Factors Affecting Late Implant Bone Loss: A Retrospective Analysis

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Purpose: *Prevention of late implant bone loss is a critical component in long-term success of implants. The aim of the present study was to evaluate factors affecting late implant bone loss.* ***Materials and Methods:*** *Three hundred thirty-nine endosseous root-form dental implants placed between April 1981 and April 2002 in 69 patients were analyzed. The implants were categorized based on the following factors:* (1) *surface characteristics (smooth versus rough),* (2) *length (short [< 10 mm] versus long [≥ 10 mm]), width (narrow [< 3.75 mm], regular [3.75 to 4.0 mm], or wide [> 4.0 mm]),* (3) *the amount of keratinized mucosa (< or ≥ 2 mm),* (4) *location (anterior versus posterior; maxilla versus mandible),* (5) *type of prosthesis (fixed versus removable), and* (6) *type of opposing dentition. The effects of these factors on clinical parameters, especially average annual bone loss (ABL), were evaluated clinically and radiographically by a blinded examiner. The parameters evaluated were modified Plaque Index, Gingival Index, modified Bleeding Index, probing depth, and ABL.* ***Results:*** *Shorter implants, wider implants, implants supporting fixed prostheses, and implants in smokers were found to be associated with greater ABL (*P *< .05). The random intercept mixed effects model showed that implant length was the most critical factor for maintenance of ABL.* ***Conclusions:*** *Shorter implants, wider implants, implants supporting fixed prostheses, and implants in smokers were associated with greater ABL. Implant length was the most significant factor in the maintenance of dental implants. Randomized controlled clinical trials are needed to confirm the results obtained from this retrospective clinical study.* (Case Series) (More than 50 references.) INT J ORAL MAXILLOFAC IMPLANTS 2007;22:117–126

Key words: *implant maintenance, implant surfaces, late implant bone loss, peri-implantitis*

Dental implants have revolutionized contemporary dentistry. Since the concept of osseointegration was introduced in 1969,[1] the science and technology of dental implants have been greatly enhanced. The predictability and efficacy of dental implants in the rehabilitation of lost complete and partial dentition have been thoroughly tested and confirmed.[1–5] As a result, their indications have expanded. The overall success rate has improved from 85% in the 1980s to almost 99% today,[2–7] regardless of type or location. Astonishingly enough, some patients now have the luxury of receiving implants and implant-supported prostheses on the same day.[6–8] However, as the number of implants placed has increased over the past 3 decades, a number of new questions have been raised. One critical question is how to maintain osseointegrated implants in a state of health with appropriate function and esthetics.

It is important to remember that implants only replicate natural teeth and that the implant-mucosa-bone interface only approximates the natural periodontium. Lack of cementum and periodontal ligament, less vasculature and fibroblasts, parallel orientation of supracrestal connective tissue, and the

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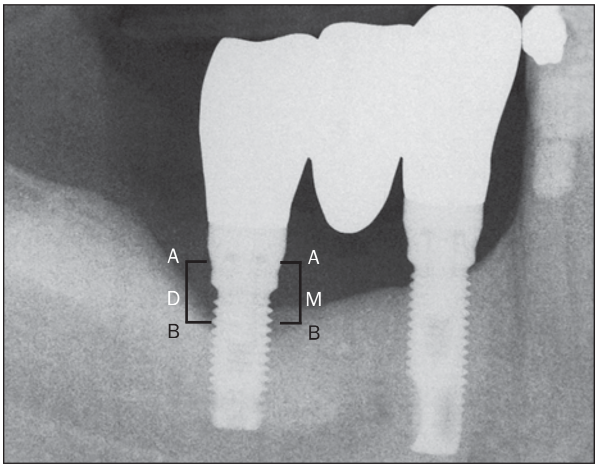


Fig 1 Measurement of radiographic bone loss. A = implant shoulder; B = the most coronal aspect of the alveolar crest; D = amount of bone loss distal to the implant; M = amount of bone loss mesial to the implant.

subgingival location of crowns make the implant structures more susceptible to the development of inflammation and bone loss when exposed to plaque accumulation or microbial invasion.[9–19] In addition, a history of poor oral hygiene and edentulism among implant patients differentiates them from regular periodontal patients. As a result of these distinctive differences between natural dentition and dental implants, more meticulous attention is required for implant maintenance, and negligence of its significance may result in an unnecessary breakdown of integration between the implant and intraoral tissues, including hard and soft tissues.[20] The success rate obtained with dental implants depends to a great extent on the quality of osseointegration. The early identification of signs and symptoms of bone loss is, therefore, essential to prevent implant loss.

Bone loss around implants can be classified as early or late bone loss.[3,21,22] Early implant bone loss occurs at the crestal region during healing and up to the first year of loading and may lead into failure without establishing initial osseointegration. Previous studies have shown that quality of bone, occlusal overloading, surgical trauma, microgap, violation of biological width, and implant crestal module are possible causative factors of early implant bone loss.[1,12,17,23–32] Late implant bone loss, on the other hand, is the gradual loss of marginal bone following osseointegration; over time, such bone loss may risk maintenance of the achieved osseointegration.[2,3,21,33–37] Although peri-implantitis and occlusal overloading are the 2 most likely etiologies for late implant bone loss, the literature is still inconclusive regarding the clinical factors affecting late implant bone loss. Therefore, the purpose of this study was to investigate factors affecting late implant bone loss.

MATERIALS AND METHODS

This retrospective clinical trial was reviewed and approved by the University of Michigan Institutional Review Board. All participants read and signed an informed consent form before inclusion in the study. The participants, who had received dental implants between April 1981 and April 2002, were recruited from the Department of Periodontics and Oral Medicine at the University of Michigan School of Dentistry (U of M), in Ann Arbor, MI, and the Misch International Implant Institute (MI), in Beverly Hills, MI, between July 2004 and May 2005. Only endosseous root-form dental implants that had been in place for more than 3 years were included. After potential participants were screened during follow-up appointments, a single calibrated examiner (DC) clinically evaluated the implants. Clinical parameters included presence or absence of suppuration, modified Bleeding Index (mBI),[38] modified Plaque Index (mPI),[38] Gingival Index (GI),[39] probing depth (PD), and width of keratinized mucosa (KM). These were recorded by the examiner. PD was measured from the free gingival margin to the most apical part of the sulcus mesiobuccally, midbuccally, distobuccally, and midlingually to the nearest mm with a pressure-sensitive probe (PDT Sensor Probe Type CP-12; tip diameter, 0.45 mm; probing force, 20 g/pressure; Pro-Dentec, Batesville, AR). The PD in each implant site was obtained by averaging PD measurements at the 4 sites. Castroviejo calipers (Salvin Dental Specialties, Charlotte, NC) with short 30-degree angled tips were used to measure the width of KM at the midbuccal point between the mucogingival junction (MGJ) and the free gingival margin to the nearest 0.1 mm. Patients' dental records were reviewed to reveal dates of implant placement, types of implants and surfaces, and any significant medical history (ie, diabetes, smoking). In addition, average annual bone loss (ABL) was calculated by evaluating periapical radiographs and panoramic radiographs. Patients were asked to complete a questionnaire regarding their satisfaction with their implants. The examiner remained blinded during the clinical examination, and calibration trials were conducted prior to, during, and after the study to assure adequate intraexaminer reliability.

Radiographic Evaluation

Changes in marginal bone were evaluated in each implant using periapical radiographs, panoramic radiographs, or both (Fig 1). Two sets of radiographs, one obtained at least 1 year after implant loading (baseline) and the other obtained during the research period (follow-up), were compared to deter-

Table 1 Implant Brands Used

Implant/Manufacturer	Location of manufacturer	No. of implants placed
Brånemark System/Nobel Biocare	Göteborg, Sweden	87
Maestro/BioHorizons	Birmingham, AL	148
Steri-Oss/Nobel Biocare	Göteborg, Sweden	53
CoreVent (formerly Paragon Implants)	Encino, CA	16
Osseotite/3i Implant Innovations	Palm Beach Gardens, FL	15
Screw-Vent/Zimmer Dental	Carlsbad, CA	14
Straumann	Basel, Switzerland	4
MicroVent (formerly Paragon Implants)	Encino, CA	2

mine annual osseous change. Radiographs were obtained using the paralleling technique using a plastic film holder (XCP; Rinn, Elgin, IL) and were processed on a scanner (Epson Perfection 4870 Photo, Epson America, Long Beach, CA) with an optical density of 3.4 units. The resolution of the image was standardized at 675 dpi, with a resulting average size of 940 × 620 pixels at 16 bits grayscale. The digitized radiographic images were analyzed using image analysis software (ImagePro Plus version 4.5.1; Media Cybernetics, Silver Spring, MD). The computer software was programmed to automatically magnify the images 15 times. Computer-assisted calibration was carried out for each implant by evaluating actual radiograph width. For each implant, the proximal distance between the implant shoulder and the most coronal aspect of the alveolar crest was measured at the mesial and distal aspects, and the mean of the 2 measurements provided the bone loss for that implant. The difference between the bone loss from the initial and final radiographs for each implant was calculated for the total bone loss of that implant. The total bone loss for each implant was divided by the age difference between the initial and final radiographs for the ABL of each implant being studied. Both periapical ABL and panoramic ABL were determined. The measurement agreement was 98% for periapical ABL and 94% for panoramic ABL. All assessments of peri-implant bone levels were performed by a single calibrated examiner (DC).

Patient Satisfaction Questionnaire

A questionnaire regarding satisfaction with the dental implant experience was distributed to all participants. The questionnaire consisted of 1 question in each of the following 6 categories: *(1)* comfort, *(2)* appearance, *(3)* ability to chew food, *(4)* ability to speak, *(5)* ability to clean implants, and *(6)* general satisfaction. For each question, there were 4 possible scores: *(1)* excellent, *(2)* good, *(3)* fair, and *(4)* poor.

Statistical Analysis

A statistical software program (SAS, Cary, NC) was used for all statistical analyses, and data was reported as mean ± standard error (SE). The chi-square test was used to evaluate the categorical clinical parameters. The Student t test was performed to analyze differences for the continuous clinical parameters within the groups (periapical and panoramic), and analysis of variance (ANOVA) was performed to analyze differences among the 4 groups. In addition, panoramic ABL was modeled using the random intercept mixed-effects model. All tests were 2-sided analyses, and differences were considered statistically significant when $P < .05$ with a confidence level of 95%.

RESULTS

Implants

Three hundred thirty-nine root-form dental implants were examined in 69 patients (mean age, 61.3 ± 13.6 years; range, 23 to 86 years). The sample included 87 Brånemark implants, 148 Maestro implants, 53 Steri-Oss implants, and 51 other implants (Table 1). The average service time of the dental implants was 8.1 ± 0.23 years (range, 3.0 to 24.0 years). One hundred ninety-eight of the implants (58.4%) were placed in the maxilla; 141 implants (41.6%) were placed in the mandible. Of the 198 maxillary implants, 57 implants replaced molars, 75 implants replaced premolars, 35 replaced canines, and 31 implants replaced incisors. Of the 141 mandibular implants, 40 implants replaced molars, 33 implants replaced premolars, 24 implants replaced canines, and 44 implants replaced incisors.

Average ABL

Figure 2 shows the average ABL for the main implant systems used in the study. The differences in average ABL among different implant systems failed to reach

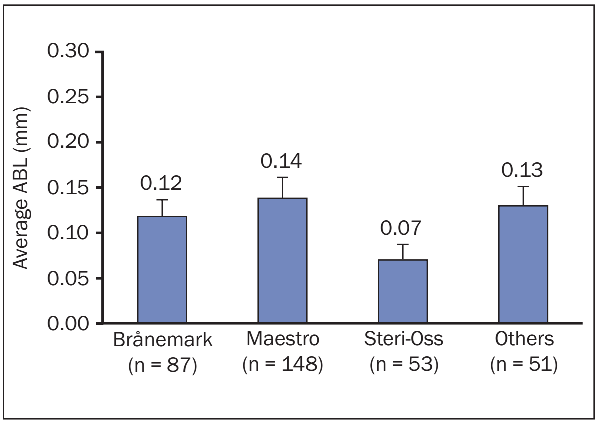


Fig 2 Average ABL by implant system. The "others" group included CoreVent (n = 16), Osseotite (n = 15), ScrewVent (n = 14), Straumann (n = 4), and MicroVent (n = 2).

statistical significance (*P* > .05). The average periapical ABL was 0.14 mm, the average panoramic ABL was 0.10 mm, and the average overall ABL was 0.12 mm. The difference between the periapical ABL and panoramic ABL was not statistically significant (*P* > .05).

Factors affecting average ABL were analyzed. Comparisons of ABL (periapical, panoramic, and overall) of implants based on different clinical variables are presented in Table 2. The results showed that average ABL was significantly influenced by type of implant prosthesis, implant location, implant length, and implant diameter (*P* < .05 for all). The average ABL for implants supporting fixed prostheses was twice that of implants supporting removable prostheses (0.14 mm versus 0.07 mm; *P* < .05). ABL (panoramic and overall) was significantly greater for posterior implants than for anterior implants (*P* < .05). When periapical ABL was used as the primary variable, only the difference between short and long implants was significant (0.19 mm versus 0.12 mm; *P* < .05).

Other Clinical Parameters

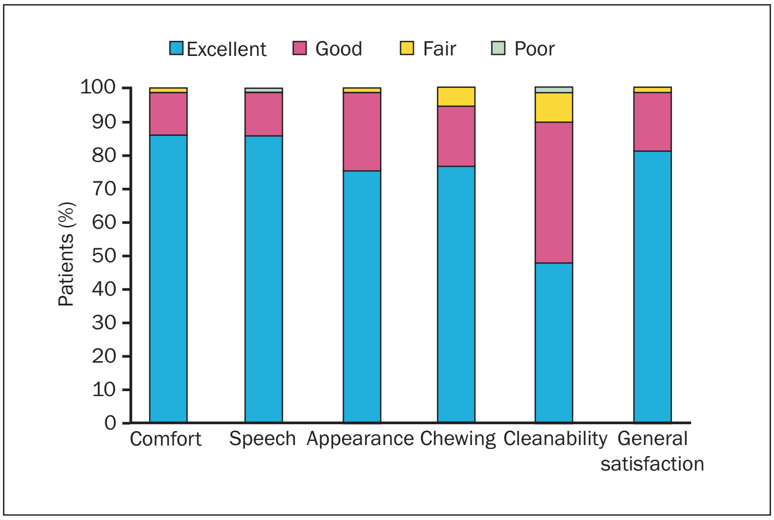
Analyses of clinical parameters (ie, mBI, GI, mPI, PD) that are commonly used to assess the degree of soft tissue health revealed that implants that were long, had smooth surfaces, had less than 2 mm of KM, or supported removable prostheses were associated with significantly greater gingival inflammation and

Table 2 Factors Affecting Late Implant Bone Loss

	Average ABL					
	Periapical		Panoramic		Overall	
Factors	n	Mean ± SE (mm)	n	Mean ± SE (mm)	n	Mean ± SE (mm)
Surface						
Smooth	65	0.10 ± 0.01	12	0.00 ± 0.00	77	0.09 ± 0.01
Rough	143	0.15 ± 0.02	119	0.11 ± 0.02	262	0.13 ± 0.01
KM						
< 2 mm	43	0.14 ± 0.03	41	0.08 ± 0.02	84	0.11 ± 0.02
≥ 2 mm	165	0.14 ± 0.09	90	0.11 ± 0.03	255	0.11 ± 0.02
Type of prosthesis						
Fixed	184	0.14 ± 0.02	66	0.13 ± 0.03	250	0.14 ± 0.03 *
Removable	24	0.08 ± 0.02	65	0.07 ± 0.02	89	0.07 ± 0.01
Location						
Anterior	76	0.13 ± 0.02	58	0.04 ± 0.01	134	0.09 ± 0.01
Posterior	132	0.14 ± 0.02	73	0.14 ± 0.03 *	205	0.14 ± 0.02 *
Maxilla	116	0.14 ± 0.02	82	0.13 ± 0.03	198	0.13 ± 0.02
Mandible	92	0.13 ± 0.02	49	0.04 ± 0.02 *	141	0.10 ± 0.01
Length						
Short (≤ 10 mm)	59	0.19 ± 0.03	41	0.07 ± 0.02	100	0.14 ± 0.02
Long (> 10 mm)	149	0.12 ± 0.01 *	90	0.11 ± 0.03	239	0.11 ± 0.01
Diameter						
Narrow (< 3.75 mm)	25	0.07 ± 0.01	6	0.00 ± 0.00	31	0.05 ± 0.01
Regular (3.75 to 4.0 mm)	158	0.14 ± 0.01	105	0.09 ± 0.02	263	0.12 ± 0.01 *
Wide (> 4.0 mm)	25	0.17 ± 0.07	20	0.18 ± 0.08	45	0.18 ± 0.05
Opposing dentition						
Natural	39	0.08 ± 0.02	10	0.02 ± 0.01	49	0.07 ± 0.02
Noble metal	29	0.17 ± 0.03	16	0.07 ± 0.03	45	0.14 ± 0.02
Resin/composite	33	0.15 ± 0.02	59	0.08 ± 0.02	92	0.10 ± 0.01
Porcelain	104	0.15 ± 0.02	45	0.15 ± 0.02	149	0.15 ± 0.02
Amalgam	3	0.12 ± 0.09	1	0.00	4	0.09 ± 0.07
Overall	208	0.14 ± 0.01	131	0.10 ± 0.02	339	0.12 ± 0.01

* Difference significant at *P* < .05.

Fig 3 Patient satisfaction regarding the implant experience. Sixty-nine patients responded to the questionnaire.



plaque accumulation than their counterparts (Table 3; *P* < .05). Interestingly, a significant difference in mBI was revealed only between smooth-surface implants (0.57) and rough-surface implants (0.41) (*P* < .05). Furthermore, there was no correlation between clinical parameters assessing the degree of soft tissue health or disease and average ABL.

The Effect of Systemic Conditions on Clinical Parameters

To explore the roles of smoking and diabetes in maintenance of hard and soft tissues around implants, overall ABL and other clinical parameters were compared for implants placed in smokers versus those in nonsmokers and for implants in patients with diabetes versus those without diabetes. Because the patient sample included only 7 patients who smoked and 26 with diabetes, ABL analysis was not broken down by type (panoramic versus periapical). Overall ABL was approximately 3 times greater in smokers (0.32 mm) than in nonsmokers (0.12 mm), and the difference was statistically significant (*P* < .05). Interestingly, significantly less plaque accumulation was observed in smokers versus nonsmokers (mPI of 0.86 versus 1.33; *P* < .05). When implants placed in patients with diabetes were compared to implants in patients without diabetes, only the difference in mPI between the 2 groups was significant (mPI of 1.81 versus 1.28, respectively; *P* < .05).

Patient Satisfaction

The vast majority of patients indicated general satisfaction with their implant experience; 81.2% said that their general satisfaction was "excellent," and 17.4% said it was "good" (Fig 3). One patient felt that his overall implant experience was "fair" (1.4%), but none of the patients felt that the overall experience was "poor." The best scores were received for satisfaction with comfort (1.16) and ability to speak (1.17), followed by appearance (1.26), ability to chew (1.29), and ease of cleaning (1.64). Less than 50% of the subjects responded "excellent" to the question regarding ease of cleaning of the implants.

Random Intercept Effects Analysis for Periapical ABL

Periapical ABL, the primary outcome in the present study, was modeled using the random intercept mixed effects analysis due to the fact that some implants were clustered within patients, which created correlation among some implants (Table 4). The influence of the following specific factors was investigated: implant location (ie, maxilla versus mandible, or anterior versus posterior), implant size (ie, short versus long, or narrow versus wide), implant type (ie, Brånemark versus Maestro versus Steri-Oss versus Others), type of prosthesis (ie, fixed versus removable), implant surface (ie, smooth versus rough), and the presence of KM on the buccal aspect. Overall, implant length showed statistical significance in relation to predicting average ABL. Periapical ABL was 0.09 mm less in the long implants group (length > 10 mm) than in the short implants group (*P* = .008). A statistically significant difference in ABL was not observed for any other other variable (*P* > .05). The intraperson correlation r = 0.14 interpreted as 14% of the variation in periapical ABL, unexplained by the model, is due to intersubject variation.

Table 3 Factors Affecting Soft Tissue Health Around Implants

Factors	n	mBI Mean ± SE (mm)	GI Mean ± SE (mm)	mPI Mean ± SE (mm)
Surface				
Smooth	77	0.57 ± 0.07 *	1.08 ± 0.08 *	1.69 ± 0.10 *
Rough	262	0.41 ± 0.03	0.73 ± 0.03	1.21 ± 0.05
KM				
< 2 mm	84	0.40 ± 0.06	0.94 ± 0.07 *	1.51 ± 0.09 *
≥ 2 mm	255	0.54 ± 0.09	0.76 ± 0.04	1.26 ± 0.05
Type of prosthesis				
Fixed	250	0.48 ± 0.04	0.77 ± 0.04 *	1.30 ± 0.05
Removable	89	0.37 ± 0.06	0.91 ± 0.06	1.38 ± 0.09
Location				
Anterior	134	0.43 ± 0.05	0.87 ± 0.05	1.32 ± 0.07
Posterior	205	0.46 ± 0.04	0.77 ± 0.04	1.32 ± 0.06
Maxilla	198	0.36 ± 0.04 *	0.68 ± 0.04 *	1.15 ± 0.06 *
Mandible	141	0.57 ± 0.05	0.99 ± 0.05	1.56 ± 0.07
Length				
Short (≤ 10 mm)	100	0.47 ± 0.06	0.79 ± 0.05 *	1.41 ± 0.08 *
Long (> 10 mm)	239	0.44 ± 0.04	0.81 ± 0.04	1.28 ± 0.06
Diameter				
Narrow (< 3.75 mm)	31	0.06 ± 0.12	0.74 ± 0.10	1.35 ± 0.15
Regular (3.75 to 4.0 mm)	263	0.43 ± 0.04	0.83 ± 0.04	1.32 ± 0.05
Wide (> 4.0 mm)	45	0.47 ± 0.09	0.69 ± 0.09	1.31 ± 0.13
Opposing dentition				
Natural	49	0.45 ± 0.08	0.78 ± 0.09	1.18 ± 0.12
Noble metal	45	0.49 ± 0.09	0.73 ± 0.09	1.47 ± 0.14
Resin/composite	92	0.36 ± 0.05	0.86 ± 0.05	1.33 ± 0.08
Porcelain	149	0.50 ± 0.05	0.81 ± 0.05	1.31 ± 0.07
Amalgam	4	0.25 ± 0.25	0.50 ± 0.29	1.00 ± 0.71

*Difference significant at $P < .05$.

Table 4 Overall Random Intercept Mixed Effect Analysis for Periapical ABL

Parameter	Estimate	SE	*t*	*P*
β_0 (intercept)	0.1115	0.1049	1.06	.2923
β_1 (length)	−0.0900	0.0334	−2.70	.0078*
β_2 (location [1])	0.0101	0.0309	0.33	.7446
β_3 (prosthesis type)	−0.0311	0.0567	−0.55	.5843
β_4 (location [2])	−0.0016	0.0344	−0.05	.9638
β_5 (surface)	0.0459	0.0337	1.36	.1749
β_6 (KM)	0.0266	0.0359	0.74	.4606
β_7 (width)	0.0279	0.0344	0.81	.4186

The dependent variable was the average periapical ABL. The predictor variables were implant length, implant location (posterior versus anterior [1] and mandible versus maxilla [2]), type of prosthesis, type of surface, presence of KM, and implant width.
Model: $ABL(PA) = \beta_0 + \beta_1 LN + \beta_2 LC(1) + \beta_3 PR + \beta_4 LC(2) + \beta_5 SF + \beta_6 KM + \beta_7 WD + \epsilon$ ($P < .05$*).
Intra-person correlation $r = 0.005270 / (0.005270 + 0.03194) = 0.14$.
*Statistically significant.

DISCUSSION

The maintenance of dental implants depends on integration between the implant and both the hard and soft oral tissues. Although 0.2 mm of annual marginal bone loss in successfully osseointegrated implants is accepted as an ordinary biologic process, not all implants are influenced by late bone loss.[3,21] The search for factors causing late bone loss has been inconclusive in the literature. Discovering factors that compromise the maintenance of hard and soft tissue around implants is probably the first and easiest step in preventing the breakdown of peri-implant structures. Therefore, the present study was performed to evaluate factors affecting the maintenance of hard and soft tissue around implants at later stages.

Because of the differences in resolution and magnification between periapical and panoramic radiographic techniques, the analyses of osseous change in the current studies were performed using the 2 techniques separately and together. The difference between the average ABL found using the 2 methods was not statistically significant ($P > .05$). The average ABL from the periapical radiographic analysis (0.14 ± 0.01 mm) in the study was comparable to that reported in other studies.[37,40,41] The results of the present study showed that the average ABL was significantly greater in posterior implants, maxillary implants, shorter implants, wider implants, and implants with fixed restorations than their counterparts ($P < .05$). However, implant type (brand), surface configuration, type of opposing dentition, and amount of KM did not significantly affect average ABL. When periapical ABL was modeled using the random intercept effects analysis for all clinical factors, implant length was found to be the most critical factor. This analysis suggested that the chance of ABL being 0.09 mm greater than average was significantly higher for short implants (length ≤ 10 mm) than for long implants (length > 10 mm) ($P = .008$). It is speculated that shorter implants are more likely to be placed in the posterior regions that are usually less ideal due to compromised accessibility, increased crown-implant ratio, poorer bone quality, and anatomic limitations.[42–48] Also, a heavier occlusal force on these implants increases the bending moment, possibly increasing the implant crest module, which has been associated with greater marginal bone loss.[44,45] Studies have shown that bone quality and loading condition have a major influence on implant survival.[34,43,49,50] In a comparison of bone quality between the maxilla and mandible and between anterior and posterior regions, it was shown that the mandible is composed of a thicker and denser cortical bone than the maxilla and that the cortices of both jaws tend to become thinner and more porous posteriorly.[51–53] In the present study, less bone loss was revealed in anterior implants and mandibular implants than in posterior implants and maxillary implants, respectively. Hence, the results from the current study confirmed previous findings.[42,54–59]

It is interesting to note that surface configuration and presence of KM did not affect average ABL. Although average ABL was higher for rough implants than for smooth implants, the difference was not statistically significant. The beneficial effects of rough implants on peri-implant bony healing, especially during the earlier stages, have been documented in numerous experimental and clinical studies.[60–66] A meta-analysis comparing success rates between smooth- and rough-surface implants concluded that rough-surface implants have significantly higher success rates in most situations, with the exception of single-tooth replacements; when used for single tooth replacement, the success rates for the 2 surfaces were comparable.[67] On the other hand, another meta-analysis of randomized clinical trials on clinical parameters between smooth and rough surface implants reported that smooth-surface implants were associated with peri-implantitis 20% less often than rough-surface implants.[68] The different conclusions between the studies might have resulted from several factors, including *(1)* different criteria for success, survival, and marginal bone loss; *(2)* analyses of implants with different surfaces; and *(3)* different inclusion criteria for the studies. Both the 2 meta-analyses and the present study demonstrated that implant therapy, regardless of implant surface configuration, is a predictive treatment modality in the long-term for the replacement of missing dentition. The relationship between late implant bone loss and cumulative success rate should be further explored through randomized, controlled clinical trials with large sample sizes.

The effect of smoking and diabetes on the maintenance of implants was also analyzed in the current study. Although only 2.1% (n = 7) of implants had been placed in current smokers, average ABL was approximately 2.7 times greater in smokers (0.32 mm) than that in nonsmokers (0.12 mm), and the difference was statistically significant ($P < .05$). These results confirmed previous studies.[69–72] A study analyzing 2,194 implants placed in 540 subjects showed that failure rate was 2.4 times significantly higher in smokers (11.3%) than nonsmokers (4.8 %).[47] In a 10-year prospective study, Karoussis and associates reported that marginal bone level of implants at 10 years was significantly associated with smoking.[73] Since all the implants in smokers had rough surfaces, it has not been confirmed that modification of the implant surface can decrease risk of failure in smokers.[74,75] Moreover, the influence of smoking was underrepresented in the current study because of the small number of smokers. When marginal bone loss with respect to diabetes was evaluated, marginal bone loss was not found to be associated with diabetes in the current study. An interesting observation was that 85.7% (6 of 7) of implants that exhibited suppuration were from the patients with type II diabetes. However, the diagnosis of diabetes in the present study was established based on self-monitored glucose profiles. Although all the diabetic patients in the present study reported having type II diabetes which was being regularly monitored by their physicians and controlled with exercise or medications, an investigation utilizing the glycated hemoglobin level is warranted to confirm the relationship between the severity of diabetes and late implant bone loss.

The analysis of the factors affecting the health of soft tissue and those affecting ABL suggested that there is no correlation between the degree of soft tissue health and osseous changes during implant maintenance. In clinical periodontology, greater gingival inflammation and plaque accumulation are often associated with more attachment and bone loss.[76] Lang and associates reported that continuous absence of bleeding on probing is a reliable predictor for the maintenance of periodontal health, as evidenced by high specificity (88%) and a high negative predictive value (98%).[77] The validity of bleeding on probing, GI, and PI for assessing the status of peri-implant mucosal health or disease has been confirmed in the same center.[78] In the current study, however, none of these parameters (ie, mBI, GI, or mPI) was correlated with either periapical or panoramic ABL. For example, with respect to implant surface configurations, significantly higher mBI, GI, and mPI scores were observed in smooth-surface implants than rough-surface implants ($P < .05$). The results of the current study corresponded with an investigation by Salcetti and associates, which showed that plaque and bleeding scores could not be used as indicators of a healthy or diseased peri-implant state.[79] The use of different probes in the studies (Florida Probe, PDT Sensor Probe Type CP-12, and UNC 15 probe by Lang and associate, the current research team, and Salcetti and colleagues, respectively) may be one reason for the differences in conclusions. Caution should be exercised in interpreting data regarding clinical parameters and in correlating these results to osseous changes, and further research is needed to clarify the influence of these factors.

In contemporary dentistry, the implant procedure as a whole is not truly a success if the patient is not completely satisfied, even if perfect functionality and esthetics are achieved from standpoint of the master clinicians. For this reason, Smith and Zarb stated that 1 criterion for success is that "the implant design does not preclude placement of a crown or prosthesis with an appearance that is satisfactory to the patient and dentist."[21] In the present study, the majority of patients (98.6%) rated their general satisfaction with their implant therapy as good or excellent. The results of the questionnaire demonstrated that cleaning feasibility was problematic from the patients' standpoint; 10% reported that their satisfaction with this aspect of their treatment was fair or poor. Similar findings were reported by Pjetursson and colleagues; in their study, 17% of 104 patients complained of unsatisfactory ability to clean the implants.[80] Although the validity of the questionnaire created for this study has not been tested, it appears that improvement in cleaning feasibility is necessary to improve the overall implant experience and satisfy more patients.

The present study was a retrospective cross-sectional clinical investigation with several inherent limitations. First, causality can not be established. Secondly, there were multiple confounding factors (eg, grafted sites versus native tissue) that could not be controlled. In addition, small sample size and uneven distribution of each variable group may have abated statistical significances of data and consequently led to false negative results. Nonetheless, information presented in the current study is essential for increasing our understanding of the factors affecting late implant bone loss.

CONCLUSIONS

Within the limitations of current retrospective clinical trial, it can be concluded that shorter implants, wider implants, implants supporting fixed prostheses, and implants placed in smokers were associated with greater average ABL. Furthermore, implant length was the most significant factor in the maintenance of dental implants. Randomized controlled clinical trials are recommended to verify the results obtained from this retrospective clinical study.

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