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Association between soft-tissue thickness and early marginal bone loss around mandibular dental implants

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Abstract

Objective: This study aimed to evaluate the association between soft-tissue thickness and crestal bone resorption over 12 months in patients receiving mandibular dental implants.

Methods: This retrospective study analyzed the records of 66 patients (33 males and 33 females; mean age, 37.41 ± 6.23 years) who received 66 bone-level implants in the mandible between June 2021 and February 2023. Soft tissue thickness was measured intraoperatively using a standardized periodontal probe technique, and patients were categorized into thin (≤ 2.0 mm) and thick (> 2.0 mm) soft-tissue groups. Peri-implant marginal bone loss was measured on standardized periapical radiographs after 12 months. Associations between marginal bone loss and soft-tissue thickness, sex, implant diameter, and implant location were evaluated. Data were analyzed using the chi-square and Mann-Whitney U tests (α = 0.05).

Results: Thirty-five patients (53%) had thin soft tissue, whereas 31 (47%) had thick soft tissue. The thin-tissue group showed slightly greater marginal bone loss than the thick-tissue group (0.24 ± 0.17 vs. 0.19 ± 0.17 mm, respectively), although this difference was not statistically significant (P = 0.228). No significant associations were found between marginal bone loss and sex (P = 0.078), implant diameter (P = 0.871), or implant location (P = 0.433).

Conclusions: Soft-tissue thickness at the implant site was not significantly associated with early marginal bone loss around mandibular implants over the 12-month follow-up period. These findings suggest that, under the conditions of this study, soft-tissue thickness alone may not be a major determinant of early marginal bone stability.

Keywords: Alveolar bone loss, Bone-implant interface, Dental implants, Mandible, Peri-implant tissues, Soft tissue

Introduction

Dental implants have substantially improved the treatment of complete and partial tooth loss over recent decades. Compared with conventional removable prostheses, implant-supported restorations can improve masticatory function, patient satisfaction, and oral-health-related quality of life (1).

One of the factors contributing to the success of implant treatment is the maintenance of crestal bone around the implant neck. Progressive marginal bone loss can compromise biomechanical stability, prosthetic function, and peri-implant soft-tissue support, thereby increasing the risk of biological complications and treatment failure over time (2-4). In this context, the stability of peri-implant soft tissues plays a key role, because breakdown of the peri-implant soft-tissue seal may facilitate bacterial penetration and local inflammation, which in turn can contribute to progressive crestal bone loss and adversely affect prosthetic function (5-9).

The relationship between soft-tissue thickness and marginal bone stability has generated considerable interest since Berglundh and Lindhe (10) first described the dimensional requirements of peri-implant soft tissues in 1996. They suggested that a minimum soft-tissue thickness is needed to establish a stable peri-implant mucosal seal, and that insufficient thickness may be associated with marginal bone resorption as part of early tissue remodeling around the implant. Since then, peri-implant soft-tissue dimensions have been recognized as one of several factors that may influence crestal bone stability and early bone remodeling around dental implants(11-14). Other studies have also suggested that peri-implant soft-tissue thickness may influence crestal bone stability. Implants placed in sites with thin mucosa (≤ 2 mm) have been associated with significantly greater marginal bone loss than those placed in sites with thicker mucosa (> 2 mm) during the

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first year of follow-up (8, 15). Although several biological mechanisms have been proposed to link peri-implant soft-tissue thickness to crestal bone stability, the exact pathways remain uncertain (16, 17).

However, clinical studies have reported conflicting results about the influence of soft tissue thickness on peri-implant marginal bone loss. Some have found significantly greater marginal bone loss at thin-tissue sites (8, 15), whereas others have observed no significant association between soft-tissue thickness and crestal bone changes (18, 19). Therefore, the present study aimed to evaluate the association between soft-tissue thickness at the implant site and crestal bone resorption over a 12-month period in patients undergoing implant placement in various mandibular regions.

Materials and methods

Study design and setting

This retrospective study was conducted at the Department of Implantology of Mashhad Dental School, Mashhad University of Medical Sciences, Mashhad, Iran. The study included clinical and radiographic records of patients who underwent implant placement between June 2021 and February 2023. The study protocol was approved by the ethics committee of Mashhad University of Medical Sciences (approval no. IR.MUMS.DENTISTRY.REC.1401.146) and was conducted in accordance with the principles of the Declaration of Helsinki.

Participants

The study included the clinical records of consecutive adult patients (aged >18 years) who underwent mandibular implant placement at the Department of Implantology, Mashhad Dental School, between June 2021 and February 2023. Patients were eligible if they had a single missing mandibular tooth and sufficient residual bone for placement of a standard implant (minimum ridge width of 6 mm and residual bone height of 8 mm), as determined by clinical and radiographic evaluation. In addition, patients were required to have periodontal health or well-controlled periodontal disease (full-mouth bleeding on probing < 20%) and a minimum keratinized tissue width of 4 mm at the implant site. Only patients classified as American Society of Anesthesiologists (ASA) physical status I or II were included.

Patients were excluded if they had active periodontitis or a history of periodontitis, current or recent tobacco use (within the previous 12 months), poorly controlled diabetes, alcohol dependence, a history of head and neck radiotherapy, severe bruxism, or systemic conditions or medications that could impair wound healing, including bisphosphonate therapy or immunosuppressive medications. Patients with incomplete clinical records or without radiographic follow-up at 12 months were also excluded.

Sample size calculation

The sample size was calculated using G*Power software (version 3.1.9.4; Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany) based on the study of Saglanmak et al. (20). They reported mean ± SD marginal bone loss values of 0.96 ± 0.49 mm for sites with thin soft tissue and 0.55 ± 0.41 mm for sites with thick soft tissue.

An independent-samples comparison was assumed, with a two-sided α level of 0.05 and a statistical power of 95%. The minimum required sample size was estimated at 27 participants per group. To enhance the reliability of the analysis, 66 eligible patients (n = 33 per group) with complete clinical and radiographic records were identified from the institutional archive and included in the study.

Surgical procedures and tissue assessment

All implant surgeries were performed by the same surgical team using a standardized protocol. Local anesthesia was achieved using 2% lidocaine with 1:80,000 epinephrine (Loghman, Tehran, Iran).

Soft-tissue thickness was measured at each planned implant site before flap elevation using a standardized measurement protocol. A Williams periodontal probe (Medesy, Maniago, Italy) equipped with a rubber stop was inserted perpendicular to the mucosal surface until firm resistance was encountered. The distance between the probe tip and the rubber stop was measured and recorded to the nearest 0.5 mm. Three measurements were obtained along the buccolingual axis of the crestal ridge: one at the mid-crestal point and two at points approximately 1 mm mesial and 1 mm distal to the midpoint. The mean of the three measurements was calculated and recorded as the soft-tissue thickness for each implant site. Crestal incisions were then made, and full-thickness mucoperiosteal flaps were elevated. Patients were categorized into thin soft-tissue (≤ 2.0 mm) and thick soft-tissue (> 2.0 mm) groups according to the measured soft-tissue thickness. The 2.0-mm threshold has been widely used in the literature to distinguish thin and thick peri-implant soft-tissue phenotypes (8).

Postoperative management and prosthetic phase

Implant sites were prepared according to the manufacturer's protocol using sequential drills (Dentium Co., Seoul, Korea) under copious sterile saline irrigation. Bone-level tapered implants (Dentium Co.) were placed at the crestal level or 1 mm below the crest, depending on the available bone width and esthetic requirements. Implant diameter (3.8 or 4.3 mm) was selected according to the available bone width, with 3.8-mm implants used for narrower ridges and 4.3-mm implants for wider ridges. All implants had a minimum length of 10 mm. Adequate primary stability was confirmed by an insertion torque of at least 35 Ncm. After placement of the cover screws, the flaps were repositioned and closed with 4-0 non-resorbable sutures (Ethicon, Johnson & Johnson, Somerville, NJ, USA), which were removed 10 days after surgery.

All patients received standardized postoperative instructions and were prescribed amoxicillin 500 mg three times daily for 1 week (Loghman), along with ibuprofen 400 mg (Loghman) as needed for pain relief. Patients were instructed to rinse with 0.2% chlorhexidine gluconate twice daily for 2 weeks (Iran Najo, Tehran, Iran) and to avoid mechanical cleaning of the surgical site during the initial healing period.

After 8–10 weeks of healing, the implants were exposed using a tissue punch, and healing abutments were connected. Two weeks later, final impressions were obtained using the open-tray technique with polyether impression material (Impregum, 3M ESPE, Seefeld, Germany).

Metal-ceramic crowns were fabricated and delivered 2–3 weeks later. During crown delivery, occlusal contacts were carefully adjusted to ensure even load distribution and to eliminate premature contacts. All patients were enrolled in a maintenance program that included professional oral hygiene care every 3 months.

Data collection

Data were extracted from clinical records and the digital radiographic archive of the Department of Implantology. Patient demographics, including age, sex, and medical history, were recorded from the clinical files. For each implant, the diameter (3.8 or 4.3 mm) and mandibular location were documented. Implant location was classified according to the type of missing tooth as anterior (incisors and canines), middle (premolars), or posterior (molars). The outcome was marginal bone loss at 12 months, measured as a continuous variable in millimeters.

Standardized intraoral periapical radiographs were obtained using the paralleling technique with a film holder (Rinn XCP, Dentsply Sirona, York, PA, USA) at two time points: immediately after implant placement (baseline) and at the 12-month follow-up. All radiographs were acquired using a digital sensor (Trophy RVG, Carestream Dental, Rochester, NY, USA) with consistent exposure parameters of 70 kVp, 8 mA, and 0.3 seconds. Image acquisition and measurements were performed using dedicated software (RVG Windows Trophy 7.0, Carestream Dental).

For each radiograph, marginal bone level was measured as the distance from the implant shoulder to the first visible bone-to-implant contact on the mesial and distal aspects. The mean of the mesial and distal measurements was calculated for each time point. Marginal bone loss was defined as the change in marginal bone level from baseline to the 12-month follow-up.

To account for potential image magnification, all linear measurements were calibrated using the known dimensions of the corresponding implant. A single blinded examiner, who was unaware of the soft-tissue thickness measurements, performed all radiographic evaluations. To assess intra-examiner reliability, 20% of the radiographs were randomly selected and re-measured after a 2-week interval. The intraclass correlation coefficient was 0.94 (95% CI: 0.89–0.97), indicating excellent intra-examiner reliability.

Statistical analysis

Statistical analyses were performed using SPSS version 26.0 (IBM Corp., Armonk, NY, USA). The distributions of sex, implant diameter, and implant location between the thin- and thick-tissue groups were compared using the chi-square test. Age was compared between groups using an independent-samples t-test. Marginal bone loss was analyzed according to soft-tissue thickness and other variables, including sex, implant diameter, and implant location, using the Mann–Whitney U test. A two-tailed P value < 0.05 was considered statistically significant.t.

Results

Demographics and baseline characteristics

Table 1 summarizes the patient demographics and implant characteristics in the study groups. A total of 66 patients (33 males and 33 females) were included, with a mean age of 37.41 ± 6.23 years (range, 25–55 years). Based on the soft-tissue thickness measured during implant placement, 35 patients (53%) were classified

Table 1. Patient demographics and implant characteristics in the study groups

Parameter	Thin tissue (n = 35)	Thick tissue (n = 31)	P value
Age (years)	38.29 ± 6.90	36.42 ± 5.32	0.227
Sex (M/F)	17/18	16/15	0.805
Implant location			0.615
- Middle	24 (68.6%)	23 (74.2%)	
- Posterior	11 (31.4%)	8 (25.8%)	
Implant diameter			0.581
- 3.8 mm	30 (85.7%)	25 (80.6%)	
- 4.3 mm	5 (14.3%)	6 (19.4%)	

The quantitative variables have been shown by mean ± SD and qualitative variables by n (%).
SD: Standard deviation

into the thin-tissue group (≤ 2.0 mm), whereas 31 patients (47%) were classified into the thick-tissue group (> 2.0 mm). No significant differences were observed between the two groups in terms of age (P = 0.227) or sex distribution (P = 0.805), indicating comparable baseline demographic characteristics in the study groups.

The majority of implants were placed in the middle region of the mandible (47 implants, 71.2%), followed by the posterior region (19 implants, 28.8%). No implant was placed in the anterior region. Regarding implant diameter, 55 implants (83.3%) had a diameter of 3.8 mm, whereas 11 implants (16.7%) had a diameter of 4.3 mm. No significant differences were observed in the frequency distribution of implant location (P = 0.615) or implant diameter (P = 0.581) between the two groups.

Marginal bone loss

All implants survived throughout the 12-month follow-up period, resulting in a 100% survival rate. The overall mean marginal bone loss was 0.22 ± 0.17 mm, with values ranging from 0.00 to 0.50 mm.

Table 2 presents the marginal bone loss values for the thin- and thick-tissue groups. Patients in the thin-soft tissue group had a mean marginal bone loss of 0.24 ± 0.17 mm, compared with 0.19 ± 0.17 mm in the thick-soft tissue group. The difference in marginal bone loss was not statistically significant between the two groups (P = 0.228).

Mean marginal bone loss was slightly higher in men than in women (0.26 ± 0.18 mm vs. 0.18 ± 0.14 mm, respectively); however, this difference was not statistically significant (P = 0.078).

Implant location and diameter

The mean marginal bone loss was 0.21 ± 0.16 mm in the middle region, compared with 0.25 ± 0.19 mm in the posterior region. No significant difference in marginal bone loss was observed between the middle and posterior regions of the mandible (P = 0.433).

Implant diameter was not significantly associated with marginal bone loss (P = 0.871), with mean values of 0.22 ± 0.17 mm for 3.8-mm implants and 0.23 ± 0.18 mm for 4.3-mm implants.

Table 2. Comparison of marginal bone loss according to peri-implant soft-tissue thickness and other variables

Variable		**n**	**Mean ± SD (mm)**	**Median (mm)**	**Range (mm)**	**P value**
						0.228
Tissue thickness	- Thin (≤2 mm)	35	0.24 ± 0.17	0.25	0.00-0.50	
	- Thick (>2 mm)	31	0.19 ± 0.17	0.25	0.00-0.50	
						0.078
Sex	- Female	33	0.18 ± 0.14	0.25	0.00-0.50	
	- Male	33	0.26 ± 0.18	0.25	0.00-0.50	
						0.433
Implant location	- Middle	47	0.21 ± 0.16	0.25	0.00-0.50	
	- Posterior	19	0.25 ± 0.19	0.25	0.00-0.50	
						0.871
Implant diameter	- 3.8 mm	55	0.22 ± 0.17	0.25	0.00-0.50	
	- 4.3 mm	11	0.23 ± 0.18	0.25	0.00-0.50	

SD: standard deviation

Discussion

The primary objective of this retrospective study was to evaluate the association between soft-tissue thickness and marginal bone loss around mandibular implants over a 12-month follow-up period. The results showed a mean marginal bone loss of 0.24 ± 0.17 mm in the thin-tissue group, compared with 0.19 ± 0.17 mm in the thick-tissue group; however, this difference was not statistically significant. Marginal bone loss also did not differ significantly according to sex, implant location, or implant diameter. Although marginal bone loss tended to be higher in men than in women and in posterior implant sites than in middle sites, these differences were not statistically significant.

The 2-mm threshold has been commonly used in the literature to distinguish between thin and thick soft-tissue phenotypes (21, 22). Although the biological mechanisms linking peri-implant soft-tissue thickness to crestal bone stability are not fully understood, several explanations have been proposed. Thin peri-implant mucosa may provide less protection at the implant–abutment interface and may therefore be more susceptible to bacterial penetration and local inflammation (16, 17). Reduced vascularity and greater susceptibility to mechanical trauma during functional loading or oral-hygiene procedures have also been proposed as possible contributing factors to peri-implant bone loss (23). However, in carefully selected patients with good oral hygiene and regular maintenance, the potential impact of soft-tissue thickness may be attenuated, which could partly explain the absence of a significant association between soft-tissue thickness and peri-implant marginal bone loss in the present study.

The findings of the present study are consistent with some studies that have reported no significant association between soft-tissue thickness and marginal bone loss (18, 19). Van Eekeren et al. (18) conducted a randomized clinical trial and found that initial soft-tissue thickness did not significantly affect crestal bone changes when implants with similar macrogeometry were compared. They observed no statistically significant difference in marginal bone loss between the thin- and thick-tissue groups. A systematic review by Akcali et al. (19) reported that the relationship between soft-tissue thickness and bone loss is complex and may be influenced by several confounding factors, including maintenance protocols, implant design, and surgical technique. Their analysis revealed considerable heterogeneity among the included studies, with some reporting significant associations between soft-tissue thickness and marginal bone loss, whereas others found no significant relationship.

In contrast to the findings of the present study, several investigations have reported significantly greater marginal bone loss at thin-tissue sites than at thick-tissue sites (15, 20, 23, 24). Linkevicius et al. (15, 23) conducted two prospective clinical trials investigating the influence of soft-tissue thickness on crestal bone stability. In their initial study of 46 implants, sites with thin mucosa (≤ 2 mm) showed significantly greater mean marginal bone loss than sites with thick mucosa (> 2 mm) after 1 year (1.61 ± 0.24 mm mesially and 1.28 ± 0.17 mm distally in the thin group vs. 0.26 ± 0.08 mm mesially and 0.09 ± 0.05 mm distally in the thick group; $P < 0.05$ for both) (15). A subsequent study by the same group reported similar findings, with implants placed at thin-mucosa sites showing significantly greater marginal bone loss than those placed at thick-mucosa sites (23).

Saglanmak et al. (20) evaluated 44 conical implants and observed significantly greater crestal bone loss at the thin-tissue sites than at thick-tissue sites after 1 year. The mean bone loss was 0.96 ± 0.49 mm in the thin-tissue group and 0.55 ± 0.41 mm in the thick-tissue group (20). Jaiswal et al. (25), in a prospective study of 156 implants, reported significantly higher marginal bone loss in the thin-mucosa group at 24 months (1.78 ± 0.62 mm vs. 0.67 ± 0.34 mm), identifying soft-tissue thickness as an independent predictor of bone loss.

A systematic review by Suárez-López Del Amo et al. (24) analyzed eight studies and concluded that greater initial soft-tissue thickness was associated with reduced marginal bone loss in the short term. Furthermore, Puisys and Linkevicius (8) demonstrated that surgical thickening of thin mucosa using soft-tissue grafting significantly reduced crestal bone loss compared with untreated thin-tissue sites, suggesting that increasing soft-tissue thickness may contribute to improved crestal bone stability around dental implants. Recently, Bressan et al. (26) conducted a systematic review and meta-analysis of randomized and controlled clinical trials to evaluate the influence of initial soft-tissue thickness on marginal bone loss after implant placement. Their analysis of six studies involving 354 implants showed significantly greater bone loss around implants placed at sites with thin soft tissue (< 2 mm) than at sites with thick soft tissue (≥ 2 mm) during the first 10–14 months of follow-up (mean difference, 0.54 mm). However, the authors emphasized that further high-quality studies are needed because of the heterogeneity among the included studies and implant systems. Similarly, Breunig et al. (27), in a long-term cohort study with up to 20

years of follow-up, observed that patients with a thin gingival phenotype had significantly greater crestal bone loss only during the first 12 months of functional loading (p=0.016), with no significant differences thereafter. These heterogeneous findings suggest that the potential association between peri-implant soft-tissue thickness and marginal bone stability may be influenced by maintenance protocols, implant design, and patient-related factors. Further high-quality studies are needed to better clarify this relationship.

The slightly greater marginal bone loss observed in male patients, although not statistically significant, has also been reported in other studies and may be related to sex-related differences in bone density, bone remodeling, and oral hygiene practices (6). Similarly, the comparable marginal bone loss observed between the two implant diameters is consistent with previous evidence showing that narrow-diameter implants can achieve bone maintenance similar to that of regular-diameter implants when appropriately indicated (2).

This study has several limitations. The use of two-dimensional radiography may have limited the accurate assessment of buccal and lingual bone alterations, which cannot be fully evaluated without three-dimensional imaging. Moreover, the 12-month follow-up period may have been insufficient to identify potential long-term differences in marginal bone stability. The relatively small sample size and single-center design may have limited the generalizability of the findings to broader patient populations and different clinical settings. In addition, occlusal loading conditions and parafunctional habits were not assessed, although variations in these factors may affect peri-implant biomechanical stress and subsequently influence marginal bone remodeling.

Future studies should include larger sample sizes, longer follow-up periods, and three-dimensional imaging to further investigate the potential influence of soft-tissue thickness on peri-implant bone stability. Histological and other biological assessments may also help elucidate the potential mechanisms by which soft-tissue characteristics could influence peri-implant tissue remodeling.

Conclusions

Under the conditions of this study, peri-implant marginal bone loss was comparable between the thin- and thick-soft tissue groups (0.24 ± 0.17 mm vs. 0.19 ± 0.17 mm, respectively). Soft-tissue thickness at the implent site (≤ 2 mm vs. > 2 mm) was not significantly associated with marginal bone loss around mandibular implants over the 12-month follow-up period. No significant differences in marginal bone loss were observed according to sex, implant location, or implant diameter.

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Conflict of interest

The authors declare no conflict of interest.

Author contributions

E.Ag. and H.R.A. developed the project, helped with data analysis, and edited the manuscript. S.M. and Z.M. collected the data and edited the manuscript. F.S. and E.As. helped with data collection, analyzed the data, and wrote the original draft of the manuscript. All authors read and approved the final manuscript.

Ethical considerations

The study protocol was approved by the ethics committee of Mashhad University of Medical Sciences (approval no. IR.MUMS.DENTISTRY.REC.1401.146).

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