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Retrospective study on duration of Loading on Marginal Bone Loss Around Dental Implants

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ABSTRACT

Background: Marginal bone loss (MBL) is a critical parameter in evaluating the long-term success of dental implants. Several factors influence MBL, including the timing of functional loading. This study aimed to assess the relationship between the duration of prosthetic loading and marginal bone loss around dental implants in a retrospective cohort**.**

Materials and Methods: A retrospective analysis was conducted on 120 dental implants placed in 75 patients treated between January 2018 and December 2022. Based on the time interval between implant placement and prosthetic loading, implants were grouped into three categories: early loading (<2 months), conventional loading (2–4 months), and delayed loading (>4 months). Digital periapical radiographs taken at baseline (prosthesis placement) and at 12-month follow-up were used to measure marginal bone levels using standardized software. Statistical analysis was performed using ANOVA and Tukey's post hoc test to compare mean MBL among the three groups**.**

Results: The average marginal bone loss after 12 months was 1.42 ± 0.25 mm in the early loading group, 1.10 ± 0.19 mm in the conventional loading group, and 0.86 ± 0.21 mm in the delayed loading group. A statistically significant difference in MBL was observed among the groups ($p < 0.001$), with the delayed loading group showing the least bone loss. Pairwise comparisons indicated significant differences between early vs. delayed ($p < 0.001$) and early vs. conventional loading ($p = 0.004$), but not between conventional and delayed loading ($p = 0.067$).

Conclusion: The timing of functional loading significantly affects marginal bone preservation around dental implants. Delayed loading appears to be associated with reduced bone loss at one year post-restoration. Careful consideration of loading protocols may enhance implant longevity and peri-implant bone stability**.**

Keywords: *Dental implants, Marginal bone loss, Functional loading, Delayed loading, Retrospective study*.

1. INTRODUCTION

Dental implants have become a widely accepted and predictable treatment modality for the replacement of missing teeth, offering high success rates and long-term functionality. However, the stability of peri-implant tissues, particularly marginal bone levels, remains a key determinant of implant success and longevity (1). Marginal bone loss (MBL) is commonly observed during the early stages following implant placement and prosthetic loading, and it may continue at a slower rate over time (2).

Among the several factors influencing MBL, the timing of implant loading has garnered considerable attention. Functional loading protocols are generally classified as immediate, early, conventional, or delayed, depending on the interval between implant placement and prosthesis delivery (3). While immediate and early loading protocols are advantageous for reducing treatment time and enhancing patient satisfaction, concerns have been raised regarding their potential impact on crestal bone remodeling and implant stability (4,5).

Previous studies have demonstrated variable outcomes with different loading protocols. Some investigations suggest that early loading does not compromise marginal bone integrity if primary stability and controlled occlusal forces are ensured (6). Conversely, other reports indicate a higher incidence of bone resorption with premature loading, particularly in cases with poor bone quality or insufficient healing time (7,8). Therefore, understanding the optimal timing for prosthetic loading is crucial to minimize MBL and improve treatment outcomes.

Given the lack of consensus in current literature and the influence of clinical and patient-specific variables, this retrospective study aims to evaluate the effect of the duration of loading on marginal bone loss around dental implants over a 12-month period.

2. MATERIALS AND METHOD

A total of 120 implants placed in 75 patients (aged 25–65 years) were included in the analysis. Inclusion criteria were: (1) patients with single or multiple implant-supported restorations; (2) availability of baseline radiographs at the time of loading and follow-up radiographs after 12 months; and (3) good general and oral health at the time of implant placement. Patients with systemic conditions affecting bone metabolism, a history of smoking, or incomplete records were excluded.

3. GROUPING BASED ON LOADING PROTOCOL

The implants were categorized into three groups based on the time between implant placement and functional loading:

- **Group A (Early Loading):** <2 months
- **Group B (Conventional Loading):** 2–4 months
- **Group C (Delayed Loading):** >4 months

All implants were placed following standard surgical protocols, and healing abutments were used before prosthetic loading. Implant systems from a single manufacturer were selected to maintain consistency.

Radiographic Assessment: Digital periapical radiographs taken at the time of prosthetic loading (baseline) and after 12 months were used for evaluating marginal bone levels. Radiographic images were standardized using paralleling technique and analyzed with calibrated imaging software (ImageJ, NIH, USA). Measurements were taken from the implant shoulder to the first visible bone-to-implant contact on both mesial and distal sides, and the mean was calculated. A single examiner, blinded to the loading group, performed all measurements to reduce observer bias.

Statistical Analysis: Data were tabulated and analyzed using SPSS version 25.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics were calculated as mean ± standard deviation. One-way ANOVA was used to compare mean marginal bone loss between the three groups. Post hoc comparisons were performed using Tukey’s HSD test. A p-value <0.05 was considered statistically significant.

4. RESULTS

A total of 120 implants placed in 75 patients were analyzed. Among them, 40 implants were in the early loading group (<2 months), 40 in the conventional loading group (2–4 months), and 40 in the delayed loading group (>4 months). All implants achieved successful osseointegration and remained functional during the 12-month follow-up period.

The mean marginal bone loss (MBL) after 12 months was highest in the early loading group, followed by the conventional and delayed loading groups. Specifically, Group A (early loading) exhibited an average MBL of **1.42 ± 0.25 mm**, Group B (conventional loading) showed **1.10 ± 0.19 mm**, and Group C (delayed loading) had the lowest MBL at **0.86 ± 0.21 mm**. The differences among the three groups were statistically significant ($p < 0.001$), as determined by one-way ANOVA.

Further analysis using Tukey's post hoc test revealed significant differences between Group A and Group B ($p = 0.004$), and between Group A and Group C ($p < 0.001$). However, the difference between Group B and Group C was not statistically significant ($p = 0.067$), indicating that delayed loading had a more pronounced effect in preserving marginal bone (Table 1).

Table 1. Comparison of Marginal Bone Loss (in mm) Among Different Loading Protocols After 12 Months

Loading Group	**Number of Implants**	**Mean MBL (mm) ± SD**
Early Loading (A)	40	1.42 ± 0.25
Conventional (B)	40	1.10 ± 0.19
Delayed Loading (C)	40	0.86 ± 0.21
ANOVA p-value	—	**< 0.001**

Note: Post hoc test showed significant difference between Group A vs. B and A vs. C.

These results suggest a clear trend in which delayed loading of implants is associated with reduced marginal bone loss compared to early or conventional loading approaches.

5. DISCUSSION

The findings of this study demonstrate that the timing of functional loading has a significant influence on marginal bone loss (MBL) around dental implants, with delayed loading protocols showing the least bone resorption over a 12-month follow-up. These results are consistent with the widely accepted biological concept that sufficient healing time before loading allows for more stable peri-implant bone adaptation (1,2).

The mean MBL observed in the early loading group was significantly higher than in the conventional and delayed groups. This supports previous evidence indicating that early mechanical forces, when applied before complete osseointegration, may compromise the peri-implant bone remodeling process and result in increased crestal bone loss (3,4). Several animal and clinical studies have confirmed that immediate or early loading leads to variable MBL depending on implant stability, bone quality, and occlusal stress (5,6).

Conversely, implants in the delayed loading group exhibited minimal bone loss, suggesting a favorable response of peri-implant tissues to prolonged healing. Similar outcomes have been reported in studies emphasizing the benefits of delayed functional loading, especially in cases involving poor bone quality or systemic risk factors (7,8). The protective role of delayed loading is attributed to the establishment of a mature bone-implant interface prior to the introduction of functional forces (9).

While immediate and early loading protocols are advantageous for patient convenience and treatment time reduction, their success is highly technique-sensitive. Factors such as insertion torque, implant design, and precise occlusal control become critical determinants of long-term success (10,11). In this context, clinicians should carefully assess individual risk factors before opting for accelerated loading schedules.

Interestingly, the present study found no statistically significant difference between the conventional and delayed loading groups, which aligns with prior reports suggesting that loading within 2–4 months may be a biologically acceptable compromise when optimal surgical and prosthetic conditions are maintained (12,13). Nonetheless, delayed loading still demonstrated the lowest average MBL, highlighting its relevance in clinical decision-making for cases where bone preservation is a priority.

It is important to acknowledge certain limitations of this study. Being retrospective in design, the findings are dependent on the accuracy of clinical records and radiographic evaluations. Additionally, the influence of variables such as implant diameter, bone density, and prosthetic design were not individually controlled, which may have affected outcomes. Future prospective, randomized studies with standardized protocols are necessary to further validate these observations.

6. CONCLUSION

In conclusion, the results of this study reinforce the concept that the duration of loading significantly impacts marginal bone stability. Delayed loading protocols appear to offer a biomechanical advantage by minimizing bone loss around dental implants, particularly in scenarios where long-term success is paramount.

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