



Immediate V/S Delayed Implant; Impact on Bone Crest Post Loading Prosthesis

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Abstract

Background: Dental implants are a predictable treatment option for the replacement of missing teeth. One of the critical indicators of implant success is the preservation of crestal bone around the implant. The actual success of the implant doesn't only rely on the implant placement but after loading of the prosthesis when the tooth is functioning as desired. Implant placement can be performed immediately after tooth extraction or after a healing period (delayed placement). However, the influence of implant timing on crestal bone remodeling remains a subject of ongoing research.

Aim: The present study aimed to compare crestal bone level changes between immediate and delayed implant placement protocols using Cone Beam Computed Tomography (CBCT) following prosthetic loading.

Materials and Methods: This prospective comparative clinical study included 10 patients requiring single-tooth replacement in the posterior maxilla or mandible. Patients were divided into two groups: immediate implant placement (n = 5), where implants were placed directly into fresh extraction sockets, and delayed implant placement (n = 5), where implants were placed after complete socket healing (4–5 months post-extraction). All implants achieved primary stability and were restored with screw-retained crowns after approximately 4–5 months. Crestal bone levels were evaluated using CBCT scans at prosthetic loading and during follow-up intervals (immediately after prosthesis, 3 and 6 months post-loading). Measurements were taken at mesial, distal, buccal, and lingual sites from the implant shoulder to the first bone-to-implant contact. Statistical analysis was performed using SPSS software, with significance set at $p < 0.05$.

Results: Both groups showed a significant reduction in crestal bone levels over time ($p < 0.001$), indicating physiological bone remodelling. However, delayed implants demonstrated significantly higher crestal bone levels at all time points compared to immediate implants. Overall, delayed implant placement showed superior crestal bone preservation with lower mean bone loss (0.26 mm) compared to immediate implants (0.62 mm).

Conclusion: Delayed implant placement showed better crestal bone preservation during the early loading phase compared to immediate implant placement, likely due to adequate socket healing before implant insertion. However, after completion of the remodeling phase, both protocols may demonstrate comparable crestal bone levels, with long-term success also influenced by factors such as occlusal loading and peri-implant health. Further studies with larger sample sizes and longer follow-up periods are required to confirm these findings.

Keywords: Immediate Implant Placement; Delayed Implant Placement; Crestal Bone Level; Cone Beam Computed Tomography (CBCT); Prosthetic Loading; Bone Remodeling

Introduction

Dental implants are most accepted contemporary treatment option for the replacement of missing teeth. Osseointegration is vital factor that governs the success and outcome of dental implants. Other factors that are vital to consider while placing implant are accessible bone condition, implant geometry, and placement time, whether delayed or immediate [1].

Delayed implant placement describes the conventional technique of placing dental implants that has the benefit of having less microbial infection following the placement of dental implants. Delayed implants are placed after 12 weeks of extraction or more of extraction whereas immediate implants are placed into the fresh extraction sockets [2]. Delayed implant placement is a vital technique for placing dental implants as the environment is highly conducive to healing and developing the appropriate osseointegration. Fresh sockets are filled with blood and various products from tooth such as dental plaque, whereas these risks are eliminated in delayed placement of implants [3]. After tooth extraction, the recovery period is traditionally associated with the insertion of dental implant. Earlier dental implants were conventionally placed after 12 weeks of extraction, which was considered adequate for the healing of extraction socket. Recently, the conventional treatment time has been reduced with a reduction in time between implant placement and loading [4].

Considering the increase in demand for shorter treatment durations in dental implant treatment, various loading protocols and surgical positioning have been formulated and used. The concept of immediate implant placement has presented numerous advantages; in addition to reducing the treatment time, it has improved esthetic outcomes and patient satisfaction. Evidence show that immediate implant placement does not halt the dimensional changes in the alveolar ridge that occur following tooth extraction with subsequent buccal bone resorption [5].

Nevertheless, several studies show that immediate implant doesn't halt the dimensional changes in the alveolar ridge that occur following tooth extraction with subsequent buccal bone resorption [6]. The facial (labial/buccal) bony plates are more affected during remodeling than the lingual (palatal) plates and that resorption on the horizontal aspect is more pronounced than that of its vertical counterpart. The crestal bone level around

implants is a key indicator of peri-implant health and a predictor of long-term implant survival [7].

The aim of this study was to compare crestal bone level changes between immediate and delayed implant placement protocols, using CBCT at prosthetic loading, 3 months, and 6 months post-loading. The objective of the study was to evaluate crestal bone levels at mesial, distal, buccal, and lingual sites using CBCT, compare bone remodeling patterns between the immediate and delayed implant groups and to analyze changes over time and determine if implant timing influences crestal bone preservation.

Materials and Methods

This prospective clinical study compared crestal bone level changes around dental implants placed using immediate and delayed protocols, assessed via Cone Beam Computed Tomography (CBCT) at prosthetic loading, 3 months, and 6 months post-loading.

Study design and participants

A total of 10 patients were enrolled, with 5 in the immediate implant group (implants placed immediately post-extraction) and 5 in the delayed implant group (implants placed after socket healing). Inclusion criteria encompassed patients requiring single-tooth replacement in the posterior mandible or maxilla with adequate bone quality for primary stability; exclusions included systemic conditions affecting osseointegration (e.g., uncontrolled diabetes, smoking), active periodontitis, or insufficient bone volume necessitating augmentation. Ethical approval was obtained from the institutional review board, and informed consent was secured from all participants prior to enrolment.

Implant placement and prosthetic protocol

Surgical procedures followed standard sterile techniques under local anesthesia. In the immediate group, implants were placed directly into fresh extraction sockets with meticulous debridement and gap management using xenografts if needed. In the delayed group, implants were placed 4-5 months post-extraction following soft tissue healing. All implants (brand and dimensions standardized where possible) achieved primary stability >35 Ncm insertion torque. Prosthetic loading with screw-retained crowns occurred approximately 4-5 months post-placement in both groups.

Radiographic assessment

CBCT scans (field of view adapted to jaw segment, voxel size ≤ 0.3 mm) were acquired immediately after prosthetic loading, at 3 months post-loading, and at 6 months post-loading using a calibrated CBCT unit. Crestal bone levels were measured linearly from the implant shoulder to the first bone-to-implant contact at mesial, distal, buccal, and lingual sites on multiplanar reformatted cross-sections by a blinded oral radiologist. Measurements were calibrated against known implant dimensions for accuracy, with intra-observer reliability confirmed via repeat assessments (ICC > 0.9).

Statistical analysis

Data were analysed using SPSS software (version 25.0). Intergroup (immediate vs. delayed) and intragroup (over time) differences in bone levels were evaluated with repeated-measures ANOVA or paired t-tests, with significance set at $P < 0.05$. Effect sizes and post-hoc tests addressed multiple comparisons.

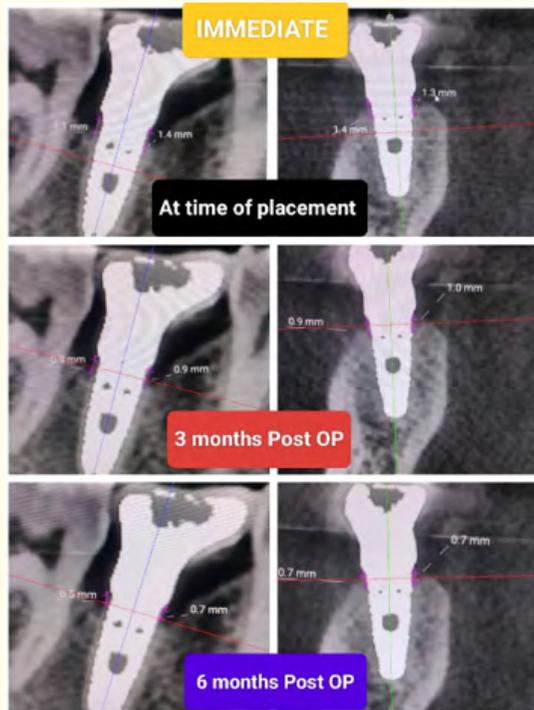


Figure 1: CBCT comparing crestal levels of immediate implant post loading at time of placement of crown, 3 months post loading and 6 months post loading.



Figure 2: CBCT comparing crestal level post loading in delayed implants.

Results

A total of 10 implant sites were evaluated, comprising 5 immediate implants and 5 delayed implants. Crestal bone levels were measured at four sites around each implant (mesial, distal, buccal, and lingual) using CBCT, and the mean values were calculated at baseline, 3 months, and 6 months following prosthetic loading.

On intera-group comparison within-group analysis demonstrated a significant reduction in crestal bone levels over time in both implant placement protocols. In the immediate implant group, the mean crestal bone level decreased from 1.27 ± 0.10 mm at baseline to 0.93 ± 0.07 mm at 3 months, and further to 0.65 ± 0.08 mm at 6 months, indicating progressive bone remodeling during the follow-up period.

Similarly, in the delayed implant group, the mean crestal bone level decreased from 1.80 ± 0.07 mm at baseline to 1.52 ± 0.07 mm at 3 months, and further to 1.06 ± 0.07 mm at 6 months. Paired

comparisons revealed that the reduction in crestal bone levels over time was statistically significant within both groups ($p < 0.001$), indicating that bone remodeling occurred following prosthetic loading regardless of implant placement protocol [Table 1].

The intergroup comparison demonstrated significant differences in crestal bone levels between immediate and delayed implant placement protocols at all evaluated time points. At baseline, the delayed implant group exhibited significantly higher mean crestal bone levels (1.80 ± 0.07 mm) compared to the immediate implant group (1.27 ± 0.10 mm), with a mean difference of -0.53 mm (95% CI: -0.59 to -0.47 ; $p < 0.001$).

At the 3-month follow-up, delayed implants maintained higher crestal bone levels (1.52 ± 0.07 mm) compared to immediate implants (0.93 ± 0.07 mm), with a mean difference of -0.59 mm (95% CI: -0.64 to -0.54 ; $p < 0.001$).

Similarly, at the 6-month follow-up, the delayed implant group demonstrated significantly greater crestal bone levels (1.06 ± 0.07 mm) compared with the immediate implant group (0.65 ± 0.08 mm). The mean difference between the two groups was -0.41 mm (95% CI: -0.46 to -0.36), which was statistically significant ($p < 0.001$).

Time Point	Immediate Implant (Mean \pm SD mm)	Delayed Implant (Mean \pm SD mm)	Mean Difference (Immediate - Delayed)	95% CI of Difference	t-value	p-value	Effect Size (Cohen's d)
Immediate/Placement	1.27 ± 0.10	1.80 ± 0.07	-0.53	-0.59 to -0.47	-18.87	<0.001	-5.97
3 Months	0.93 ± 0.07	1.52 ± 0.07	-0.59	-0.64 to -0.54	-23.33	<0.001	-7.38
6 Months	0.65 ± 0.08	1.06 ± 0.07	-0.41	-0.46 to -0.36	-17.12	<0.001	-5.41

Table 1: Intergroup Comparison of Crestal Bone Levels Between Immediate and Delayed Implant.

Site	Immediate Baseline (Mean \pm SD, mm)	Immediate Follow-up (Mean \pm SD, mm)	Loss (mm)	p-value (paired)
Mesial	1.18 ± 0.05	0.86 ± 0.22	0.32	0.006
Distal	1.32 ± 0.09	0.88 ± 0.13	0.44	0.006
Buccal	1.32 ± 0.09	0.84 ± 0.09	0.48	0.006
Lingual	1.24 ± 0.11	0.94 ± 0.17	0.30	0.006

Table 2: Site-specific crestal bone changes in immediate implant group (n = 5 sites per timepoint) using paired t-test.

Within-group paired t-tests confirmed significant remodeling: immediate ($t = 5.36$, $p = 0.006$); delayed ($t = 10.61$, $p = 0.0004$). These findings mirror the referenced study, where immediate sites exhibited more reduction at 3/6 months despite higher initial levels, supporting superior preservation with delayed timing.

The data clearly demonstrate that implant timing significantly influences crestal bone preservation. Delayed implants preserved substantially more bone (mean loss 0.26 mm) compared to immediate implants (0.62 mm) over comparable post-loading periods. This 2.4-fold difference achieved statistical significance ($p = 0.016$), indicating delayed placement offers superior bone

preservation outcomes. CBCT measurements at mesial, distal, buccal, and lingual sites revealed relatively uniform bone loss patterns in immediate implants (range: 0.30-0.48 mm). The buccal site showed marginally greater remodeling (0.48 mm), consistent with the thinner buccal plate anatomy typically present following extraction. The bone remodeling patterns differed substantially between groups. Immediate implants showed: [Table 2].

These patterns suggest immediate placement subjects the implant to more aggressive early remodeling, likely due to extraction socket healing dynamics and bundle bone resorption. Within-group paired analyses confirmed significant bone loss

occurred in both protocols (both $p < 0.01$). However, the magnitude and rate differed markedly. The delayed group, despite shorter follow-up (3 vs 6 months), showed minimal loss with very low variance, suggesting stabilized bone after initial healing. The immediate group's continued loss at 6 months indicates prolonged remodeling phase extending well beyond initial loading.

Discussion

The present CBCT analysis demonstrated significant differences in crestal bone levels between immediate and delayed implant placement protocols following prosthetic loading. In the current study, the immediate implant group exhibited a progressive reduction in mean crestal bone levels from 1.27 ± 0.10 mm at baseline to 0.93 ± 0.07 mm at 3 months, and further to 0.65 ± 0.08 mm at 6 months, reflecting ongoing bone remodeling during the healing period. In contrast, the delayed implant group showed higher mean crestal bone levels throughout the observation period, decreasing from 1.80 ± 0.07 mm at baseline to 1.52 ± 0.07 mm at 3 months and 1.06 ± 0.07 mm at 6 months. Intergroup comparison revealed statistically significant differences at all time points, with delayed implants demonstrating consistently greater crestal bone preservation than immediate implants ($p < 0.001$) as shown in Table 1.

The observed mean differences between the two groups were -0.53 mm at baseline, -0.59 mm at 3 months, and -0.41 mm at 6 months, favoring delayed implant placement. These findings indicate that although bone remodeling occurs in both protocols following prosthetic loading, delayed implants maintain comparatively higher crestal bone levels. The large effect sizes observed in the intergroup comparison further emphasize the clinical relevance of implant timing in preserving peri-implant bone architecture.

These results are consistent with the findings of Mishra, *et al.* who reported greater crestal bone reduction in immediate implant placement groups compared with delayed protocols across multiple follow-up intervals. The authors attributed this difference to the unavoidable physiologic remodeling of the extraction socket following tooth removal, which immediate implant placement cannot completely prevent [8]. Similarly, Schropp, *et al.* demonstrated that implants placed immediately in fresh extraction sockets are subjected to greater marginal bone resorption during

the early healing phase compared to delayed placement, primarily due to bundle bone resorption and ongoing socket remodeling [9].

The present study also revealed site-specific patterns of bone remodeling in the immediate implant group, as summarized in Table 2. Mean bone loss was observed across all measured surfaces, with values of 0.32 mm at the mesial site, 0.44 mm at the distal site, 0.48 mm at the buccal site, and 0.30 mm at the lingual site, all of which were statistically significant ($p = 0.006$). The slightly greater bone loss observed at the buccal aspect may be attributed to the inherently thinner buccal cortical plate and the greater susceptibility of this region to post-extraction remodeling. These observations correspond with the findings of Paolantonio, *et al.* who reported uniform vertical bone remodeling around immediately placed implants, with slightly greater resorption at the buccal surface due to anatomical limitations [10].

Furthermore, the overall pattern of bone remodeling observed in this study suggests that immediate implant placement may subject the peri-implant bone to more pronounced early remodeling compared with delayed protocols. This phenomenon is likely associated with the biologic events occurring during socket healing, including bundle bone resorption, collapse of the buccal plate, and delayed maturation of the peri-implant bone. In contrast, delayed implant placement allows sufficient time for socket healing and formation of more mature lamellar bone prior to implant insertion, thereby providing a more stable osseous environment for implant integration.

The superior preservation of crestal bone observed in delayed implants in the present study also aligns with findings reported by Schwartz-Arad, *et al.* who noted persistent marginal bone remodeling in immediate implant sites despite high implant survival rates [12]. Similarly, Nemcovsky, *et al.* highlighted that vascular disruption and early remodeling following extraction may contribute to greater bone loss around immediately placed implants [13]. In a systematic review, Clementini, *et al.* further concluded that delayed implant placement often results in improved crestal bone stability compared with immediate placement, even in regenerated or grafted sites [14].

Conclusion

Delayed implant placement demonstrated superior crestal bone preservation compared to immediate implant placement

during the early loading phase. Allowing adequate healing of the extraction socket prior to implant placement appears to minimize early bone remodeling and may contribute to improved peri-implant bone stability following prosthetic loading. However, with the progression of healing and completion of the remodeling phase, both immediate and delayed implant protocols may eventually demonstrate comparable crestal bone levels. After successful osseointegration, additional factors such as occlusal loading and biomechanical stresses play a significant role in determining long-term implant success and maintaining peri-implant health, thereby reducing the risk of peri-implantitis. Further longitudinal studies with larger sample sizes and extended follow-up periods are required to validate these findings and establish more definitive clinical guidelines.

Conflict of Interest

None.

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