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Immediate Versus Early Functional Loading of Single Dental Implants: A Six-Month Prospective Comparative Study

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ABSTRACT

Aim

To compare peri-implant marginal bone loss, Modified Plaque Index (mPI), and Modified Gingival Index (mGI) between immediate and early functional loading protocols after 3 and 6 months of implant loading.

Materials and Methods

Eighteen patients requiring single-tooth implant placement were included in this prospective in□vivo radiographic study. Participants were divided into two groups: Immediate loading (ISQ ≥70) and Early functional loading (ISQ 65–69). Each group consisted of 9 patients. Standardized surgical protocols were followed. Radiographic evaluation of marginal bone loss was performed at baseline, 3 months, and 6 months using standardized IOPA with LCP holder. mPI and mGI were recorded at the same intervals. Statistical analysis was performed using independent and paired t-tests with significance set at $p<0.05$.

Results

Both groups showed 100% implant survival at 6 months. Marginal bone loss was observed in both groups; however, the difference between immediate and early loading was not statistically significant ($p>0.05$). mPI and mGI scores increased slightly over time in both groups but showed no statistically significant intergroup difference.

Conclusion

Immediate and early functional loading protocols

demonstrated comparable peri-implant bone stability and soft tissue health at 6 months when adequate primary stability and proper case selection were ensured.

Keywords

Immediate loading, Early loading, Dental implants, Marginal bone loss, Implant stability quotient

INTRODUCTION

Dental implants have become an integral component of contemporary prosthodontic rehabilitation. The principle of osseointegration, defined as a direct structural and functional connection between living bone and a load-bearing implant surface, underpins the long-term success of implant therapy.[1] High survival rates and predictable functional outcomes have positioned implant-supported restorations as a preferred alternative to conventional fixed and removable prostheses.[2] In addition to restoring masticatory efficiency and esthetics, implants preserve adjacent tooth structure and help maintain alveolar bone volume by transmitting physiologic forces to the surrounding bone.

Conventional protocols recommended a healing period of three to six months before prosthetic loading to ensure undisturbed osseointegration.[3] This delayed loading concept aimed to prevent micromovements at the bone–implant interface that could compromise integration and result in fibrous encapsulation. However, advancements in implant macrodesign, surface topography, and surgical techniques have significantly enhanced primary stability and accelerated bone healing, allowing reconsideration of traditional loading timelines.[1]

Loading protocols are currently classified as delayed, early, and immediate.[3] Delayed loading involves restoration after a conventional healing phase of 3–6 months. Early loading refers to prosthetic rehabilitation between 2 weeks and 3 months after implant placement, whereas immediate loading entails placement of a provisional restoration within 48 hours of surgery. [3]

Reduced treatment duration, earlier functional rehabilitation, and improved patient satisfaction have contributed to the increasing adoption of early and immediate loading strategies.

The success of these protocols largely depends on adequate primary stability at implant placement. Resonance frequency analysis provides an objective assessment of implant stability through the Implant Stability Quotient (ISQ).[4] Higher ISQ values are associated with improved predictability for early or immediate functional loading. Nonetheless, concerns remain regarding peri-implant marginal bone remodeling and soft tissue response during the initial healing phase under functional loading conditions.

Therefore, the present study aimed to compare peri-implant marginal bone loss, Modified Plaque Index, and Modified Gingival Index between immediate and early functional loading protocols over a six-month follow-up period.

Materials and Methods

This prospective radiographic in-vivo study was conducted in the Department of Prosthodontics, Bapuji Dental College and Hospital, Davangere, after obtaining institutional ethical clearance.

Sample Size

Sample size calculation for the primary objective (peri-implant bone loss) resulted in 16 participants. Considering 20% attrition, 18 participants were included (9 in each group).

Inclusion Criteria

- Age between 25–50 years
- Single implant placement
- ISQ ≥70 (Immediate loading)
- ISQ 65–69 (Early functional loading)
- Good oral hygiene (OHI-S 0–1.2)
- Adequate bone quality (D1, D2, D3)
- Non-smokers

Exclusion Criteria

- Systemic illness
- Uncontrolled diabetes (HbA1c >7%)
- Parafunctional habits
- Radiation history
- Insufficient interocclusal clearance

Surgical Procedure

Implants (JD and DIO implant systems) were placed under local anesthesia following strict aseptic protocol. Sequential osteotomy was performed according to manufacturer instructions. Insertion torque ≥35 Ncm was achieved in all cases.

Resonance frequency analysis was used to determine ISQ values.

Loading Protocol

Immediate Loading Group:

Provisional crown delivered within 48 hours when ISQ ≥70. No occlusal contact protocol was followed.

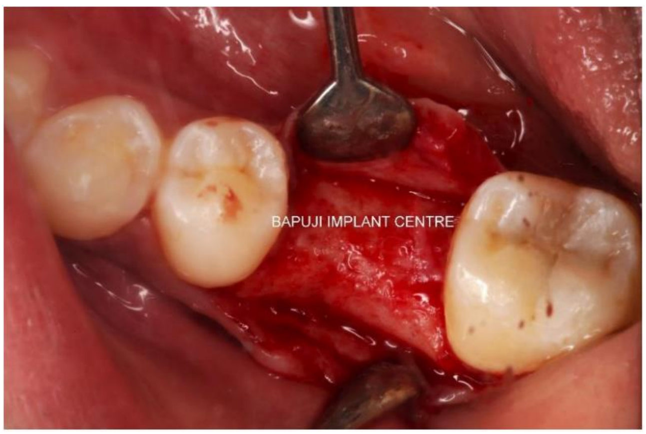


Figure 1: Full thickness flap reflected

Figure 2: Implant

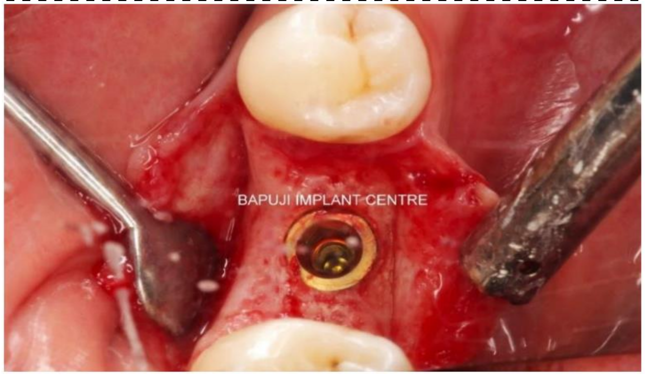


Figure 3: Implant Placed

Figure 4: Intraoral scanning with scan body placed

Figure 5: Intraoral scanning with scan body placed

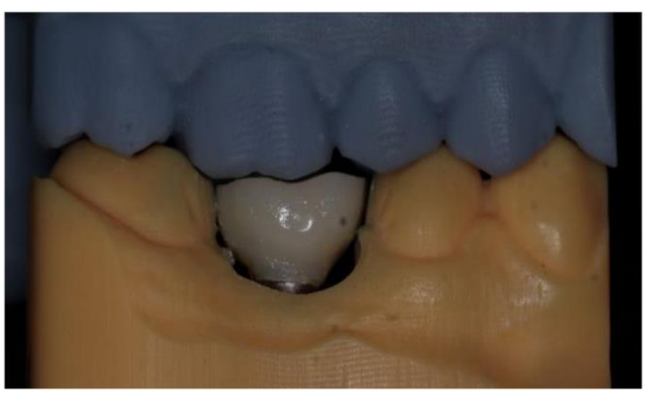


Figure 15: Model printed

Figure 16: Provisional Crown

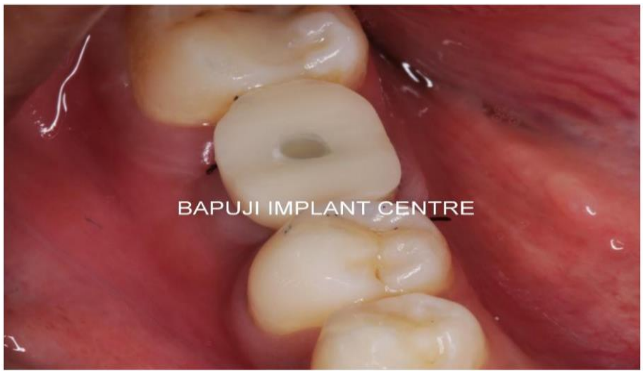


Figure 17: One point contact achieved through articulating paper

Figure 21: Formation of the Gingival cuff

Figure 22: Final Prosthesis placed

Early Loading Group:

Provisional crown delivered within 6 weeks when ISQ 65–69 with controlled functional loading

Figure 24: Full thickness flap reflected

Figure 27: Measurement of ISQ after implant placement

Figure 28: Healing cap placed

Figure 29: Open tray impression made

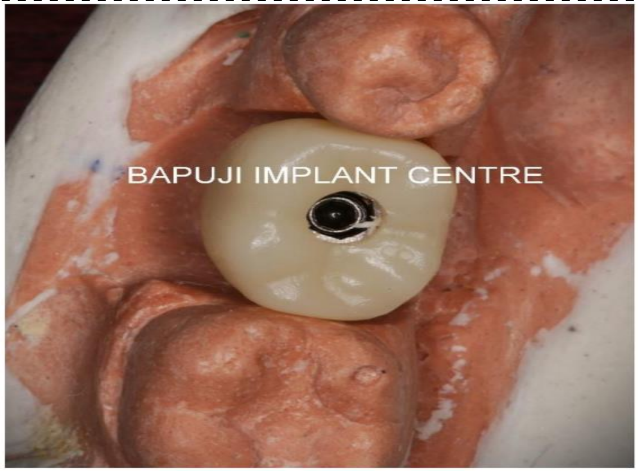
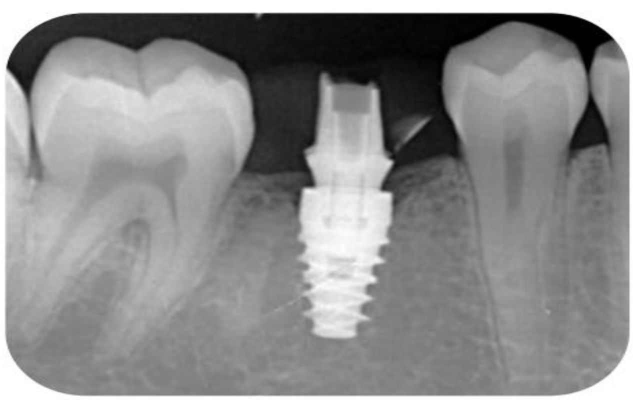


Figure 33: Provisional Crown cemented with abutment

Early loading done

Radiographic Evaluation

Standardized IOPA radiographs using LCP holder was taken at baseline, 3 months, and 6 months. Mesial and distal marginal bone levels were measured using digital software



immediate loading after 6 months

early loading after 6 months

Clinical Parameters

- Modified Plaque Index (mPI)
- Modified Gingival Index (mGI)

Recorded at mesial, distal, buccal, and lingual surfaces.

Statistical Analysis

Data were analyzed using SPSS software. Independent t-test and paired t-test were applied.

Statistical significance was set at $p<0.05$.

RESULTS

A total of 18 subjects (25–50 years) were included and divided based on implant stability quotient (ISQ) into Immediate loading (ISQ ≥70; n=9) and Early loading (ISQ 65–69; n=9) groups. Radiographic evaluation of crestal bone levels and clinical assessment of Modified Plaque Index (MPI) and Modified Gingival Index (MGI) were performed at baseline, 3 months, and 6 months. Inter-group comparison:

At baseline (T0), mesial bone loss was significantly greater in the Early group (0.289 mm) compared to the Immediate group (0.078 mm) ($p=0.003$). However, at 3 months (T1) and 6 months (T2), mesial bone loss differences were not statistically significant ($p>0.05$). Distal bone loss was consistently higher in the Early group at all time intervals, but the differences were not statistically significant ($p>0.05$). MPI and MGI scores showed no statistically significant inter-group differences at 3 and 6 months ($p>0.05$), indicating comparable peri-implant soft tissue health between the two loading protocols.

Intra-group comparison:

Both groups demonstrated a statistically significant increase in mesial and distal bone loss from baseline to 6 months ($p<0.05$). Bonferroni post-hoc analysis confirmed significant progression between successive time intervals for mesial bone loss in both groups. For distal bone loss, all intervals showed significant differences in the Immediate group, whereas in the Early group, the increase between 3 and 6 months was not significant, suggesting a plateau trend. MPI scores significantly increased from 3 to 6 months in both Immediate ($p=0.014$) and Early ($p=0.046$) groups, indicating a decline in plaque control over time. Although MGI scores showed a trend toward increased gingival inflammation at 6 months in both groups, the changes were not statistically significant (p=0.083). Overall, both immediate and early loading protocols demonstrated comparable peri-implant bone changes and soft tissue outcomes over a 6-month period, with no significant inter-group differences at the end of the study.

Table 1: Master chart of data obtained for crestal bone loss and soft tissue evaluation in 9 subjects undergone immediate loading of implant (group 1) at baseline, 3 months and 6 months.

MEAN VALUES OF PERI IMPLANT BONE LOSS (In mm)								SOFT TISSUE EVALUATION			
S. NO	NAME	BONE LOSSS (mm)						MPI (MODIFIED PLAQUE INDEX)		MGI (MODIFIED GINGIVAL INDEX)	
		Baseline (T0)		3 Months (T1)		6 Months (T2)		3 months (ST1)	6 months (ST2)	3 months (ST1)	6 months (ST2)
		Mesial	Distal	Mesial	Distal	Mesial	Distal				
1.	PT 1	0	0.1	0.2	0.4	0.2	0.6	0	1	0	0
2.	PT 2	0.2	0.2	0.8	0.8	1.0	1.2	1	2	1	1
3.	PT 3	0.1	0.2	0.4	0.6	0.6	0.8	0	1	0	0
4.	PT 4	0.2	0.1	0.8	0.6	0.8	0.6	1	1	0	1
5.	PT 5	0	0	0.2	0.2	0.4	0.4	0	1	0	0
6.	PT 6	0	0	0.1	0.2	0.2	0.3	1	1	1	1
7.	PT 7	0.1	0.1	0.4	0.4	0.6	0.6	0	1	0	1
8.	PT 8	0.1	0.1	0.6	0.6	0.8	0.8	1	1	1	1
9.	PT 9	0.1	0	0.4	0.2	0.6	0.6	0	1	0	1

Table 2: Master chart of data obtained for crestal bone loss and soft tissue evaluation in 9 subjects undergone early loading of implant (group 2) at baseline, 3 months and 6 months.

MEAN VALUES OF PERI IMPLANT BONE LOSS (In mm)								SOFT TISSUE EVALUATION			
S. NO	NAME	BONE LOSSS(mm)						MPI (MODIFIED PLAQUE INDEX)		MGI (MODIFIED GINGIVAL INDEX)	
		Basline (T0)		3 months (T1)		6 months (T2)		3 months (ST1)	6 months (ST2)	3 months (ST1)	6 months (ST2)
		Mesial	Distal	Mesial	Distal	Mesial	Distal				
1.	PT 1	0.1	0.2	0.2	0.4	0.2	0.4	1	1	1	1
2.	PT 2	0.2	0.4	0.4	0.4	0.6	0.8	0	1	0	1
3.	PT 3	0.4	0.5	0.6	0.8	1.0	1.2	1	2	1	1
4.	PT 4	0.2	0.3	0.6	0.6	0.8	1.0	1	1	0	1
5.	PT 5	0.2	0.4	0.4	0.6	0.5	0.6	0	1	0	1
6.	PT 6	0.6	0.4	0.8	0.7	0.8	0.9	1	1	1	1
7.	PT 7	0.5	0.3	0.8	0.6	0.8	0.6	1	1	1	1
8.	PT 8	0.2	0.1	0.4	0.2	0.6	0.4	0	0	0	0
9.	PT 9	0.2	0.2	0.2	0.4	0.4	0.4	0	1	0	0

Inter-group comparison

Table 3: Inter-group comparison of mesial bone loss between the two groups

Time	Group	Mean	Standard deviation	P value
T0	Immediate	.078	.066	.003
	Early	.289	.169	
T1	Immediate	.433	.255	.631
	Early	.489	.226	
T2	Immediate	.578	.272	.656
	Early	.633	.244	

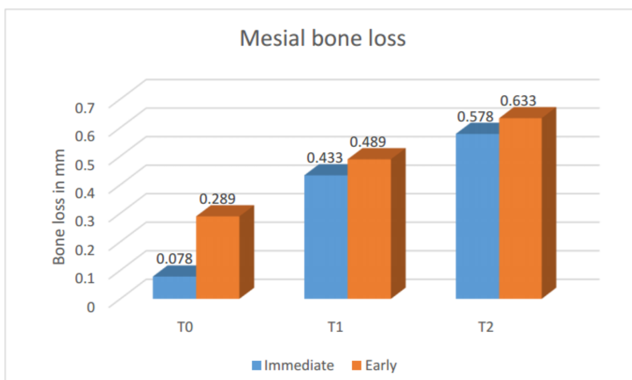
Mesial bone loss at T0 was significantly greater in the early group, but did not vary at T1 and T2

Table 4 Inter-group comparison of distal bone loss between the two groups.

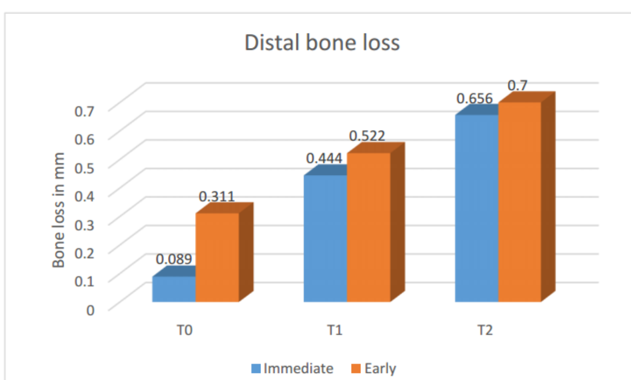
Time	Group	Mean	Standard deviation	P value
T0	Immediate	.089	.078	.145
	Early	.311	.126	
T1	Immediate	.444	.218	.520
	Early	.522	.185	
T2	Immediate	.656	.260	.424
	Early	.700	.291	

Distal bone loss did not vary between the two groups at any of the three time points assessed.

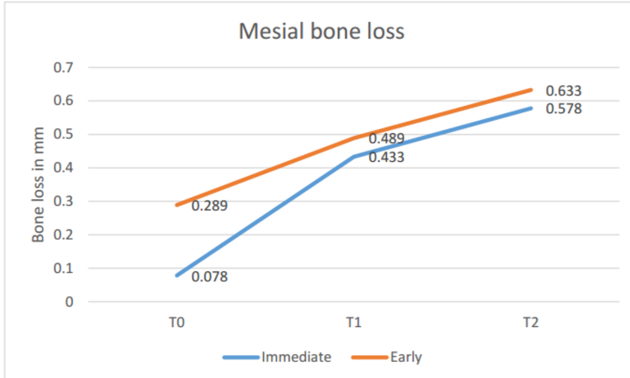
Graph 1: Inter-group comparison of mesial bone loss



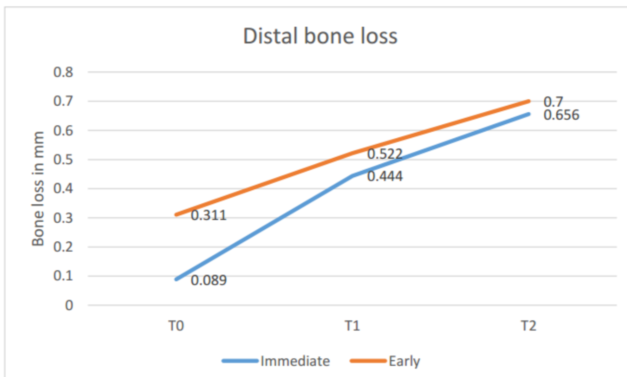
Graph 2: Inter-group comparison of distal bone loss



Graph 5: Intra-group comparison of mesial bone loss at T0, T1, and T2



Graph 6 Intra-group comparison of distal bone loss at T0, T1, and T2



DISCUSSION

Tooth loss significantly impairs oral function and esthetics and is commonly the final outcome of untreated caries, trauma, or periodontal disease. Traditionally, missing teeth were replaced using removable partial dentures or fixed partial dentures; however, these approaches either compromise patient comfort or require irreversible preparation of adjacent teeth.5 The advent of osseointegrated dental implants has revolutionized tooth replacement by providing a self□supporting restoration that preserves adjacent dentition and offers high long-term success rates, reportedly around 97%, thereby becoming the gold standard for tooth replacement.[6]The concept of osseointegration, introduced by Per-Ingvar Brånemark, describes the direct structural and functional connection between living bone and the surface of a load-bearing implant.[7]Traditional implant protocols recommended a healing period of 3–6 months before loading to prevent micromovement and fibrous encapsulation.[8] However, contemporary evidence indicates that implant success is influenced more by the magnitude of micromotion (critical threshold 50–150 µm) rather than simply the timing of loading.[9] Advances in implant surface technology, macrodesign, and surgical precision have enabled predictable immediate and early loading protocols, particularly in cases with favorable bone quality and adequate primary stability.[10]

According to Misch et al., loading protocols are categorized as delayed, early, and immediate loading.[3] Early loading typically occurs between 2 weeks and 3 months, while immediate loading involves restoration within 48 hours. Implant Stability Quotient (ISQ), measured using resonance frequency analysis, serves as a reliable indicator for determining loading protocol selection.[4] ISQ ≥70 indicates suitability for immediate loading, whereas ISQ 65–69 is acceptable for early loading under controlled conditions.

In the present study, immediate loading was performed in cases demonstrating high primary stability (insertion torque ≥35 Ncm; ISQ ≥70), consistent with recommended thresholds.[411] A minimally invasive surgical protocol was followed, and provisional crowns were fabricated using PMMA to reduce occlusal stress and allow optimal soft tissue contouring.[12,13,14] One-point occlusal contact was maintained using articulating paper and shimstock to minimize lateral forces during healing.[14,15]

Early loading was performed in cases with ISQ values between 65–69, typically in D3 bone quality, where immediate loading was not feasible.16 Controlled functional stimulation was provided after a short healing period to promote favorable bone remodeling without exceeding physiologic micromotion limits.17 Studies by Brånemark et al. and Cochran et al. have demonstrated high survival rates (>99%) with early loading protocols, supporting their predictability.[18]

Modified Plaque Index (mPI)

The Modified Plaque Index introduced by Mombelli et al. (1987) is widely used to assess plaquaccumulation around implants.12 Inter-group comparison showed no statistically significant difference in MPI scores at 3 and 6 months (p = 0.637 and p = 0.587, respectively), consistent with Albertini et al.19 Intra-group comparison revealed a statistically significant increase in plaque accumulation from 3 to 6 months in both immediate (p = 0.014) and early (p = 0.046) groups.12,19,20 These findings suggest that plaque control, rather than loading protocol, influences peri-implant soft tissue health.

Modified Gingival Index (mGI)

The Modified Gingival Index by Mombelli et al. is used to evaluate peri-implant mucosalinflammation without probing.12 Inter-group comparison demonstrated no statistically significant difference in MGI scores at 3 and 6 months (p = 0.629 and p = 0.599, respectively), consistent with findings by Gjelvold et al.21 Intra-group analysis showed a mild increase in gingival inflammation from 3 to 6 months in both groups; however, these changes were not statisticallysignificant (p = 0.083).12,19,20

Crestal Bone Loss

Marginal bone loss of less than 1.5 mm during the first year and less than 0.2 mm annually thereafter is considered acceptable for implant success.22 Crestal bone plays a crucial role in maintaining implant stability, esthetics, and peri-implant tissue health.[23,24,25]

In the present study, inter-group comparison revealed significantly greater mesial bone loss at baseline in the early loading group (p = 0.003), but no statistically significant differences were observed at 3 and 6 months.[1,11,26] Similarly, distal bone loss showed no significant inter-group differences at any time interval (p > 0.05).[1,17] These findings correlate with previous studies reporting comparable marginal bone loss between immediate and early loading protocols.[3,17,21,27,28]

Intra-group analysis demonstrated a statistically significant increase in mesial and distal bone loss over time in both groups ($p < 0.05$), consistent with the physiologic remodeling phase observed during early implant healing.[11,17,20] Reported mean bone loss values at 6 months were comparable with previous literature (0.5–0.8 mm), remaining within acceptable limits.[1,21,28,29,30,31,32]

The slightly higher bone loss in the early loading group may be attributed to transient disuse atrophy before functional loading.26 Greater distal bone loss may be related to occlusal stress and difficulty in maintaining hygiene in posterior regions.[3]

Clinical Implications

The findings of this study indicate that both immediate and early loading protocols produce comparable peri-implant bone and soft tissue outcomes over a 6-month period when appropriate case selection, primary stability, and occlusal control are ensured.11,17,20 Immediate loading may offer the advantage of early functional stimulation and reduced treatment duration, whereas early loading provides a safer alternative in cases with moderate primary stability.

CONCLUSION

Limitations

The study was limited by a relatively small sample size and a short follow-up period of 6 months, restricting long-term evaluation of implant stability and peri-implant tissue changes. Additionally, radiographic assessment using IOPA provides two-dimensional measurements, which may have inherent limitations in precision compared to three-dimensional imaging techniques.

CONCLUSION

high survival rates and clinically acceptable peri-implant outcomes over a 6-month period. Although the early loading group exhibited slightly greater initial mesial bone loss, inter-group differences were not statistically significant at subsequent follow-up intervals.

Both protocols showed progressive but physiologically acceptable crestal bone remodeling within established success criteria. Soft tissue parameters (MPI and MGI) were comparable between groups, indicating that loading timing did not significantly influence peri-implant tissue health when adequate plaque control was maintained.

Therefore, with proper case selection, sufficientprimary stability, and controlled occlusal loading, both immediate and early loading protocols can be considered predictable and safe treatment approaches for single implant restorations. Long-term studies are recommended to further substantiate these findings.

Clinical Significance

Immediate and early functional loading of single implants can reduce treatment time without compromising peri-implant bone stability when adequate primary stability and controlled occlusion are maintained.

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