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CBCT-Based Comparative Evaluation of Immediate and Delayed Implant Loading Protocols

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ABSTRACT

Traditionally, dental implants are placed several months following tooth extraction. Immediate implants, however, are inserted on the same day as extraction, preserving the crestal bone. Immediate loading allows for prosthetic reconstruction within forty eight hours of implant placement. This study aimed to evaluate peri-implant bone changes, implant stability, and soft-tissue outcomes in both immediately and delayed placed implants that were immediately loaded. 14 patients participated, with seven in Group A (delayed placement) and seven in Group B (immediate placement). Clinical assessments, including plaque index, bleeding on probing, and probing depth, were recorded at baseline, three months, and six months. Implant stability was measured using a resonance frequency analyzer (implant stability quotient), and crestal bone levels were assessed radiographically with cone-beam computed tomography preoperatively and at 6 months postoperatively. No statistically significant differences (P>0.05) were observed between the groups for clinical parameters or radiological outcomes at baseline, three months, and six months. However, implant stability quotient and crestal bone loss showed significant differences between the groups at baseline and six months, with Group A exhibiting higher stability and less crestal bone loss than Group B. Delayed implants with immediate loading demonstrated better outcomes than immediate implants with immediate loading.

Keywords: Delayed implants, Immediate implants, Implant stability quotient, Immediate loading

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Introduction

Tooth loss represents a major challenge to oral health, affecting both function and aesthetics. Dental implants have become a modern solution for rehabilitating partially or fully edentulous areas, with variations in timing of placement and loading. In 1952, Branemark coined the concept of osseointegration by successfully placing titanium implants into bone, recommending a 6–8 month healing period, which resulted in lengthy overall treatment times.

Following tooth extraction, the alveolar bone naturally resorbs, a phenomenon confirmed by numerous animal and human studies [1]. Immediate implant placement was developed to address this limitation. Schulte and Heimke first described placing implants immediately after extraction in 1976. Immediate placement provides advantages such as combining extraction and implantation in a single procedure, reducing surgical interventions, preserving crestal bone and alveolar height, minimizing bone resorption, and improving soft-tissue appearance [2].

The timing of implant loading is another determinant of success. Traditionally, implants are loaded after 6–8 months in the maxilla and 3–4 months in the mandible [3]. Recent protocols have shortened this interval, introducing immediate loading (within 1 week), early loading (1 week to 2 months), and conventional loading (after 2 months) [4].

Healthy peri-implant tissues are essential for long-term stability. Subgingival plaque accumulation fosters pathogenic bacteria, delaying soft-tissue healing and promoting bone loss. Persistent plaque can cause bleeding on probing, deeper peri-implant pockets, peri-implantitis, and eventual implant failure. Crestal bone loss can also result from localized inflammation or mechanical stress at the implant neck, increasing the risk of failure. Immediate loading introduces additional mechanical stress during healing, which may impede osseointegration.

Implant stability is a critical factor for successful integration and is assessed in two stages: primary stability at insertion, provided by mechanical engagement with the surrounding bone, and secondary stability, which develops as bone and soft tissues remodel around the implant.

This study aimed to compare clinical and radiographic outcomes of immediate versus delayed implant placement under immediate loading, evaluating peri-implant soft-tissue health (plaque index, bleeding on probing, probing depth), implant stability (implant stability quotient), and crestal bone levels using cone-beam computed tomography (CBCT).

Materials and Methods

The study was approved by the institutional ethics committee of a public teaching hospital and conducted in compliance with the Helsinki Declaration (1975, revised 2000). Fourteen patients were enrolled and randomly assigned into two groups of seven each: Group A (delayed implant placement) and Group B (immediate implant placement). Sample size calculations using G*Power 3.1.9.4, assuming an effect size of 1.7, $\alpha = 0.05$, and power of 0.80, indicated that 14 participants were sufficient to detect a meaningful clinical difference.

Eligible participants were systemically and periodontally healthy individuals aged 18–60 years, with single-unit edentulous spaces. Immediate implants were indicated for teeth with vertical root fractures, failed endodontic treatment, or nonrestorable caries, with at least 4 mm of apical bone. Exclusion criteria included systemic diseases (e.g., diabetes, pregnancy), active periodontal pathology (e.g., periodontitis, interproximal bone loss, narrow ridges, absent buccal wall, periapical lesions), and smoking.

Clinical parameters—plaque index, bleeding on probing, and probing depth—were recorded at baseline, 3 months, and 6 months. Implant stability was assessed via resonance frequency analysis (implant stability quotient), and CBCT was used to measure crestal bone levels at baseline and 6 months. To ensure reproducible measurements, a custom acrylic stent with two gutta-percha markers (mesial and distal to the implant site) was fabricated, and bone heights were measured from the marker base to the alveolar crest. Changes in these distances represented bone level alterations.

Patients provided written informed consent and received preoperative antibiotics (amoxicillin 500 mg, thrice daily starting one day before surgery) and analgesics (ibuprofen 400 mg, one hour prior to surgery).

For delayed implants (Group A), under local anesthesia, a mucoperiosteal flap was reflected and the osteotomy site marked using a round bur and surgical guide. Sequential drilling was performed, and the implant was placed with a 2–3 mm distance from adjacent teeth and positioned 1 mm subcrestally. A smart peg was attached to record implant stability via resonance frequency analysis (**Figure 1**, Group A). The flap was sutured with 4-0 silk, and a temporary restoration was fabricated and delivered within 48 hours.

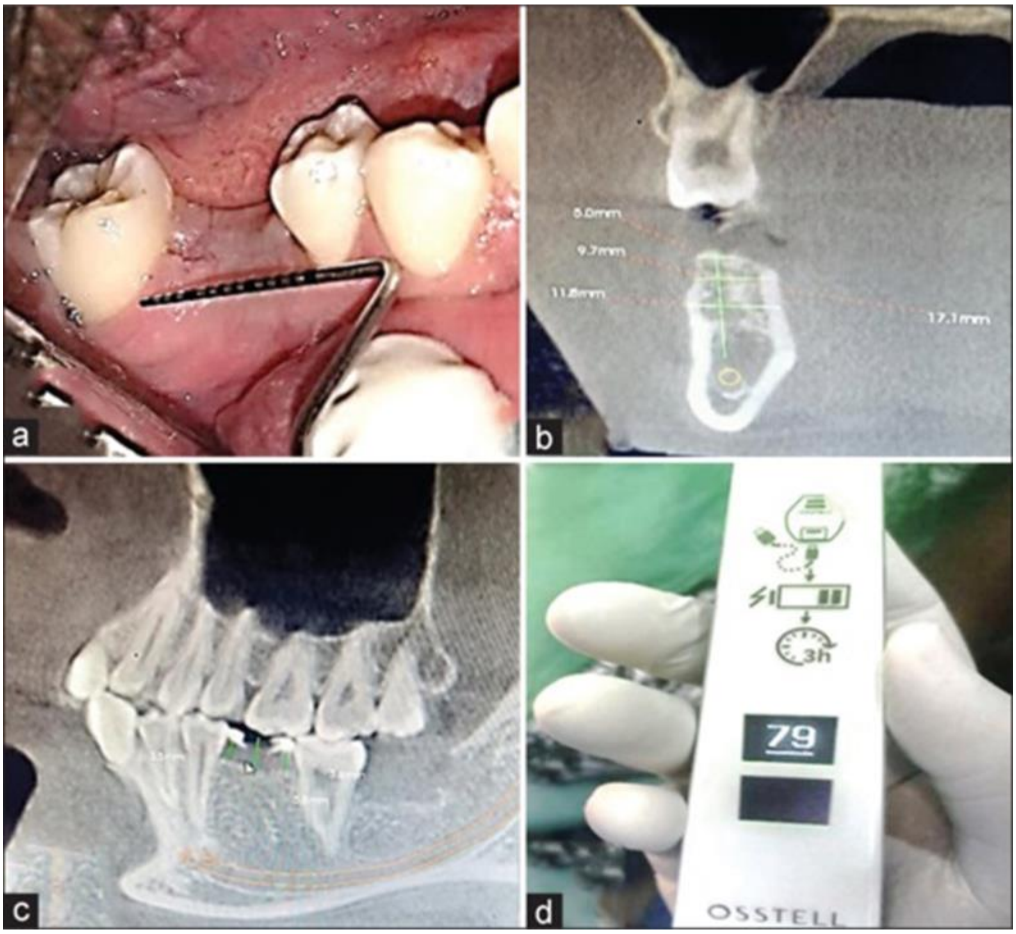

Figure 1. Group A – Preoperative: (a) Clinical image; (b) Baseline CBCT scan; (c) Acrylic stent positioned; (d) Initial implant stability quotient

For patients in Group B (immediate implant placement), the procedure began with careful, minimally invasive tooth extraction under local anesthesia using periotomes to avoid trauma to the surrounding alveolar bone. After removal, the extraction socket was meticulously cleaned with a curette and irrigated with saline. A blunt instrument was then used to inspect the socket walls for any fractures or defects.

The osteotomy was prepared stepwise, and the implant was placed without a surgical guide. Drilling was aligned along the palatal or lingual wall of the socket to ensure optimal positioning, following the same placement principles as Group A. Primary stability was secured by engaging bone beyond the apex of the extraction site. Once positioned, a smart peg was attached to the implant, and resonance frequency analysis was performed to record the stability quotient **(Figure 2)**.

Next, a straight abutment was connected, and any residual space between the implant and the socket walls (“jumping gap”) was filled with bone graft material if necessary. The surgical site was closed with 5–0 absorbable sutures, and a provisional crown was immediately delivered over the abutment to complete the restoration.

Figure 2. Group B – Preoperative: (a) Clinical image; (b) Baseline CBCT scan; (c) Stent positioning; (d) Baseline implant stability quotient values

Results and Discussion

Data analysis, including descriptive and inferential statistics, was performed using IBM SPSS version 27.0 (IBM Corp., Armonk, NY, USA). In this study, all 14 implants successfully achieved osseointegration, with no early failures or complications observed. Healing proceeded smoothly in all cases, and patients reported high satisfaction, as their missing teeth were restored on the same day of surgery.

Regarding plaque accumulation, the mean plaque index at 3 months was 0.714 ± 0.1345 for Group A and 0.729 ± 0.0951 for Group B. At six months, the scores were 0.614 ± 0.1345 for Group A and 0.614 ± 0.0976 for Group B. Statistical comparison between the two groups indicated no significant differences in plaque index at either three or six months **(Table 1)**.

Table 1. Intergroup comparison of plaque score, bleeding on probing, and probing pocket depth between Groups A and B

Parameters	Timeline	Group A	Group B	*t*-test	*P*
Plaque score	Baseline	0.814±0.1069	0.843±0.0976	−0.522	0.611
	3 months	0.714±0.1345	0.729±0.0951	−0.229	0.822
	6 months	0.614±0.1345	0.614±0.0976	0.000	1.000
Bleeding on	Baseline	0	35.7143±13.363	−7.071	0.000
probing	3 months	21.428±17.2516	10.7143±13.3630	1.299	0.218
	6 months	14.2857±13.3630	7.1429±12.19875	1.044	0.317
Probing	Baseline	0	1.657±0.0976	−44.927	0.000
pocket depth	3 months	1.5514±0.21874	1.5857±0.10690	−0.373	0.716
	6 months	1.443±0.1397	1.543±0.1512	−1.285	0.223

*Independent *t*-test, *P*≤0.05 is considered statistically significant, *P*-level of significance. Inference: There is no statistically significant difference

Regarding bleeding on probing, Group A recorded mean values of 21.43 ± 17.25 at 3 months and 14.29 ± 13.36 at 6 months, whereas Group B showed 10.71 ± 13.36 at 3 months and 7.14 ± 12.20 at 6 months. Statistical analysis indicated no meaningful differences between the two groups at either time point **(Table 1)**.

For peri-implant probing depth, the mean measurements for Group A were 1.55 ± 0.22 mm at 3 months and 1.44 ± 0.14 mm at 6 months, while Group B had values of 1.59 ± 0.11 mm and 1.54 ± 0.15 mm, respectively. Comparison between groups revealed that these differences were not statistically significant at both intervals **(Table 1)**.

In terms of implant stability (ISQ), Group A consistently showed higher values than Group B, with differences reaching a high level of statistical significance (P < 0.001) in both mesiodistal and buccolingual directions at baseline and 6 months **(Table 2)**.

Evaluation of crestal bone levels also revealed highly significant differences between the groups (P < 0.001) at mesial and distal markers at both baseline and 6 months, with Group A exhibiting less bone loss compared to Group B **(Table 3)**.

Table 2. Intergroup assessment of implant stability quotient between Groups A and B

Parameters	Timeline	Group A (mean±SD)	Group B (mean±SD)	*t*-test	*P*
ISQ	Baseline	75.57±3.259	60.14±8.971	4.277	0.001
mesiodistal	6 months	76.43±3.552	65.71±7.064	2.328	0.041
ISQ	Baseline	72.00±6.298	62.14±9.263	3.585	0.006
buccolingual	6 months	77.43±2.370	68.57±5.473	3.929	0.004

*Independent t-test; P≤0.05 is considered statistically significant; P-level of significance. Inference: A statistically significant difference was observed between Groups A and B at both mesiodistal and buccolingual sites at baseline and 6 months, indicating that Group A exhibited superior implant stability quotient (ISQ) values compared to Group B. SD – Standard deviation; ISQ – Implant stability quotient.

Table 3. Intergroup assessment of crestal bone levels between Groups A and B

Parameters	Timeline	Group A, (mean±SD)	Group B, (mean±SD)	*t*-test	*P*
Mesial marker	Baseline	2.514±0.8783	3.400±0.5802	−2.226	0.049
	6 months	3.571±0.8341	6.500±0.6928	−0.876	<0.001
Distal marker	Baseline	2.886±1.2747	3.371±0.7274	−7.146	0.000
	6 months	3.871±1.1221	6.429±0.9928	−4.516	0.001

*Independent t-test, P≤0.05 is considered statistically significant, P-level of significance. Inference: A statistically significant difference was found between Groups A and B at both mesial and distal markers at baseline and 6 months, indicating that Group A experienced less crestal bone loss compared to Group B. SD – Standard deviation.

No significant differences (P > 0.05) were observed in clinical or radiographic parameters within the groups at baseline, 3 months, or 6 months.

Modern implant dentistry increasingly focuses on protocols that reduce treatment time and enhance patient convenience and esthetic outcomes. Traditionally, implants were left unloaded for 3–8 months to achieve full osseointegration [3,5,6]. More recent approaches advocate early, or even immediate, loading to shorten the healing period without compromising success.

Immediate loading is considered possible when implants reach insertion torque values of 30–40 Ncm or higher and the bone quality at the site is adequately evaluated using computed tomography. Implant stability can be assessed using resonance frequency analysis, which provides the implant stability quotient (ISQ) as a measure of bone-implant fixation [7,8].Implants with ISQ values between 55 and 80 are generally considered stable enough for predictable outcome s[9].

This study aimed to compare two implant placement strategies over six months. Group A involved implants placed in healed ridges with immediate loading, whereas Group B received immediate implants in fresh extraction sockets.

Throughout the study, plaque scores did not differ significantly between groups, reflecting effective oral hygiene practices. These results are consistent with previous studies by Weber *et al.* [10] Renvert *et al.* [11] and Parvini *et al.* [12].

Bleeding on probing decreased notably in Group B over six months, although the difference between groups was not significant. These findings echo the observations of Cosyn *et al.* [13] who reported a reduction in bleeding from 41% to 24% over three years in immediate implants, and align with Bhutani *et al.* [14].

Group A showed a significant reduction in peri-implant probing depth over six months, while comparisons between groups revealed no statistically significant differences. This supports findings by DeAngelo *et al.* [15] though Schou *et al.* [16] and Al-Ahmari [17] did not observe similar reductions in delayed implants.

Regarding implant stability, ISQ measurements at baseline and six months showed significant differences (P < 0.000) **(Figures 3 and 4)**, indicating that delayed implants with immediate loading achieved higher primary and secondary stability than immediate implants in fresh sockets. These results are in agreement with Cannizzaro *et al.* [18] and Stanley *et al.* [19], but contrast with Naeem and Al-Jumaily [20], who reported better stability with immediate implants.

Figure 3. Group A – Postoperative evaluation: (a) Cone-beam computed tomography at six months; (b) Clinical image; (c) Implant stability quotient measurement at six months

Figure 4. Group B – Postoperative assessment: (a) Cone-beam computed tomography at six months; (b) Clinical image; (c) Implant stability quotient at six months

From baseline to six months, the average crestal bone loss measured at both mesial and distal sites indicated that delayed implants with immediate loading experienced less bone loss compared to immediate implants with immediate loading. These results align with Chaushu *et al.* [21] who reported that immediate loading in newly extracted sites carries a 20% higher risk of implant failure compared to healed sites. Similar findings were reported by den Hartog *et al.* [22] Mangano *et al.* [23], and Keshari *et al.* [24], who demonstrated that immediate loading of single implants is safe, effective, and associated with minimal marginal bone loss. Conversely, Pitman *et al.* [25] found no significant differences in crestal bone changes between immediate and conventional loading protocols.

Conclusion

Over a 6-month period, this study evaluated and compared the clinical and radiographic outcomes of immediate versus delayed implants, both subjected to immediate loading. Clinical parameters—including plaque index, bleeding on probing, and probing pocket depth—were recorded at baseline, 3 months, and 6 months. Implant stability was assessed at the time of surgery and after 6 months using a resonance frequency analyzer, while CBCT imaging was used to evaluate crestal bone changes.

The findings demonstrated that delayed implants with immediate loading exhibited superior outcomes. Specifically, these implants showed higher primary and secondary stability and reduced crestal bone loss compared with immediately loaded implants placed in fresh extraction sockets. After 6 months, final restorations were completed following careful assessment of hard- and soft-tissue conditions to ensure optimal results.

Within the limits of this study, immediate loading of delayed implants outperformed immediate loading of implants in fresh sockets. For long-term success, meticulous surgical planning and execution are recommended. Further studies with larger sample sizes and longer follow-up periods are needed to validate these results.

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