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# A Retrospective Evaluation of Marginal Bone Loss Around Dental Implants Using Different Implant Systems

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## ABSTRACT

**Objectives:** This study aimed to evaluate marginal bone loss (MBL) around different dental implant systems and its relationship with patient demographics, edentulism status, implant position, loading time, and prosthesis type.

**Materials and Methods**: Fifty-one patients and 187 implants who underwent surgery between 2014 and 2018 were included. MBL was measured using panoramic radiographs taken immediately after implant placement and at 1-2 and 2-4 years post-surgery. Data on patient demographics, edentulism type, implant location, loading periods, and augmentation presence were recorded. MBL was analyzed using Kruskal-Wallis, pairwise comparisons, and t-tests.

**Results**: MBL in the 1-2 year interval was significantly influenced by age, implant location, edentulism status, and prosthesis type. Bone loss was more significant in patients aged 70 and older, with the least observed in the 50-59 age group. Molar regions of the maxilla and mandible had the most bone loss, while the anterior mandibular region showed the least. Single-tooth edentulous patients experienced more MBL than completely edentulous patients. Loading time and prosthesis type also influenced MBL; early loading and overdenture prostheses resulted in less bone loss. Augmentation procedures were associated with greater bone loss in the 2-4 year interval.

**Conclusions:** These results suggest that patient age, implant position, edentulism status, and prosthesis type are key factors influencing MBL within 1-2 years post-implantation. Augmentation procedures notably impacted bone loss in the 2-4 year period. These findings emphasize the importance of considering these factors to reduce bone loss and optimize implant outcomes.

***Keywords:*** Dental implants, edentulism status, loading time, marginal bone loss

# Farklı İmplant Sistemlerinde Dental İmplantların Çevresindeki Marjinal Kemik Kaybının Retrospektif Değerlendirilmesi

## ÖZ

**Amaç:** Bu çalışmanın amacı, farklı dental implant sistemleri çevresindeki marjinal kemik kaybını değerlendirmek ve marjinal kemik kaybının hasta demografik özellikleri, dişsizlik durumu, implant konumu, yükleme zamanı ve protez tipi ile ilişkisini incelemektir.

**Gereç ve Yöntemler:** Çalışmaya, 2014-2018 yılları arasında implant cerrahisi uygulanan 51 hasta ve 187 implant dahil edildi. Marjinal kemik kaybı, implant yerleştirilmesinden hemen sonra ve cerrahiden sonraki 1-2 yıl ile 2-4 yıl aralıklarında alınan panoramik radyografiler kullanılarak ölçüldü. Hastaların demografik özellikleri, dişsizlik tipi, implant lokalizasyonu, yükleme dönemleri ve augmentasyon varlığı kaydedildi. Marjinal kemik kaybı Kruskal-Wallis testi, ikili karşılaştırmalar ve t-testleri kullanılarak analiz edildi.

**Bulgular:** 1-2 yıllık takip aralığında marjinal kemik kaybı; yaş, implant lokalizasyonu, dişsizlik durumu ve protez tipinden anlamlı düzeyde etkilendi. Kemik kaybı 70 yaş ve üzerindeki hastalarda daha fazla iken, en düşük kemik kaybı 50-59 yaş grubunda gözlendi. Maksilla ve mandibulanın molar bölgelerinde kemik kaybı en yüksek düzeyde saptanırken, anterior mandibular bölgede en düşük düzeyde saptandı. Tek diş eksikliği olan hastalarda, tam dişsiz hastalara kıyasla daha fazla marjinal kemik kaybı görüldü. Yükleme zamanı ve protez tipi de marjinal kemik kaybını etkiledi; erken yükleme ve overdenture protezler daha düşük kemik kaybı ile ilişkilendirildi. Augmentasyon işlemleri ise 2-4 yıllık takip aralığında daha fazla kemik kaybı ile ilişkili bulundu.

**Sonuçlar:** Bu bulgular; hasta yaşı, implant konumu, dişsizlik durumu ve protez tipinin implantasyon sonrası 1-2 yıllık dönemde marjinal kemik kaybını etkileyen temel faktörler olduğunu göstermektedir. Augmentasyon işlemleri ise 2-4 yıllık dönemde kemik kaybı üzerinde belirgin bir etki göstermiştir. Elde edilen sonuçlar, kemik kaybını azaltmak ve implant tedavi sonuçlarını optimize etmek için bu faktörlerin dikkate alınmasının önemini vurgulamaktadır.

***Anahtar Kelimeler:*** Dental implantlar, dişsizlik durumu, yükleme zamanı, marjinal kemik kaybı

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## Introduction

Dental implants are commonly used treatment modalities to restore lost teeth' chewing, speech, and aesthetic functions. Their increased use is attributed to several advantages over conventional dental treatments, such as high patient satisfaction and satisfactory success rates. Assessing the quality and quantity of the surrounding alveolar bone plays a critical role in evaluating implant success.

Mombelli et al.[1] stated that a successful implant should exhibit no pockets deeper than 5 mm and no bleeding upon probing. Misch's success criteria highlight the absence of pain during implant function, no mobility, less than 2 mm of bone loss after surgery, and the absence of suppuration.[2] Long-term studies indicate that marginal bone loss occurring within the first year of implant placement shows no significant progression in subsequent years.[3–5] Hence, minimizing bone loss during the initial year is critical. Historically, 1.5–2 mm of marginal bone loss within the first year of function was considered normal; however, recent implant designs and contemporary research suggest that this standard should be re-evaluated.[6]

Although there is no universally agreed-upon definition, peri-implantitis typically refers to progressive bone loss around implants. The 2017 World Workshop on Periodontal and Peri-Implant Diseases defined peri-implantitis as a pathological condition characterized by inflammation in the peri-implant mucosa and progressive loss of supporting bone around dental implants.[7] Marginal bone loss (MBL) is a multifactorial condition occurring around the cervical region of dental implants and is considered a key factor in the development of peri-implantitis. Although MBL does not always lead to peri-implantitis, peri-implantitis does not occur without preceding marginal bone loss. Thus, the presence or absence of MBL determines the staging of peri-implant lesions.[8,9]

A recent narrative review emphasized that MBL arises from a combination of various factors, such as biological aspects (like HbA1c levels, smoking status, and peri-implant soft tissue characteristics), material-related elements (including the design of the implant neck, the type of implant-abutment interface, and abutment shape), as well as technical considerations (such as the extent of cortical bone drilling, how often the abutment is removed, and the regularity of maintenance care around implants). Addressing and optimizing these parameters may help in minimizing MBL. Adjustments to these factors could reduce MBL.[10]

Despite high success rates and long-term survival in dental implant treatments, failures can still occur, often linked to patient-specific factors such as age, gender, socioeconomic status, smoking habits, bone quality, oral hygiene practices, implant maintenance, and unresolved infections.[11,12] Additionally, implant-related factors such as size, design, surface characteristics, location, loading protocols, and clinician experience significantly impact implant success.[13,14] Although research provides clinicians with well-documented guidelines regarding implant design, surface characteristics, and abutments, limited information exists concerning the demographic distribution of patients, regional distribution of implants in jaws, specific indications for implants, and usage patterns of implants of varying lengths and diameters.[15–18]

The present study aims to determine potential risk factors for marginal bone loss observed around dental implants by examining correlations with patient demographics, edentulism status, implant locations, loading periods, and prosthesis type.

## Materials and Methods

The study was approved by the Ethics Committee for Non-Interventional Scientific Research of Afyonkarahisar Health Sciences University (reference number: 2025/4). This retrospective study included patients who underwent implant surgery for partial or complete edentulism between 2014 and 2018, with radiographic follow-up of up to four years. The implants studied were from the following systems: Dentium (Dentium Co., Ltd., South Korea), BTK (Biotec S.r.l., Italy), BioHorizons (BioHorizons, Inc., USA), Implance (NTA Implant, Turkey), Biomet 3i (Zimmer Biomet Dental, USA), Implant Direct (Implant Direct Sybron International, USA), and Bioinfinity (Bioinfinity Dental Implant Systems, Germany).

Demographic data included gender and age groups, classified as 20–29, 30–39, 40–49, 50–59, 60–69, and 70+. Implant treatment indications were categorized into four groups: single-tooth loss, tooth-bounded partial edentulism, distal extension partial edentulism, and complete edentulism. Implant positions were categorized into anterior maxilla, premolar maxilla, molar maxilla, anterior mandible, premolar mandible, and molar mandible. Implants were classified by loading time as early or conventional and by restoration type as single crowns, implant-supported fixed partial dentures, and overdentures. The presence or absence of augmentation procedures during implant surgery was also recorded.

Two panoramic radiographs, taken immediately after implant placement and during follow-up appointments, were digitized using a scanner. Implant lengths were measured using Image J software. The magnification ratio was calculated by comparing the radiographic measurement with the implant size. Marginal bone levels were measured at mesial and distal points using the implant neck as a reference, and averages were calculated. The difference in marginal bone level between the two radiographs represented bone loss, which was recorded separately for 1–2 and 2–4-year intervals.

MBL data were analyzed using Jamovi statistical software (V2.3.21, The Jamovi Project, Australia). Normality of the data was assessed using the Shapiro–Wilk test. As the data were not normally distributed, marginal bone loss values were expressed as median (minimum–maximum). Intergroup comparisons were performed using the Kruskal–Wallis test, followed by the Dwass–Steel–Critchlow–Fligner post hoc test for multiple comparisons. Comparisons between the 1–2 year and 2–4 year follow-up periods were conducted using the Wilcoxon signed-rank test. A p value $< 0.05$ was considered statistically significant.

This retrospective study included all eligible implants that met the inclusion criteria; therefore, no a priori sample size calculation was performed. A total of 187 implants were analyzed, and a post hoc power analysis (G*Power 3.1.9.7) based on MBL indicated adequate statistical power (effect size $f = 0.30$, $\alpha = 0.05$, power = 0.86).

*Table 1. Marginal bone loss values (mm) according to demographic and clinical variables at 1–2 and 2–4 years*

| Variables | Subgroups | Number of implants | 1-2 year Median (min–max) | 2-4 year Median (min–max) |
|---|---|---|---|---|
| Age (years) | 20-29 | 4 | 0 (0-2.8) ab | 0.4 (0.4-2.24) a |
| | 30-39 | 6 | 1.49 (0.5-3.7) ab | 0 (0-1.91) a |
| | 40-49 | 32 | 0.82 (0-2.89) ab | 1.29 (0-2.75) a |
| | 50-59 | 57 | 0.7 (0-2.27) a | 1.45 (0-4.5) a |
| | 60-69 | 74 | 0 (0-3.39) ab | 1 (0-3.56) a |
| | 70+ | 14 | 1.71 (0-3.44) b | 1.71 (0.55-4.2) a |
| p value | | | 0.005 | 0.058 |
| Implant location | mandibular molar | 36 | 1.08 (0-2.25) ab | 1.10 (0-4.14) a |
| | maxillary molar | 41 | 1.14 (0-3.7) a | 1.47 (0-4.33) a |
| | mandibular premolar | 26 | 0.61 (0-2.89) ab | 0.97 (0-3.56) a |
| | maxillary premolar | 32 | 0.95 (0- 2.69) a | 1.08 (0-2.8) a |
| | mandibular anterior | 32 | 0 (0-1.19) b | 1.07 (0-4.5) a |
| | maxillary anterior | 20 | 0.5 (0-2.47) ab | 0.98 (0-3) a |
| p value | | | 0.002 | 0.542 |
| Edentulism status | single tooth loss | 32 | 1.5 (0-3.7) a | 1.40 (0-4.14) a |
| | distal extension partial edentulism | 53 | 0.97 (0-2.89) ab | 1.11 (0-4.33) a |
| | complete edentulism | 89 | 0 (0-3.44) b | 1.19 (0-4.50) a |
| | tooth-bounded partial edentulism | 13 | 0.54 (0-2.47) ab | 1.19 (1.1-3.37) a |
| p value | | | 0.03 | 0.953 |
| Augmentation | augmented | 40 | 0.5 (0-3.7) a | 1 (0-4.5) a |
| | non-augmented | 147 | 1 (0-3.44) b | 1.56 (0-4.33) b |
| p value | | | 0.044 | 0.009 |
| Prosthesis type | single crown | 32 | 1.49 (0-3.7) a | 1.36 (0-4.14) a |
| | fixed partial denture | 141 | 0.84 (0-3.44) a | 1.19 (0-4.33) a |
| | overdenture | 14 | 0 (0-1) b | 1.1 (0.8-4.5) a |
| p value | | | <0.001 | 0.668 |

** Values are presented as median (minimum–maximum). Intergroup comparisons were performed using the Kruskal–Wallis test. Pairwise comparisons were conducted using the Dwass–Steel–Critchlow–Fligner post hoc test. Different lowercase letters within the same column indicate statistically significant differences between subgroups (p < 0.05).*

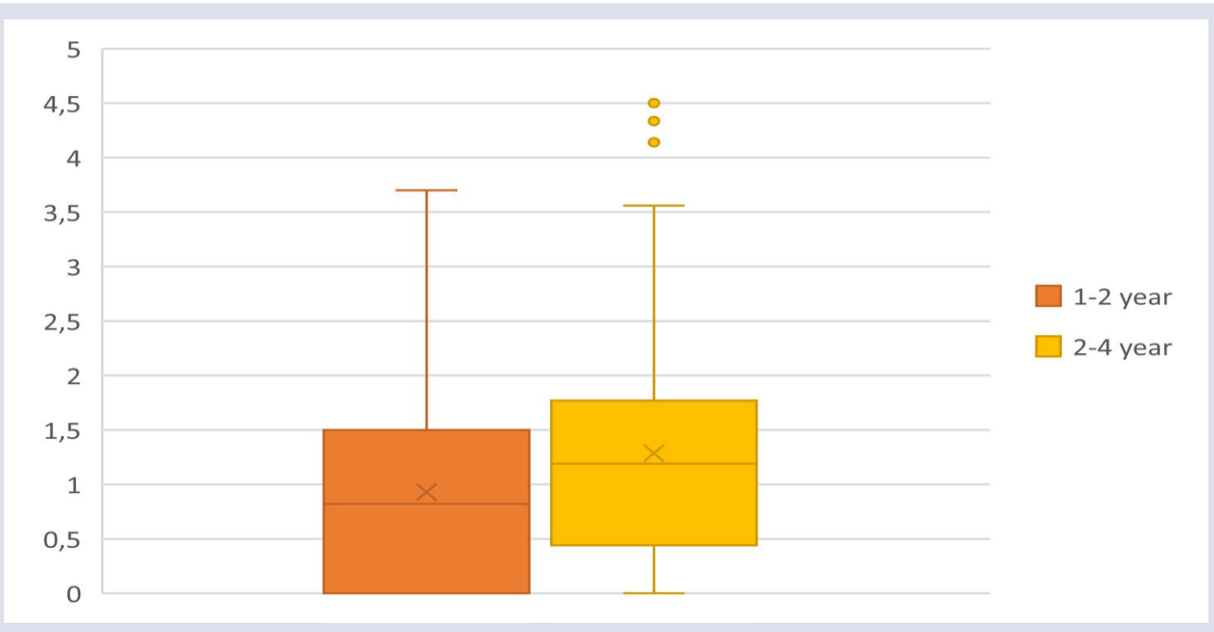



*Figure 1. Marginal bone loss (mm) at 1-2 year and 2-4 year intervals.*

## Results

The study evaluated 187 dental implants treated in 51 patients aged between 20 and 75. Of these patients, 59.6% (n = 29) were female, and 43.1% (n = 22) were male. MBL at 1–2 and 2–4 year intervals showed no significant differences based on gender (p > 0.05) (Table 1).

The mean age of patient was 51.7 years. Age distribution indicated the highest number of patients in the 60–69 years group (39.6%, n = 74), followed by the 50–59 years group (30.5%, n = 57). The most minor groups were 20–29 (2.1%, n=4) and 30–39 (3.2%, n = 6). MBL at the 1–2 year interval significantly varied by age group (p = 0.005), with less bone loss observed in the 50–59 years group [0.7 (0–2.27) mm] compared to the 70+ age group [1.71 (0–3.44) mm] (Table 1). There was no significant difference in bone loss among age groups at the 2–4-year interval (p > 0.05).

The most frequently implanted teeth were 46 and 16 (8%, n = 15), while the least commonly implanted were 31 and 41 (0.5%, n = 1). No significant difference was found between implant location and MBL at 1–2 and 2–4-year intervals (p > 0.05).

Of 187 implants, 93 were placed in the maxilla and 94 in the mandible. Molar maxilla (21.9%, n = 41) and molar mandible (19.3%, n = 36) were the most frequent implant locations, whereas anterior maxilla (10.7%, n = 20) was the least. MBL significantly differed based on implant location at the 1–2 year interval (p = 0.002). Anterior mandible implants [0 (0–1.19) mm] showed significantly less bone loss compared to molar mandible [1.08 (0–2.25) mm], premolar maxilla [0.995 (0–2.69) mm], and molar maxilla [1.14 (0–3.70) mm] (p < 0.05) (Table 1). There was no significant difference at the 2–4 year interval (p > 0.05).

Regarding edentulism status, complete edentulism had the highest number of implants (47.6%, n = 89), followed by distal extension partial edentulism (28.3%, n = 53) and single-tooth loss (17.1%, n = 32). Single-tooth loss patients had significantly more significant MBL [1.5 (0–3.7) mm] at 1–2 years compared to completely edentulous patients [0 (0–3.44) mm] (p = 0.03) (Table 1). No significant difference was observed at 2–4 years (p>0.05).

Augmentation was performed in 21.4% (n = 40) of the implants. A statistically significant difference in MBL was observed between augmented and non-augmented implants at both the 1–2 year (p = 0.044) and 2–4 year intervals (p = 0.009). At 1–2 years, non-augmented implants demonstrated higher median MBL compared to augmented implants. In contrast, at the 2–4 year interval, augmented implants exhibited significantly greater bone loss (Table 1).

Conventional loading was preferred in 91% (n = 172) of cases, and the loading protocol had no significant effect on MBL at either interval (p > 0.05).

The most common prosthesis type was implant-supported fixed partial dentures (75.4%, n=141), followed by single crowns (17.1%, n = 32) and overdentures (7.5%, n = 14). Overdentures exhibited significantly lower MBL [0 (0–1) mm] compared to single crowns [1.49 (0–3.7) mm] and fixed partial dentures [0.84 (0–3.49 mm)] at the 1–2 year interval (p < 0.001) (Table 1). No significant differences were found at the 2–4 year interval (p > 0.05).

MBL at the 2–4 year interval [1.19 (0–4.5) mm] was significantly greater than at the 1–2 year interval [0.82 (0–3.7) mm] (p < 0.001) (Figure 1).

## Discussion

Long-term success in implant treatment depends on maintenance without MBL. When evaluating the success of implants, examining the quantity and quality of the surrounding alveolar bone plays a critical role. Studies have shown that periapical and panoramic radiographs assess bone loss around implants.[12,14] Among these, periapical radiographs provide the most accurate measurements using the parallel technique. However, in this study, panoramic radiographs were preferred to evaluate the anatomical structures surrounding the implants and their relationship with adjacent teeth. Albrektsson et al.[7] stated that the success of implants can be assessed radiographically by measuring bone loss. Brägger[19] emphasized that radiographic examination of peri-implant tissues is an essential diagnostic method and that radiographs can monitor peri-implant bone changes. It has been demonstrated that radiographic evaluations play a critical role in the long-term success of implants.

In a study by Renouard et al.,[20] dental implants were followed for two years, and the mean MBL was reported as 0.44 mm, which they considered to be reliable data. In the present study, the average MBL over a 1–2-year follow-up period was higher, at 0.93 mm. This may be due to the inclusion of more implants than in the reference study. Albrektsson et al.[8] reported that MBL should not exceed 1.5 mm during the first year after loading and 0.2 mm for each subsequent year. In this context, the MBL observed during 1–2-year and 2–4-year follow-ups falls within a reliable range.

Although advanced age may be considered a factor that negatively affects implant success, it is generally not considered a contraindication. Reduced vascularization and diminished cellular regeneration in elderly individuals may impair osseointegration and lead to implant failure.[21] Aging-related conditions such as osteoporosis, diabetes, and decreased local bone quality and quantity have been identified as more significant factors influencing implant success.[22] While some studies have reported that advanced age adversely affects implant success, [21,23] numerous studies have found no significant effect of age on implant outcomes.[24–28] Differences in MBL between older and younger patients and reduced bone and soft tissue healing capacity with age have also been reported.[29] Brocard et al.[23] noted high implant survival rates (88.6%) in middle-aged patients (40–60 years) but lower rates (78.1%) in patients over 60 years of age. In the present study, the MBL over a 1–2-year period was lower in the 50–59 age group than those aged 70 and above. This may be attributed to reduced oral hygiene habits and systemic conditions impairing the healing capacity of older people. However, no statistically significant

differences were observed between age groups during the 2–4-year follow-up.

While some studies suggest that female patients experienced more implant failures than men, indicating that gender may be a risk factor, [30–32] others have reported higher failure rates in men.[33–35] Strietzel et al.[30] found statistically significantly higher failure rates in females. Nevertheless, studies by Fatrash et al.,[36] Andersson et al.,[37] and Schwartz et al.[34] found that gender did not significantly affect MBL. Similarly, our study found no statistically significant differences in MBL between genders during either the 1–2-year or 2–4-year follow-up periods.

Negri et al.[38] reported that implants placed in the maxillary molar region failed in 13% of cases, compared to 6% in the mandible. Findings indicating lower MBL and higher survival rates in the mandible have been corroborated by other studies. [39,40] Some studies have also compared implants placed in anterior and posterior regions. For example, Boronat et al. [41] found that implants in the posterior areas showed more significant MBL than those in the anterior regions. Conversely, other studies reported no significant differences in MBL between maxillary and mandibular implants.[42,43] In a study involving 1,183 implants, Kumar et al.[44] also found no significant difference between the two jaws. Tamizi et al.[45] reported comparable MBL in the maxilla and mandible. However, a few studies have indicated lower success rates for mandibular implants than those in the maxilla.[46-48] The present study observed statistically significant differences in MBL across different regions during the 1–2-year follow-up period. MBL was lower in the anterior mandible than in the mandibular molar, maxillary premolar, and maxillary molar regions. These findings are consistent with previous research showing reduced bone loss in properly placed implants in the anterior mandible.

In treating complete and partial edentulism, ensuring passive fit between implants and prostheses is crucial to minimize biomechanical complications.[49,50] In poor adaptation, some areas may be overloaded while others receive insufficient force. Passive occlusion is generally easier to achieve with single crowns than splinted ones. Therefore, some researchers suggest that single crowns may lead to less MBL.[51,52] de Souza et al.[53] reported more significant MBL in partial crown bridges (1.83 mm) and full-arch monolithic bridges (more than 2 mm) compared to single crowns over follow-up periods longer than four years. In a 10-year follow-up study, it was compared splinted and single crowns with three consecutive implants in the posterior maxilla. It was found that an average MBL of 1.2 mm in splinted crowns and 1.3 mm in single crowns.[54] In a meta-analysis by Firme et al., [55] mean MBL was 0.9 mm in splinted crowns and full-arch bridges and 0.58 mm in single crowns; however, this difference was not statistically significant. Similarly, the present study found no significant difference in MBL between single crowns and implant-supported fixed partial dentures. However, overdenture prostheses caused less MBL than single crowns or bridges. This could be due to easier hygiene maintenance and plaque control, as overdentures are removable and do not require interproximal cleaning.

In the present study, augmentation procedures significantly influenced marginal bone loss at both the 1–2-year and 2–4-year follow-up intervals. Interestingly, non-augmented implants exhibited greater bone loss during the first 1–2 years, whereas augmented implants demonstrated significantly higher bone loss in the 2–4-year period. This temporal variation may reflect differences in early remodeling dynamics between native bone and grafted sites. In a retrospective study comparing implants placed in maxillary sinus augmented areas versus native bone over a three-year functional loading period, higher marginal bone loss was observed in the augmented sites, with most of the bone loss occurring within the first 12 months.[56] However, variations in augmentation type, graft material, anatomical location, and healing capacity may explain discrepancies between studies. These findings suggest that augmentation procedures may influence marginal bone stability over time and should be carefully considered during treatment planning.

In line with previous systematic reviews, a meta-analysis comparing immediate and conventional loading protocols found no statistically significant differences in MBL between the two approaches.[57-59] Similarly, the present study showed no significant relationship between loading time and MBL. This finding suggests that different loading protocols perform similarly after successful osseointegration.

## Conclusions

Although dental implants are widely used and reliable treatments for managing complete and partially edentulous patients, MBL remains a common complication that can lead to implant failure. Based on the data obtained from our study, age, implant location, edentulism status, prosthesis type, and augmentation procedures were found to influence marginal bone loss during the 1–2-year follow-up period. During the 2–4-year period, augmentation remained a significant factor associated with marginal bone loss, while other variables did not demonstrate statistically significant effects. The MBL observed in the 2–4-year follow-up was more significant than in the 1–2-year period. Further controlled clinical, experimental, and retrospective studies with larger sample sizes and extended follow-up periods are recommended to understand the mechanisms behind MBL better and develop effective treatment strategies.

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## Conflicts of Interest Statement

The authors declare no conflict of interest.

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