of bone loss around Brånemark dental implant and implant body diameter.
 (b) Spearman rank correlation between progress of bone loss around Replace Select dental implant and implant body diameter.

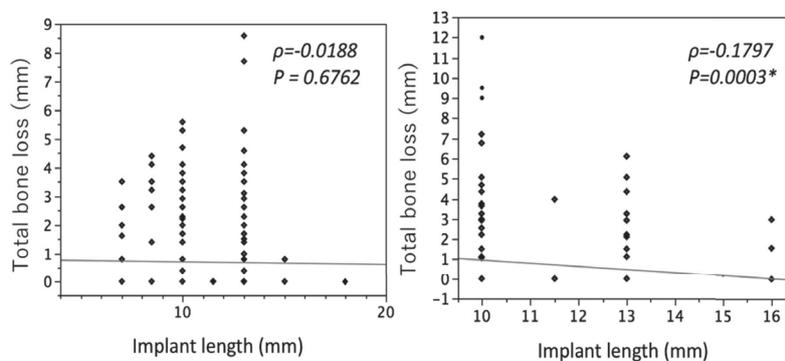


Fig. 8 The relationship between progress of bone loss around dental implant and implant body length.
 (a) Spearman rank correlation between progress of bone loss around Brånemark dental implant and implant body length.
 (b) Spearman rank correlation between progress of bone loss around Replace Select dental implant and implant body length.

Measures for the success of oral implants has been the subject of revisions from various researchers over the years. Albrektsson et al. suggested the most widely used criterion in recent times. This appraisal cited, that a < 0.2 mm bone loss yearly after the first 12 months of installation can still be efficacious²³. Perhaps within satisfactory MBL confines according to Duyck and Naert is mean MBL within the 0.9 to 1.6 mm range throughout the first 12 months prior to a yearly loss of bone in the range of 0.01 to 0.2 mm²⁸. Afterwards, a < 2 mm bone loss for the period of the first 60 months is compulsory for a system of dental implant to be deemed effective according to the declarations of Wennström and Palmer²⁹. The MBL criteria as a predictor of dental implant success has undergone several revisions and improvements, although the disparity between them must be deemed as of lesser clinical consequence. Benn reviewed the consistency of the x-ray dimensions of bone level fluctuations at the tooth

surfaces³⁰. According to Benn, the existing methods are unsatisfactory to gauge true bone loss up until the resorption of bone reaches 1.0 mm. There are apparent variations concerning a threaded, biocompatible implant and a tooth, although the alterations that are < 1 mm must be considered with restraint³¹. Supposing the estimations may be false-positive or false-negative, the same ambiguity is insignificant with the evaluation of a successive successions of a large implant body quantity. Hence, the ambiguity in this sample size is perhaps way lesser than 1.0 mm.

Furthermore, this study showed that after 5 years in function, 15.8 % (n = 79) of the Brånemark implants presented a bone loss of 2 mm. The consequent score for the Replace Select implants was 13.9 % (n = 57). This is consistent with some previous studies, that also found late implant failure to be more common than early failure^{32, 33}. The dental implants presented a bone loss that is objectionable and are considered

as failures based on the measures proposed by Wennström and Palmer²⁹). Nevertheless, with sufficient dental management contemporary explorations has confirmed that advancing bone loss may be prevented with sufficient treatment and that even bone restitution is achievable³⁴⁻³⁷). The proportion of dental implants reinforcing a full denture, in spite of jaw, with a > 2 mm bone loss increased as time passes. The outcomes conveyed that for patients with an average bone loss of > 2 mm, irrespective of follow-up interval, the incidence of the greatest bone loss, extreme of mesial or distal aspect, was considerably greater 12 months before than 12 months after the incidence of bone loss. This suggests that the bone loss may not be constant³⁸).

The most distally installed implant bodies sustaining a prosthetic device have higher risks for bone loss because they are subjected to greater forces, bending actions, and focused stress. The location of the implant body is significant for lower jaw installations, but not for the upper jaw restorations. Conversely, less bone loss was detected for implant bodies that are placed posteriorly. In the mandibular jaw, anteriorly placed implant bodies underwent greater bone loss than the other implant bodies at the posterior. This is in agreement with the outcomes discovered by Carlsson et al³⁹) and Ekelund et al⁴⁰). To further make the success measures recommended by Albrektsson and Isidor⁴¹) more appropriate for single implant assessments, Lekholm et al. mentioned minimal modifications⁴²). When a bone loss is at the marginal third of the total length of the implant body or was > 3 mm, that thought of it being unsuccessful is to be considered⁴³). By means of the prosthetic insertion as baseline in the current research and a bone loss of > 3 mm as a ceiling score for progressive bone loss, 32 implant bodies (6.4 % of the implant bodies) of all 497 Brånemark implants in 19 patients (16.3 %) were identified. In the Replace Select group, 26 implant bodies (6.3 % of the implant bodies) of the 408 implant bodies in 21 patients (20.7 %) exhibited bone loss of > 3 mm. Among patients with complete fixed dentures, dental implants with this amount of bone loss were discovered to be widespread (79 %). The greatest bone loss ensued 1 to 15 years, prior the last examination in 32.8 %, implying that the bone level can discontinue even at surfaces with progressive bone loss. Interfaces that are created between the implant components as part of the implant restoration is another factor that can influence bone remodeling, resulting in bone loss around the implant body. If these involve butt-joint interface, significant amount of inflammation develops around the interface, likely in response to bacterial contamination⁴⁴⁻⁴⁷). Bacterial products stimulate inflammatory cells to enter the surrounding tissues, and these cells release proinflammatory molecules that recruit more inflammatory cells; osteoclastogenesis and, eventually,

bone loss result⁴⁸). Previous data indicated that the closer this inflammation was located to the alveolar crest; the more bone loss is observed⁴⁹⁻⁵²). An MBL up to the first implant thread after 12 months of implant loading, with a minimal average yearly bone change is normal according to the other studies involving the Brånemark system⁵³⁻⁵⁵). Emerging to have functioned within this range are the Brånemark implants in the current investigation. Numerous reports in the last few years have examined the conceivable reasons for the radiographic findings stated above. Bacterial outflow transpires in the abutment-implant attachment micro gap. The Brånemark morphologic features may create a possibility not only for gingival irritation but also for hard-tissue resorption⁵⁶). Hermann et al found that in two-part implants such as Brånemark implants, the micro gap had a profound influence on the alveolar bone surrounding the implant body⁴³). Hard-tissue resorption of roughly 2 mm was discovered between the osseous crest and the micro gap. Ericsson et al. suggested that this was the result of a physiologic response to the micro gap. This typical bone resorption of 1.5 mm during the first 12 months of loading in the Brånemark system has not been described in Replace Select implants⁵⁷).

It is highly probable that the Replace Select implant micro gap (2 µm in width) may be less noteworthy since it has an inner conical connection creating a snugger fit between the abutment and implant body, even though both are two-stage implant systems⁵⁸) contrasted to the Brånemark system's flat top/external hexagon concept (49 µm in width)⁵⁹). Furthermore, the greater Brånemark system micro gap may be expanded further in the clinics when torquing influences throughout utilization may dislodge the screw joint⁶⁰). It coincides with the present study of the Brånemark system showing more bone loss. Another important factor in the overall MBL is osteoporosis. One of the main limitations of this study beside the retrospective character is the treatment gap in osteoporotic disease, which is around 52 % according to recent investigations⁶¹). In Austria, around 22 % of the women over 50 years of age are osteoporotic, thus a considerable amount of the patients in this study that are considered as non-osteoporotic may suffer from catabolic bone disease which is undiagnosed and untreated, potentially resulting in higher levels of MBL^{62, 63}). The causes of MBL around implants are not fully understood. Owing to a fairly limited sample size and implant disparities other than the structure of the coronal part that may have affected the results, further inquiry on fixture designs is necessary to explain the mechanism and the connection between design and MBL in dental implants. The greatest transformation in marginal bone height transpire during the first year according to most studies^{64, 65}).

Conclusion

Within the limits of this study, it can be concluded that variations in the morphologic features of these two dental implants, specifically their abutment-implant attachment, had an influence on the health of the surrounding tissues and MBL. There was significant positive correlation between progress of bone loss around dental implant and interval from implantation in the Brånemark group. Gender was a significant predictive parameter for the Brånemark group, implant body length was a predictor for the Replace Select group, while implant placement (i.e. maxilla vs. mandible) was a predictor for both implant types. The Brånemark implants showed a significant increase in MBL (> 1.8 mm) as the time of placement elapses. This marked MBL was greater in females than males, in posterior than in anterior, and in the narrow platform implants than the regular platform implants or the wide platform implants. On the other hand, results suggested that this bone loss was greater in the mandible than the maxilla, in single-unit implant crowns than multiple implant restorations in the Replace Select group.

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References

- 1) Brånemark PI, Hansson BO, Adell R, Breine U, Lindström J, Hallén O and Ohman A. Osseointegrated implants in the treatment of the edentulous jaw. Experience from a 10-year period. *Scand J Plast Reconstr Surg Suppl* 16, 1-132 (1977)
- 2) Misch CE, Steigenga J, Barboza E, Misch-Dietsh F, Cianciola LJ and Kazor C: Short dental implants in posterior partial edentulism: A multicenter retrospective 6-year case series study. *J Periodontol* 77, 1340-1347 (2006)
- 3) Ogata Y, Nakayama Y, Tatsumi J, Kubota T, Sato S, Nishida T, Takeuchi Y, Onitsuka T, Sakagami R, Nozaki T, Murakami S, Matsubara N, Tanaka M, Yoshino T, Ota J, Nakagawa T, Ishihara Y, Ito T, Saito A, Yamaki K, Matsuzaki E, Hidaka T, Sasaki D, Yaegashi T, Yasuda T, Shibutani T, Noguchi K, Araki H, Ikumi N, Aoyama Y, Kogai H, Nemoto K, Deguchi S, Takiguchi T, Yamamoto M, Inokuchi K, Ito T, Kado T, Furuichi Y, Kanazashi M, Gomi K, Takagi Y, Kubokawa K, Yoshinari N, Hasegawa Y, Hirose T, Sase T, Arita H, Kodama T, Shin K, Izumi Y and Yoshie H: Prevalence and risk factors for peri-implant diseases in Japanese adult dental patients. *J Oral Sci* 59, 1-11 (2016)
- 4) Derks J, Schaller D, Håkansson J, Wennström JL, Tomasi C and Berglundh T: Effectiveness of implant therapy analyzed in a Swedish population. *J Dent Res* 95, 43-49 (2016)
- 5) Albrektsson T, Buser D and Sennerby L: Crestal bone loss and oral implants. *Clin Implant Dent Relat Res* 14, 783-791 (2012)
- 6) Lee SY, Koak JY, Kim SK, Rhyu IC, Ku Y, Heo SJ and Han CH: A long-term prospective evaluation of marginal bone level change around different implant systems. *Int J Oral Maxillofac Implants* 31, 657-664 (2016)
- 7) Imburgia M and Del Fabbro M: Long-term retrospective clinical and radio-graphic follow-up of 205 Brånemark system Mk III TiUnite implants submitted to either immediate or delayed loading. *Implant Dent* 24, 533-540 (2015)
- 8) Esposito M, Hirsch JM, Lekholm U and Thomsen P: Biological factors contributing to failures of osseointegrated oral implants, (II). Etiopathogenesis. *Eur J Oral Sci* 106, 721-764 (1998)
- 9) Shibuya Y, Takata N, Takeuchi J, Tsuji K, Ishida S, Kobayashi M, Suzuki H, Hasegawa T, Kamae I and Komori T: Analysis of the 619 Brånemark system TiUnite implants: A retrospective study. *Kobe J Med Sci* 58, 19-28 (2012)
- 10) Balshi TJ, Wolfnger GJ, Schlauch RW and Balshi SF: A retrospective analysis of 800 Brånemark system implants following the all-on-four protocol. *J Prosthodont Dent Implant* 23, 114-120 (2015)
- 11) Misch CE, Perel ML, Wang HL, Sammartino G, Galindo-Moreno P, Trisi P, Steigmann M, Rebaudi A, Palti A, Pikos MA, Schwartz-Arad D, Choukroun J, Gutierrez-Perez JL, Marenzi G and Valavanis DK: Implant Success, Survival, and Failure: The international congress of oral implantologists (ICOI) Pisa consensus conference. *Implant Dent* 17, 5-15 (2008)
- 12) Hasegawa T, Kawabata S, Takeda D, Iwata E, Saito I, Arimoto S, Kimoto A, Akashi M, Suzuki H and Komori T: Survival of Brånemark system Mk III implants and analysis of risk factors associated with implant failure. *Int J Oral Maxillofac Surg* 46, 267-273 (2017)
- 13) Fransson C, Lekholm U, Jemt T and Berglundh T: Prevalence of subjects with progressive bone loss at implants. *Clin Oral Implants Res* 16, 440-446 (2005)
- 14) Sanchez-Siles M, Muñoz-Cámara D, Salazar-Sánchez N, Camacho-Alonso F and Calvo-Guira-do JL: Crestal bone loss around submerged and non-submerged implants during the osseointegration phase with different healing abutment designs: A randomized prospective clinical

- study. *Clin Oral Implants Res* 1-5 (2016)
- 15) Albrektsson T, Chrcanovic B, Östman PO and Sennerby L: Initial and long-term crestal bone responses to modern dental implants. *Periodontol* 73, 41-50 (2017)
 - 16) Burtscher D, Norer B, Dalla Torre D, Beier U, Schubert K and Grunert I: A 7-year prospective radiographic evaluation of marginal bone level around two different implant systems: A randomized clinical trial. *Clin Oral Implants Res* 26, 1244-1249 (2015)
 - 17) Benic GI, Bernasconi M, Jung RE and Hämmerle CHF: Clinical and radiographic intra-subject comparison of implants placed with or without guided bone regeneration: 15-year results. *J Clin Periodontol* 44, 315-325 (2017)
 - 18) Browaeys H, Dierens M, Ruyf-felaert C, Matthijs C, De Bruyn H and Vandeweghe S: Ongoing crestal bone loss around implants subjected to computer-guided flapless surgery and immediate loading using the all-on-4 concept. *Clin Implant Dent Relat Res* 17, 831-843 (2015)
 - 19) Albrektsson T, Dahlin C, Jemt T, Sennerby L, Turri A and Wenner-berg A: Is marginal bone loss around oral implants the result of a provoked foreign body reaction. *Clin Implant Dent Relat Res* 16, 155-165 (2014)
 - 20) Cassetta M, Driver A, Brandet-ti G and Calasso S: Peri-implant bone loss around platform-switched morse taper connection implants: A prospective 60-month follow-up study. *Int J Oral Maxillofac Surg* 45, 1577-1585 (2016)
 - 21) Koller CD, Pereira-Cenci T and Boscatto N: Parameters associated with marginal bone loss around implant after prosthetic loading *Braz Dent J* 27, 292-297 (2016)
 - 22) Papaspyridakos P, Chen CJ, Singh M, Weber HP and Gallucci GO: Success criteria in implant dentistry: A systematic review. *J Dent Res* 91, 242-248 (2012)
 - 23) Albrektsson T, Zarb G, Worthington P and Eriksson AR: The long-term efficacy of currently used dental implants: a review and proposed criteria of success. *Int J Oral Maxillofac Implants* 1, 11-25 (1986)
 - 24) Roos-Jansåker AM, Lindahl C, Renvert H and Renvert S: Nine to fourteen-year follow-up of implant treatment. Part I: Implant loss and associations to various factors. *J Clin Periodontol* 33, 283-289 (2006)
 - 25) De Bruyn H, Vandeweghe S, Ruyffelaert C, Cosyn J and Senner L: Radiographic evaluation of modern oral implants with emphasis on crestal bone level and relevance to peri-implant health. *Periodontol* 62, 256-270 (2013)
 - 26) Noda K, Arakawa H, Kimura-Ono A, Yamazaki S, Hara ES, Sonoyama W, Maekawa K, Okura K, Shintani A, Matsuka Y and Kuboki T: A longitudinal retrospective study of the analysis of the risk factors of implant failure by the application of generalized estimating equations. *J Prosthodont Res* 59, 178-184 (2015)
 - 27) Clementini M, Rossetti PHO, Penarrocha D, Micarelli C, Bonache-la WC and Canullo L: Systemic risk factors for peri-implant bone loss: A systematic review and meta-analysis. *Int J Oral Maxillofac Surg* 43, 323-334. (2014)
 - 28) Duyck J and Naert I: Failure of oral implants: Aetiology, symptoms and influencing factors. *Clin Oral Invest* 2, 102-114 (1998)
 - 29) Wennström J and Palmer R: Concensus report of session 3: clinical trials. In: Lang NP, Karring T, Lindhe J, eds. *Proceedings of the 3rd European Workshop on Periodontology. Implant dentistry*. Berlin, Germany: Quintessence, 255-259 (1999)
 - 30) Benn DK: A review of the reliability of radiographic measurements in estimating alveolar bone changes. *J Clin Periodontol* 17, 14-21 (1990)
 - 31) Gröndahl K, Sundén S and Gröndahl H-G: Inter- and intraobserver variability in radiographic bone level assessment at Brånemark fixtures. *Clin Oral Implants Res* 9, 243-250 (1998)
 - 32) Schropp L and Isidor F: Timing of implant placement relative to tooth extraction. *J Oral Rehabil* 35, 33-43 (2008)
 - 33) Davarpanah M, Martinez H, Tecucianu JF, Alcoforado G, Etienne D and Celletti R: The self-tapping and ICE 3i implants: a prospective 3-year multicenter evaluation. *Int J Oral Maxillofac Implants* 16, 52-60 (2001)
 - 34) Watanabe H, Mohammad Abdul M, Kurabayashi T and Aoki H: Mandible size and morphology determined with CT on a premise of dental implant operation. *Surg Radiol Anat* 32, 343-349 (2010)
 - 35) Hillerup S, Elberg JJ, Thorn JJ and Andersen M: Reconstruction of irradiated mandible after segmental resection of osteoradionecrosis-a technique employing a microvascular latissimus dorsi flap and subsequent particulate iliac bone grafting. *Craniofacial Trauma Reconstr* 7, 190-196 (2014)
 - 36) Oshima M, Inoue K, Nakajima K, Tachikawa T, Yamazaki H, Isobe T, Sugawara A, Ogawa M, Tanaka C, Saito M, Kasugai S, Takano-Yamamoto T, Inoue T, Tezuka K, Kuboki T, Yamaguchi A and Tsuji T: Functional tooth restoration by next-generation bio-hybrid implant as a bio-hybrid artificial organ replacement therapy. *Sci Rep* 4, 6044 (2014)
 - 37) Jain R and Kapoor D: The dynamic interface: A review. *J Int Soc Prev Community Dent* 5, 354-358 (2015)
 - 38) Roos-Jansåker AM, Renvert S, Lindahl C and Renvert S: Surgical treatment of peri-implantitis using a bone substitute with or without a resorbable membrane: A

- prospective cohort study. *J Clin Periodontol* 34, 625-632 (2007)
- 39) Carlsson GE, Lindquist LW and Jemt T: Long-term marginal peri-implant bone loss in edentulous patients. *Int J Prosthodont* 13, 295-302 (2000)
 - 40) Ekelund JA, Lindquist LW, Carlsson GE and Jemt T: Implant treatment in the edentulous mandible: a prospective study on Brånemark system implants over more than 20 years. *Int J Prosthodont* 16, 602-608 (2003)
 - 41) Albrektsson T and Isidor F: Consensus report of session IV. In: Lang NP, Karring T, eds. *Proceedings of the 1st European Workshop on Periodontology*. London, England: Quintessence 365-369 (1993)
 - 42) Lekholm U, van Steenberghe D and Herrmann I: Osseointegrated implants in the treatment of partially edentulous jaws: a prospective 5-year multicenter study. *Int J Oral Maxillofac Implants* 9, 627-635 (1994)
 - 43) Hermann JS, Cochran DL, Nummikoski PV and Buser D: Crestal bone changes around titanium implants. A radiographic evaluation of unloaded non-submerged and submerged implants in the canine mandible. *J Periodontol* 68, 1117-1130 (1997)
 - 44) Persson LG, Lekholm U, Leonhardt A, Dahlen G and Lindhe J: Bacterial colonization on internal surfaces of Brånemark system implant components. *Clin Oral Implants Res* 7, 90-95 (1996)
 - 45) Jansen VK, Conrads G and Richter EJ: Microbial leakage and marginal fit of the implant-abutment interface. *Int J Oral Maxillofac Implants* 12, 527-540 (1997)
 - 46) Gross M, Abramovich I and Weiss EI: Microleakage at the abutment-implant interface of osseointegrated implants: a comparative study. *Int J Oral Maxillofac Implants* 14, 94-100 (1999)
 - 47) Callan DP, Cobb CM and Williams KB: DNA probe identification of bacteria colonizing internal surfaces of the implant-abutment interface: A preliminary study. *J Periodontol* 76, 115-120 (2005)
 - 48) Li Y, Toraldo G and Li A: B cells and T cells are critical for the preservation of bone homeostasis and attainment of peak bone mass in vivo. *Blood* 109, 3839-3848 (2007)
 - 49) Waerhaug J: The angular bone defect and its relationship to trauma from occlusion and downgrowth of subgingival plaque. *J Clin Periodontol* 6, 61-82 (1979)
 - 50) Garant PR: Ultrastructural studies of inflammation induced in rats by injection of antigen-antibody precipitates. Changes in palatal bone and periosteum to a single exposure. *J Periodontol Res* 14, 26-38 (1979)
 - 51) Assuma R, Oates T, Cochran D, Amar S and Graves DT: IL-1 and TNF antagonists inhibit the inflammatory response and bone loss in experimental periodontitis. *J Immunol* 160, 403-409 (1998)
 - 52) Graves DT and Cochran D: The contribution of interleukin-1 and tumor necrosis factor to periodontal tissue destruction. *J Periodontol* 74, 391-401 (2003)
 - 53) Laney WR, Jemt T and Harris D: Osseointegrated implants for single tooth replacement: progress report from a multicenter prospective study after 3 years. *Int J Oral Maxillofac Implants* 9, 49-54 (1994)
 - 54) Anderson B, Odman P, Lindvall A-M and Lither B: Single tooth restorations supported by osseointegrated implants: results and experiences from a prospective study after 2 to 3 years. *Int J Oral Maxillofac Implants* 10, 702-711 (1995)
 - 55) Anderson B, Odman P, Lindvall A-M and Branemark P-I: Cemented single crowns on osseointegrated implants after 5 years: results from a prospective study on CeraOne. *Int J Prosthodont* 11, 212-218 (1998)
 - 56) Quirynen M, Bolen CML, Eysen H and van Steenberghe D: Microbial penetration along the implant components of the Brånemark system. *Clin Oral Impl Res* 5, 239-244 (1994)
 - 57) Ericsson I, Persson LG and Berglundh T: Different types of inflammatory reactions in peri-implant soft tissues. *J Clin Periodontol* 22, 255-261 (1995)
 - 58) Norton MR: An in vivo evaluation of the strength of an internal conical interface compared to a butt joint interface in implant design. *Clin Oral Impl Res* 8, 290-298 (1997)
 - 59) Binon P, Weir D, Watanabe L and Walker L: Implant component compatibility. In: Laney WR, Tolman DE, eds. *Tissue integration in oral, orthopedic & maxillofacial reconstruction*. Chicago: Quintessence 218-226 (1992)
 - 60) Rangert B, Jemt T and Jorneus L: Forces and moments on Brånemark implants. *Int J Oral Maxillofac Implants* 4, 241-247 (1989)
 - 61) Svedbom A, Hernlund E and Ivergard M: Osteoporosis in the European Union: a compendium of country-specific reports. *Arch Osteoporos* 8, 137 (2013)
 - 62) Kanis JA, Borgstrom F and Compston J: SCOPE: a scorecard for osteoporosis in Europe. *Arch Osteoporos* 8, 144 (2013)
 - 63) Soen S, Fujiwara S, Takayanagi R, Kajimoto K, Tsujimoto M, Kimura S, Sato M, Krege JH and Enomoto H: Real-world effectiveness of daily teriparatide in Japanese patients with osteoporosis at high risk for fracture: final results from the 24-month Japan Fracture Observational Study (JFOS). *Curr. Med. Res. Opin* 33, 2049-2056 (2017)
 - 64) Palmer RM, Smith BJ, Palmer PJ and Floyd PD: A prospective study of Astra single tooth implants. *Clin*

Oral Implants Res 8, 173-179 (1997)

- 65) Nakayama T, Sakai M and Slingsby BT: Japan's ethical guidelines for epidemiologic research: a history of their development. J Epidemiol Jpn Epidemiol Assoc 15, 107-112 (2005)