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ORIGINAL ARTICLE

Evaluation of Clinical and Radiographic Outcomes Associated With Dental Implants Subjected to Different Loading Protocols

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Abstract

Objective: **To evaluate the clinical and radiographic outcomes associated with dental implants subjected to different loading protocols in the posterior maxillary region.**

Patients and methods: **This clinical study included 16 implants placed in patients seeking the rehabilitation of single/multiple teeth in the posterior maxillary region. The patients were distributed randomly into three groups according to the loading protocol; the first group received four implants subjected to conventional loading protocol, the second group received six implants subjected to early loading protocol, additionally the third group received six implants subjected to immediate loading protocol. The evaluation was done immediately after crown cementation (T1), and after 6 months (T2) and 12 months (T3) to assess implant stability and marginal bone level and bone loss around the implants.**

Results: **This study included 14 patients with an average age of 34.79 ± 9.17 years. There were no statistically significant differences between studied groups regarding age, sex, implant position, length, and width ($P = 0.642$, $P = 0.260$, $P = 0.822$, $P = 0.053$, and $P = 0.317$, respectively). There were no statistically significant differences between studied groups regarding stability at different follow-up periods ($P = 0.06$ at T1, $P = 0.07$ at T2, $P = 0.150$ at T3). However, there were significant differences between group 1 versus group 2 at T1 and T2 ($P = 0.018$, $P = 0.028$), respectively. Regarding mean bone loss, there were statistically significant differences between studied groups specifically T2 from T1 ($P = 0.01$) and T3 from T1 ($P < 0.001$).**

Conclusions: **Earlier loading positively enhances osseointegration around immediately loaded and early-loaded implants when compared with conventionally loaded dental implants. On the other hand, greater bone loss was observed with immediately loaded and early-loaded implants than with conventionally loaded implants.**

Keywords: Loading protocols, Implant stability, Marginal bone level, Bone loss

Introduction

Aesthetic and functional rehabilitation using dental implants is an alternative for the treatment of edentulous areas with high success rates. Dental implants have shown a high success rate for the rehabilitation of edentulous patients if certain conditions are met during treatment.[1] Nevertheless, the risk of failure remains difficult to predict. The achievement of osseointegration depends on many factors, such as a suitable host, biocompatible materials, careful surgery, and an appropriate healing time.[1]

The immediate loading protocol was developed to reduce the healing time and allow prosthetic placement after implant insertion.[2,3] This technique has become an attractive option for the rehabilitation of edentulous patients, providing greater psychological and functional patient satisfaction, with success rates ranging from 85 to 100 %.[2,3]

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However, although studies evaluated the clinical success of immediately loaded implants, little is known about the molecular events associated with early-loaded dental implants in humans.[3] Animal studies suggested that in the presence of loading, osseointegration can occur early[4] with greater deposition of mineralized tissue around the implant.[5] This phenomenon suggests that functional stimulation could alter the osseointegration process through the release of molecules that act as modulators of osteogenesis and osteoclastogenesis.[5]

This study was done to evaluate clinical and radiographic outcomes associated with dental implants under different loading protocols.

Patients and methods

Sixteen implants were inserted in patients seeking maxillary posterior tooth/teeth replacement with dental implants. The patients were selected from the Outpatient Clinic of the Department of Oral and Maxillofacial Surgery, Faculty of Dentistry, Mansoura University. All included patients were informed about the study's purposes, procedures, and possible risks and each patient signed an informed consent.

The patients included were of age ranged between 18 and 65 years, with lost maxillary posterior tooth/teeth seeking implant-based rehabilitation, with sufficient ridge width greater than 6 mm. Good oral hygiene with the ability to participate and continue in this study were prerequisites for inclusion in the study.

On the other hand, the presence of underlying systemic diseases that interfere with local wound healing (such as diabetes, rheumatoid arthritis, hypothyroidism, hyperparathyroidism, osteoporosis, or people with impaired renal function), or medications like antiresorptive agents (bisphosphonates) or hormone replacement therapy, or history of bone grafting in the area of the implant, or cases requiring bone graft. Additionally, a history of recent tooth extraction at the implant site in the past 6 months, the presence of any parafunctional habits, pregnancy, or smoking greater than 10 cigarettes/daily, were factors of exclusion from the study.

Patient grouping: the patients were randomly divided into the following groups

Group (1) (control group): Included 4 single implants of 2-piece type subjected to conventional loading protocol after 6 months from implant installation, group (2): Included 6 single implants of 2-piece type subjected to early loading protocol after 2 months from implant installation, and group (3): Included 6 single implants of 2-piece type subjected to immediate loading protocol within 72 h after implant installation.

Preoperative phase

All patients were asked about their medical and dental history. All data were registered to ensure proper medical conditions. All patients were examined clinically and received oral hygiene instructions and periodontal treatment (full mouth scaling and root planning), before starting the treatment procedures and during the treatment period whenever needed. A surgical drilling guide was constructed over the study cast using a sheet of clear acrylic resin of vacuum type that can help in proper positioning and inclination of the implant about the neighboring teeth. Preoperative periapical radiographs were taken for all patients using parallel and long cone techniques to help in the assessment of preoperative bone condition.

Surgical phase

Presurgical instructions

A 0.12 % chlorhexidine mouthwash (Hexitol, ADCO, Egypt) was prescribed immediately before surgery for 1 min and a prophylactic antibiotic of 2 gm amoxicillin and clavulanic acid (Hibiotic tab, Amoun Pharmaceutical CO, Egypt) was prescribed 1 h before surgical operation.

Surgical technique

After induction of local anaesthesia using (4 % articaine, and 1 : 100 000 adrenaline) (ARTINIBSA, Spain), a mucoperiosteal incision was done in the intended surgical area. All drilling procedures were done at a speed of 800 rpm and torque of 40 Ncm. The surgical drilling was done according to the implant manufacturer's instructions under abundant saline solution irrigation through cortical penetration using the pilot drill (2.3ϕ) followed by the initial drill (2.2 ϕ) inserted to the full depth according to the selected fixture length. Then serial drilling was done till the final drill application to the full length with a diameter less than the fixture diameter by 0.5 ϕ under copious irrigation.

Implant placement was done using a hand-driven fixture driver followed by the torque ratchet wrench until the implant platform was flushed with the bone level, followed by cover screw or healing abutment insertion according to the applied protocol using a hand-driven hex driver. The surgical site was irrigated with sterile saline solution. Finally, the

mucoperiosteal flap was repositioned, interrupted, and horizontal mattress sutures were made using 4/0 silk suture material (Ghatwary Medical GMS. EGYPT), Figs. 1–3.

Postoperative care

Patients were instructed to maintain adequate oral hygiene with 0.12 % chlorhexidine mouthwash (Hexitol, ADCO, Egypt) twice daily for 7 days, and were given postoperative antibiotics (750 mg amoxicillin and 250 mg clavulanic acid) (Hibiotic tab, Amoun Pharmaceutical CO, Egypt) twice daily for 5 days, and analgesic (150 mg ketoprofen) (Biprofenid tab, Sanofi Aventis co, Egypt) when needed. During the first 3 days, all included patients should be kept only on drinking cold fluids and eating soft foods.

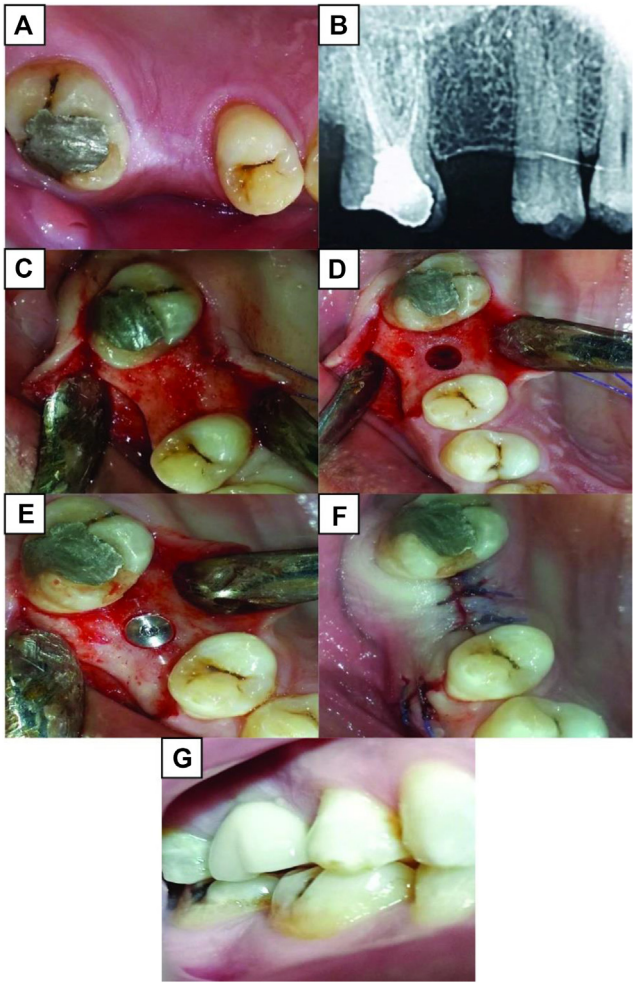

Fig. 1. Photographs of a case in first group showing; (A) intraoral occlusal view of planned implant site (B) intraoral periapical radiograph (C) alveolar ridge after mucoperiosteal flap reflection (D) implant site preparation (E) the implant with Cover screw (F) mucoperiosteal flap repositioning and suturing (G) lateral view of Cemented PFM crown after 6 months from implant installation.

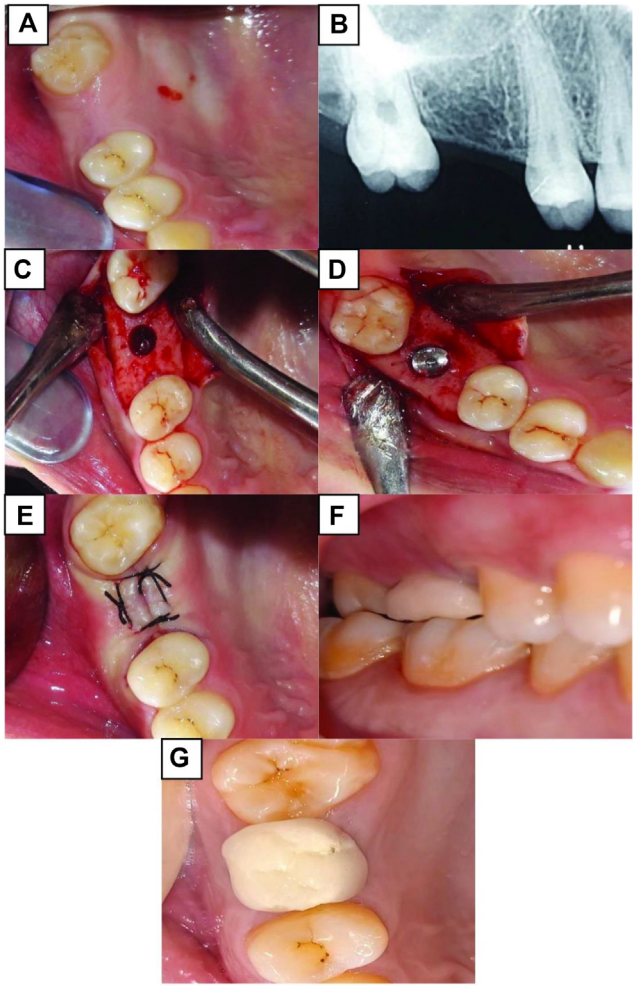

Fig. 2. Photographs of a case in second group showing; (A) intraoral occlusal view of the planned implant site (B) intraoral periapical radiograph (C) alveolar ridge after mucoperiosteal flap reflection and implant site preparation (D) the implant with Cover screw (E) mucoperiosteal flap repositioning and suturing (F) lateral view of Cemented PFM crown after 2 months from implant installation (G) occlusal view of cemented PFM crown 2 months following implant insertion.

Second stage surgery

According to the applied loading protocol (6 months in the first group and 2 months in the second group), implant fixture exposure was done through crestal incision after induction of local anesthesia. The cover screw was removed and healing abutment was placed for 2 weeks. However, in third group, the healing abutment was constructed immediately in the implant fixture during surgery without needing second-stage surgery.

Prosthetic phase

Open tray impression technique using rubber base impression material was done for each patient after removal of the healing abutment and

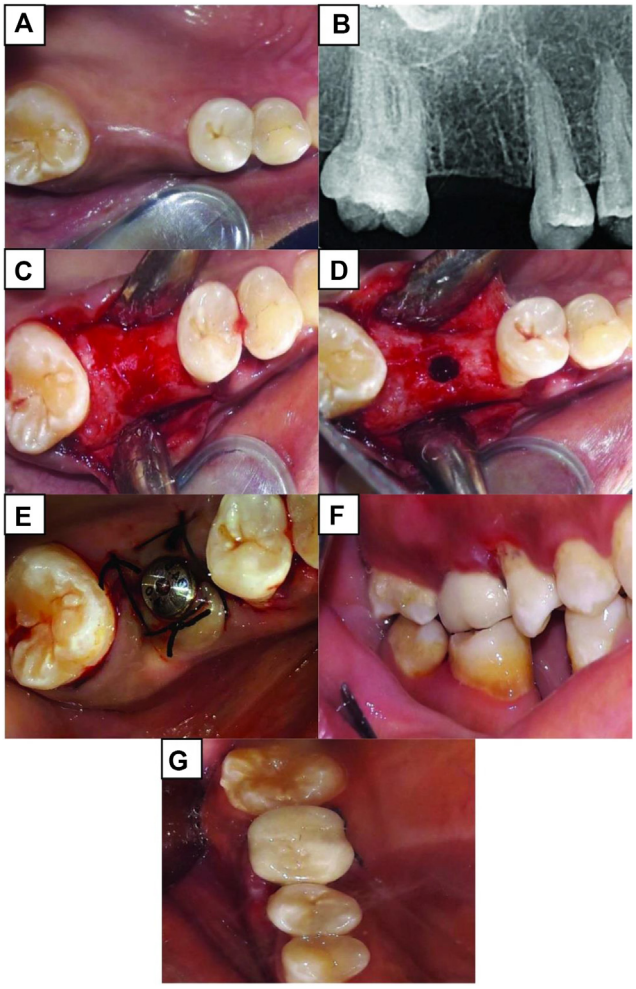

Fig. 3. Photographs of a case in the third group showing; (A) intraoral occlusal view of planned implant site (B) intraoral periapical radiograph (C) alveolar ridge after mucoperiosteal flap reflection (D) implant site preparation (E) mucoperiosteal flap repositioning and suturing after placement of the healing abutment (F) lateral view of Cemented PFM crown subjected to immediate loading (G) occlusal view of cemented PFM crown subjected to immediate loading.

placement of the transfer copy. Then, the implant analog was fixed to the transfer copy and sent to the lab. The final porcelain fused to a metal crown was cemented after making trials to ensure seatability and adaptability, Figs. 1–3.

Evaluation

Clinical evaluation

All the patients included in this study were evaluated at regular time intervals in the first year immediately (T1), 6 months (T2), and 12 months (T3) after crown cementation for the following clinical parameters.

Implant stability assessment[6]

Implant stability was measured using periotest (Medizintechnik Gulden, Bensheim, Germany) according to the following criteria: Grade I ranges from −08 to 0 (good osseointegration); The implant is well integrated and can be loaded, Grade II ranges from ±1 to ±9. A clinical examination is required; the implant loading is generally not (yet) possible, Grade III ranges from ±10 to ±20; Osseointegration is insufficient and implant loading is not possible.

Modified sulcus bleeding index[7]

Peri-implant sulcus bleeding was evaluated using a periodontal probe according to the following scores: Score 0: no bleeding when a periodontal probe is passed along the gingival margin adjacent to the implant, Score 1: isolated bleeding spots visible, Score 2: blood forms a confluent red line on margin, Score 3: heavy or profuse bleeding.

Assessment of the peri-implant probing depth[8]

A graded periodontal probe was use to measure the distance between the base of the pocket and the gingival margin. The probe was introduced until its blunt edge contacted the base of the pocket in a straight line with the implant's vertical axis. The pocket depth was measured from buccal and palatal aspects at three points for each aspect (mesially, distally, and at midpoint). The average was calculated for each implant and mesurément were taken down to the closest 0.5 mm.

Radiographic evaluation

Marginal bone level assessment (MBL) was performed by using intraoral periapical radiographs with parallel and long cone techniques at T1, T2, and T3. The MBL was measured on the mesial and distal sides of each implant using the SCANORA intraoral image tool, Fig. 4[9]

The distance from the implant platform to the most cervical point of bone-implant contact was measured mesially and distally. Bone loss at T2 and T3 was calculated by subtracting MBL at T2 and T3 from T1, respectively.[10]

Statistical analysis

Data were analyzed statistically using a statistical package for the social science program (SPSS 21 for PC, IBM Inc, Armonk, NY). Regarding inferential statistics, comparisons between the study groups were done using a one-way analysis of variance test for stability, probing depth, and MBL/loss and a Monte Carlo test for bleeding index. The statistical significance between different groups of the study

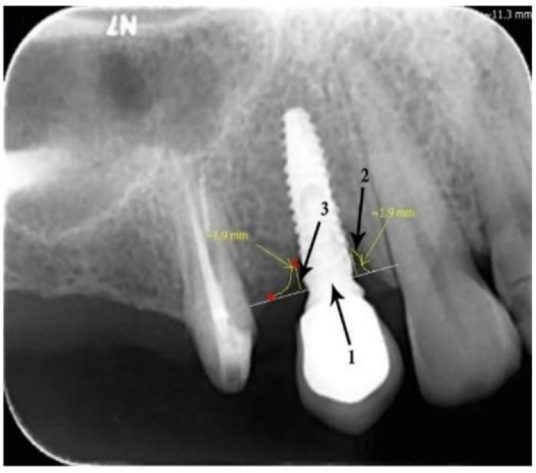

Fig. 4. Intraoral periapical radiograph showing; measurement of marginal bone level (3) from the reference line (1) using SCANORA intraoral image Tool.

regarding clinical and radiographic parameter values was calculated using the Pearson correlation coefficient. All *P* values less than 0.05 were considered statistically significant.

Results

This study included 14 patients (received 16 implants), 13 females and one male, with mean age 34.79 ± 9.17 years, with missing one or two teeth in the posterior maxillary region. No statistically significant differences between studied groups were revealed regarding age, sex, implant position, length and width ($P = 0.642$, $P = 0.260$, $P = 0.822$, $P = 0.053$, $P = 0.317$, respectively).

Clinical evaluation

Implant stability assessment

Implant stability was measured using a periotest device at T1, T2, and T3 periods for all implants. There were no statistically significant differences between studied groups regarding stability at different follow-up periods ($P = 0.06$, $P = 0.07$, $P = 0.150$). However, there were significant differences between group 1 versus group 2 at T1 and T2 ($P = 0.018$, $P = 0.028$), respectively. Pairwise comparison at T1 revealed no statistically significant differences between group 1 versus group 3 (P@=0.180), and between group 2 versus group 3 ($P! = 0.178$). At T2 there were no statistically significant differences between group 1 versus group 3 ($P@ = 0.063$), and between group 2 versus group 3 ($P! = 0.635$). Pairwise comparison at T3 revealed no significant differences between all included groups when compared against each other ($P# = 0.063$ and $P@ = 0.438$ and $P! = 0.192$), respectively, Table 1.

Modified sulcus bleeding index

Peri-implant sulcus bleeding was evaluated using a periodontal probe. Comparing all groups, no statistically significant differences were recorded at T1 and T2 periods ($P = 0.655$, $P = 0.144$), respectively. While there was a high statistical difference among all groups at T3 ($P = 0.015$). However, pairwise comparison between every two groups revealed no significant difference at T1 ($P# = 0.392$, $P@ = 0.862$, $P! = 0.256$), respectively.

While at T2 there were significant differences between group 1 versus group 2 ($P# = 0.03$) and between group 2 versus group 3 ($P! = 0.034$). How-

Table 1. Descriptive statistics and inter/intra group significance of periotest values at different time intervals of follow-up.

Group/time of assessment	Group 1 n = 4	Group 2 n = 6	Group 3 n = 6	Test of significance	Inter group significance
T1	2.50 ± 1.73	−0.67 ± 2.07	0.833 ± 1.60	F = 3.66 P = 0.06	P# = 0.018* P@ = 0.180 P! = 0.178
T2	0.50 ± 2.51	−2.33 ± 1.51	−1.833 ± 1.47	F = 3.28 P = 0.07	P# = 0.028* P@ = 0.063 P! = 0.635
T3	−0.75 ± 2.62	−3.50 ± 1.38	−2.50 ± 2.32	F = 2.20 P = 0.150	P# = 0.063 P@ = 0.438 P! = 0.192
Intragroup comparison of follow-up	P1 = 0.07 P2 = 0.07 P3 = 0.06	P1 = 0.024* P2 = 0.024* P3 = 0.02*	P1 = 0.027* P2 = 0.02* P3 = 0.480		

F: One Way analysis of variance test, p1: difference between T1 and T2, P2: difference between T1 and T3, P3: difference between T2 and T3, *P#*: difference between group 1 and 2, *P@*: difference between group 1 and 3, *P!*: difference between group 2 and 3.

Table 2. Modified sulcus bleeding index score distribution and inter/intra group significance at different time intervals of follow-up.

Group/time of assessment	Group 1 n = 4 (%)	Group 2 n = 6 (%)	Group 3 n = 6 (%)	Test of significance	Inter group significance
T1					*P*# = 0.392
0	2 (50)	4 (66.7)	2 (33.3)	MC = 2.44	*P*@ = 0.862
1	1 (25)	2 (33.3)	3 (50)	*P* = 0.655	*P*! = 0.256
2	1 (25)	0	1 (16.7)		
T2					*P*# = 0.03*
0	0	3 (50)	0	MC = 6.85	*P*@ = 0.795
1	3 (75)	3 (50)	5 (83.3)	*P* = 0.144	*P*! = 0.034*
2	1 (25)	0	1 (16.7)		
T3					*P*# = 0.004*
0	0	5 (83.3)	0	MC = 12.39	
1	3 (75)	1 (16.7)	4 (66.7)	*P* = 0.015*	*P*@ = 0.789
2	1 (25)	0	2 (33.3)		*P*! = 0.001*
Intragroup comparison of follow-up	P1 = 0.157 P2 = 0.157 P3 = 1.0	P1 = 0.564 P2 = 0.564 P3 = 0.157	P1 = 0.157 P2 = 0.276 P3 = 0.564		

MC: Monte Carlo test, p1: difference between T1 and T2, P2: difference between T1 and T3, P3: difference between T2 and T3, *P*#: difference between group 1 and 2, *P*@: difference between group 1 and 3, *P*!: difference between group 2 and 3.

ever, there was no statistically significant difference between group 1 versus group 3 (*P*@ = 0.795). Additionally, at T3 there were statistically significant differences between group 1 versus group 2 (*P*# = 0.004) and between group 2 versus group 3 (*P*! = 0.001). However, there was no statistically significant difference between group 1 versus group 3 (*P*@ = 0.789), Table 2.

Peri-implant pocket depth evaluation

A graded periodontal probe was used to measure the peri-implant pocket depth at T1, T2, and T3 periods. There were no statistically significant differences between studied groups regarding mean probing depth at different time intervals of follow-up (*P* = 0.180, 0.129, 0.961), Table 3.

Radiographic evaluation

MBL was performed by using intraoral periapical radiographs with parallel and long cone techniques at T1, T2, and T3 periods. The MBL was measured on the mesial and distal sides of each implant using the SCANORA intraoral image tool Bone loss at T2 and T3 was calculated by subtracting MBL at T2 and T3 from T1, respectively.

A statistically significant difference between studied groups regarding MBL was detected at T1, T2, and T3 periods (*P* < 0.001, *P* = 0.015, *P* = 0.02). Post Hoc Tukey test demonstrated statistically significant differences within each of the studied pairs between groups 1 versus 2 (*P*# = 0.03), between groups 1 versus 3 (*P*@ = 0.001), and between groups 2 versus 3 (*P*! = 0.001) at T1.

Table 3. Descriptive statistics and inter/intra group significance of probing depth measurements at different time intervals of follow-up.

Group/time of assessment	Group 1 n = 4	Group 2 n = 6	Group 3 n = 6	Test of significance	Inter group significance
T1	2.0 ± 0.70	1.33 ± 0.26	1.58 ± 0.58	F = 1.96 *P* = 0.180	*P*# = 0.069 *P*@ = 0.238 *P*! = 0.422
T2	2.0 ± 0.71	1.42 ± 0.37	1.83 ± 0.26	F = 2.41 *P* = 0.129	*P*# = 0.062 *P*@ = 0.569 *P*! = 0.127
T3	2.0 ± 0.81	2.08 ± 0.38	2.08 ± 0.38	F = 0.04 *P* = 0.961	*P*# = 0.805 *P*@ = 0.805 *P*! = 1.0
Comparison of follow-up	*P*1 = 1.0 *P*2 = 1.0 *P*3 = 1.0	*P*1 = 0.611 *P*2 = 0.017* *P*3 = 0.01*	*P*1 = 0.296 *P*2 = 0.203 *P*3 = 0.203		

F: One way analysis of variance test, p1: difference between T1 and T2, P2: difference between T1 and T3, P3: difference between T2 and T3, *P*#: difference between group 1 and 2, *P*@: difference between group 1 and 3, *P*!: difference between group 2 and 3.

Table 4. Descriptive statistics and inter/intra group significance of marginal bone level and bone loss at different time intervals of assessment.

Group/time of assessment	Group 1 n = 4	Group 2 n = 6	Group 3 n = 6	Test of significance	Within group significance
T1	1.70 ± 0.244	1.08 ± 0.59	0.167 ± 0.12	F = 19.44 *P* < 0.001*	*P*# = 0.03* *P*@ = 0.001* *P*! = 0.001*
T2	1.83 ± 0.53	1.38 ± 0.62	0.783 ± 0.214	F = 5.91 *P* = 0.015*	*P*# = 0.178 *P*@ = 0.005* *P*! = 0.05*
T3	2.20 ± 0.43	1.65 ± 0.66	1.20 ± 0.21	F = 5.26 *P* = 0.02*	*P*# = 0.05* *P*@ = 0.006* *P*! = 0.127
Comparison of follow-up	*P*1 = 0.478 *P*2 = 0.019* *P*3 = 0.036*	*P*1<0.001* *P*2<0.001* *P*3<0.001*	*P*1 = 0.002* *P*2<0.001* *P*3 = 0.003*		
Bone loss T1-T2	0.275 ± 0.125	0.300 ± 0.089	0.617 ± 0.248	F = 6.59 *P* = 0.01*	*P*# = 0.828 *P*@ = 0.01* *P*! = 0.008*
Bone loss T1-T3	0.500 ± 0.216	0.567 ± 0.137	1.03 ± 0.15	F = 17.31 *P* < 0.001*	*P*# = 0.538 *P*@ = 0.008* *P*! = 0.001*

F: One way analysis of variance test, p1: difference between T1 and T2, P2: difference between T1 and T3, P3: difference between T2 and T3, p#: difference between group 1 and 2, p@: difference between group 1 and 3, p!: difference between group 2 and 3.

At T2, post hoc Tukey test showed statistically significant differences between group 1 versus 3 (*P*@ = 0.005) and between group 2 versus 3 (*P*! = 0.05), while there was no statistically significant difference between group 1 versus 2 (*P*# = 0.178). At T3, there were statistically significant differences between group 1 versus 2 (*P*# = 0.05) and between group 1 versus 3 (*P*@ = 0.006), while there was no statistically significant difference between group 2 versus 3 (*P*! = 0.127), Table 4.

Regarding mean bone loss (BL) statistically significant differences between studied groups were detected when subtracting T2 from T1 (*P* = 0.01) and T3 from T1 (*P* < 0.001). Regarding bone loss assessment between T1 and T2 periods, statistically significant differences were detected between groups 1 versus 3 (*P*@ = 0.01) and between groups 2 versus 3 (*P*! = 0.008). There was no statistically significant difference between groups 1 versus 2 (*P*# = 0.828).

Regarding BL assessment between T1-T3, a statistically significant differences between group 1 versus 3 (*P*@ = 0.008) and between group 2 versus 3 (*P*! = 0.001), while there was no statistically significant difference between groups 1 versus 2 (*P*# = 0.538), Table 4.

Discussion

Immediately loaded implants are an alternative in the rehabilitation of edentulous patients. However, to date, many studies have been conducted in an attempt to understand the impact of immediate loading on osseointegration.[11] The present study aimed to evaluate stability, probing depth, bleeding on probing, and peri-implant bone loss around dental implants under different loading protocols.

Regarding the success rates of implants loaded with different protocols, there are no conclusive findings.[12] The current study examined the performance of dental implants in the posterior maxilla with single/multiple tooth/teeth replacement under immediate (within 72 h), early (8 weeks), and delayed (after 6 months) loading regimens. In our investigation, there were no recorded implant failures in any of the loading groups (survival rate: 100 %). Other investigations on implants that were loaded right away supported this high survival rate.[13–16]

The results of this study showed that, at the time of crown cementation, the mean periotest (PT) values were 2.5 ± 1.73 in the conventional loading group, −0.67 ± 2.07 in the early loading group, and 0.833 ± 1.60 in the immediate loading group. According to Tallarico et al..[17] The primary anchoring is impacted by the dental implant's macro-design. They claimed that decisions concerning immediate loading on dental implants are influenced by the high initial periotest value (PTV). Based on this finding, the thread implants were used in this study revealing strong primary stability (PT values were close to 0 score).

Regarding implant stability measurements after 6 and 12 months of follow-up, the mean PT values improved obviously in the early (−2.33 ± 1.51 and −3.50 ± 1.38) and immediate (−1.833 ± 1.47 and −2.50 ± 2.32) loading groups of a single implant in

the maxillary posterior area, being better treatment results than in delayed (0.50 ± 2.51 and −0.75 ± 2.62) loading group, respectively. These results are in harmony with those of other clinical studies, such as those conducted by Akoglan et al..[18] This investigation examined the impact of various loading techniques on secondary stability. When compared with delayed-loading procedures, immediate or early loading techniques allow patients to resume chewing sooner while also increasing implant stability and peri-implant bone density.

According to Luterbacher et al..[19] Bleeding on probing (BOP) provides statistically superior diagnostic results for implants compared with teeth. According to Ericsson and Lindhe,[20] the dog's healthy implant sites recorded higher BOP values than the dog's healthy natural dentition. The study of Bhardwaj *et a.l*[21] revealed periodontitis-free patients with good general hygiene as they were instructed to use chlorhexidine mouthwash after surgery, 87 % of implant locations display healthy gingiva. This finding is in harmony with our findings, where 83 % of implant sites show healthy gingiva.

On the other hand, according to Becker et al..[22] Elevated peri-implant probing depth (PPD) values are a significant indicator reflecting a high chance of infection developing in the implant mucosa. Our findings revealed, that mean PPD values were closer to each other at follow-up periods in group 1, they ranged from 2.0 ± 0.70 mm, 2.0 ± 0.71 mm to 2.0 ± 0.81 mm at different follow-up periods. In group 2, these values increased from 1.33 ± 0.26 mm and 1.42 ± 0.37 mm at T1 and T2, respectively to 2.08 ± 0.38 mm at T3. In group 3, the mean PPD values ranged from 1.58 ± 0.58 mm, 1.83 ± 0.26 mm, and 2.08 ± 0.38 mm at T1, T2, and T3, respectively. A significant increase in PPD was not observed with time in the present study in both group 1 (P1, P2, P3 = 1) and group 3 (P1 = 0.296, P2 = 0.203, P3 = 0.203), indicating that the implant mucosa was kept in healthy condition from the beginning of the study.

BL is considered the main clinical sign of peri-implantitis, often accompanied by a set of other signs such as augmented PPD, BOP, edema, etc., that may also be present in mucositis on their own. According to the 2017 World Workshop on the Classification of Periodontal and Peri-implant Diseases and Conditions, peri-implantitis is defined as radiographic bone loss greater than or equal to 3 mm.[23] Otherwise, if no initial radiographs and probing depth values are available, peri-implantitis is defined as radiographic BL greater than or equal to 3 mm and/or PPD greater than or equal to 6 mm, together with profuse bleeding.

Within the limitations of this study and cautious interpretation due to a small number of implants/patients, the timing of application of force during osseointegration has an impact on implant stability and peri-implant soft and bony tissues condition.

Conclusions

Earlier loading positively enhances osseointegration around the immediately loaded and the early loaded implants when compared with conventionally loaded dental implants. On the other hand, greater bone loss was observed in the immediately loaded and the early loaded implants than in the conventionally loaded implants.

Funding

This research received no external funding.

Data availability

The data sets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Conflict of interest

There are no conflicts of interest.

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