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Comparative clinical assessment of hard and soft tissue responses around dental implants placed with conventional versus relaxed bed techniques

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Abstract:
Preservation of crestal bone and peri-implant soft tissues is important for long-term implant success. Therefore, it is of interest to evaluate the 30 implants placed using conventional and relaxed bed techniques in partially edentulous patients. Crestal bone levels were assessed using IOPAR, CBCT, while soft tissue parameters were evaluated at three and six months post-loading. Data shows, no significant differences in crestal bone loss or soft tissue changes ($p > 0.05$). Thus, both techniques showed comparable clinical outcomes, indicating that relaxed bed approach is a viable alternative to conventional technique.

Keywords: Crestal bone levels (CBL), delayed implant bed, relaxed implant bed

Background:
Dental implants are a reliable option for replacing missing teeth due to their high survival rates and favorable functional and esthetic outcomes. Since the work of Brånemark, osseointegration has been the key biological principle ensuring implant success **[1].** Crestal bone loss around dental implants is influenced by multiple factors, with surgical technique and thermal injury during osteotomy playing a critical role. Bone is highly sensitive to heat (above 47°C), making proper irrigation and controlled drilling essential to preserve osseointegration **[2]**. Osseointegration is a dynamic process involving continuous bone remodeling, were primary mechanical stability transitions into biological stability. Disruptions during healing can negatively affect marginal bone levels and peri-implant soft tissue health **[3]**. Implant stability is a crucial clinical parameter, commonly assessed using insertion torque and resonance frequency analysis (RFA). These methods guide loading protocols, with higher primary stability minimizing micromotion and preserving crestal bone **[4]**. Early osteotomy with delayed implant placement may stimulate the regional acceleratory phenomenon, enhancing bone healing. This approach can support immediate loading while maintaining favorable bone response **[5]**. The "relaxed implant bed" technique involves placing implants two weeks after osteotomy with immediate loading, allowing initial healing and reduced surgical trauma. This approach enhances osseointegration and shows promising results in implant stability and marginal bone preservation **[6]**. Clinical studies show that implants placed in a delayed osteotomy site exhibit less crestal bone loss than conventional placement. This suggests that modifying implant bed preparation can improve peri-implant bone response **[7].** Prosthetically driven implantology focuses on planning implant placement based on the final prosthetic outcome to ensure optimal force distribution and emergence profile. A coordinated surgical–prosthetic approach helps prevent overload and crestal bone loss **[8].** Recent advances such as improved implant surfaces and CBCT-based planning have been shown to influence crestal bone responses and implant stability under varying clinical conditions **[9, 10].** In addition, modified drilling protocols have showed their potential in enhancing osteointegration and peri- implant bone preservation **[11, 12]**. Furthermore, systematic reviews have highlighted that modifications in drilling protocols and implant site preparation techniques may influence implant stability and marginal bone levels, although clinical outcomes remain comparable among different approaches **[13, 14]**. In addition, studies have emphasized the significance of peri-implant tissue stability in maintaining long-term crestal bone levels and overall implant success **[15]**. Studies have further highlighted the role of biological and inflammatory responses in peri-implant tissues, underlining their impact on bone remodeling dynamics **[16]**. Moreover, few studies reported that careful implant site preparation and atraumatic surgical approaches contribute to improved healing outcomes and implant longevity **[17]**. Supporting these findings, it is further showed that long-term implant success is closely associated with the maintenance of peri-implant bone and soft tissue health, reinforcing the importance of optimized surgical and prosthetic protocols **[18]**. Therefore, it is of interest to conduct a controlled clinical study comparing conventional and relaxed implant bed techniques in order to evaluate their effectiveness in preserving bone and soft tissue.

Materials and Methods:
Study settings and sample preparation:
The present randomized controlled trial was conducted in the Department of Prosthodontics and Crown & Bridge, Institute of Dental Studies & Technologies, Modinagar. A thorough clinical, laboratory and radiographic examination was done to verify the morphologic characteristics of the proposed site for implant and the location of surrounding landmarks. All patients were given adequate information about the procedure and were provided with possible alternatives. The total study sample of 30 was divided into two groups by using random number sequence generated online. The selected healthy patients were treated using titanium platform switched implants (Touareg–S; Adin, Israel) with different diameters and lengths.

Operative procedure:
Surgeries were completed following standard aseptic protocols. Local anesthesia was administered, followed by a mid-crestal incision in mandibular posterior, with releasing incisions. Osteotomy was performed and implants were placed with insertion torque of 30-50 Ncm. Cover screws were placed and

suturing was completed for implants placed with conventional technique. In relaxed implant bed technique, osteotomy was conducted followed by flap suturing without immediate implant placement, allowing the socket time to heal. After an approximate 2-week period, the surgical site was revisited for implant placement. And after slight curettage and saline irrigation, implants were placed with an insertion torque ranging from 30 to 50 Ncm. After 8 weeks of uninterrupted healing, 2nd stage surgery was performed. One week after the 2nd stage surgery, patients underwent open tray impressions to create screw-retained prostheses. A subsequent jig trial ensured a passive fit, followed by shade matching and sending casts and University of California, Los Angeles (UCLA) abutments for crown fabrication. Implants were functionally loaded within a week, with follow-up evaluations at six months to monitor tissue changes.

Evaluation parameters:

Crestal bone level was assessed by Cone Beam Computed Tomography (CBCT) as well as Intraoral Periapical Radiography (IOPAR) and the soft tissue changes were evaluated by recording the probing depth, bleeding on probing and modified plaque index. The patients were followed for 6 months, both clinically and radiographically.

Statistical analysis:

SPSS 25.0 software was used for analysis of the data and Microsoft excel have been used to generate tables. Results on continuous measurements were presented as Mean ± SD (Min-Max). Significance was assessed at 5% level of significance. Mann Whitney U Test was used to find the significance of study parameters on ordinal scale between two groups.

Table 1: Comparison of crestal bone levels measured using CBCT among two groups

Interval	Conventional	Relaxed implant bed	p value
Post-op	0.06±0.64	-0.35±0.59	0.077
6 months	-0.40±0.61	-0.69±0.56	0.171

Table 2: Comparison of crestal bone levels measured using IOPA among two groups

Interval	Conventional	Relaxed implant bed	p-value
Post-op	0.233±0.642	-0.030±0.542	0.235
2nd stage	-0.090±1.038	-0.390±0.793	0.382
Loading	-0.013±1.192	-0.430±0.769	0.265
6 months	-0.220±1.452	-0.590±0.708	0.383

Table 3: Comparison of probing depth, bleeding index, modified plaque index among two groups

Clinical Parameter (Time point)	Conventional (mean ± SD)	Relaxed Implant Bed (mean ±SD)	P value
Probing Depth (loading)	2.333±0.584	2.400±0.463	0.732
Probing Depth (3 months)	1.875±0.381	2.075±0.450	0.200
Probing Depth (6 months)	1.625±0.280	1.867±0.421	0.075
Bleeding Index (at loading)	0.930 ±0.704	1.330±0.617	0.114
Bleeding Index (3 months)	0.750±0.211	0.783±0.185	0.650
Bleeding Index (6 months)	0.470±0.551	0.870±0.743	0.130
Modified Plaque Index (at loading)	0	0	1
Modified Plaque Index (3 months)	0.600±0.632	0.800±0.561	0.321
Modified Plaque Index (6 months)	1.070±0.704	1.470±0.516	0.109

Results:

At the time of placement, crestal bone levels were 0.06±0.64 mm in conventional group compared to -0.35±0.59 mm in relaxed implant bed group (p=0.077, Mann Whitney U test) as assessed by CBCT. Whereas, crestal bone level after 6 months post loading for conventional group were -0.40±0.61mm and for relaxed implant bed group were -0.69±0.56 mm (p=0.171, Mann Whitney U test). Both showed a non-significant difference at each interval **(Table 1).** Measurements at the time of implant placement, checked using IOPAR were 0.233 ± 0.642 mm for conventional group whereas in relaxed implant bed the measurements were -0.030 ± 0.542 mm (p=0.235, Mann Whitney U test). Measurements after 6 months post loading checked using IOPAR were -0.220 ± 1.452 mm for conventional group whereas in the relaxed implant bed the measurements were -0.590 ± 0.708 mm (p=0.383, Mann Whitney U test). Both showed a non-significant difference at each interval **(Table 2).** All implants remained stable with a 100% survival rate at 6 months. Probing depth decreased in both groups, with a greater reduction in the relaxed implant bed group, though the difference was not significant (p=0.075). Bleeding index also decreased over time, showing overall improvement by 6 months (p=0.130). Plaque index was zero at loading and showed no significant differences at 3 and 6 months (p=0.321, p=0.109) **(Table 3).**

Discussion:

The present study compared crestal bone levels (CBL) and soft tissue parameters around implants placed using the conventional technique and the relaxed implant bed technique (delayed implant placement 2 weeks after osteotomy). Both groups were loaded following early loading protocols in accordance with the consensus statements reported by Weber *et al.* **[15].** Early healing around implants includes fibrin clot formation, inflammatory cell migration and woven bone deposition. In the relaxed implant bed technique, a 2-week interval between osteotomy and implant placement was intended to enhance biologic activity at the recipient site **[16]**. Animal studies also showed accelerated healing and higher implant stability quotient values with delayed placement compared to immediate placement **[17]**. A similar study, reported greater bone-to-implant contact and bone volume in implants placed 14 days post-osteotomy using microcomputed tomography and histomorphometric analysis. These findings support the theoretical advantage of the relaxed implant bed concept in promoting enhanced osseointegration **[18].** However, in the present study, marginal differences in crestal bone loss were observed between the two groups, with slightly greater CBL in the relaxed implant bed group. The osteoclastic activity predominates during early healing, particularly around the second week, when necrotic bone fragments are resorbed before peak osteoblastic activity is established. Thus, placing implants at the 2-week mark may coincide with heightened osteoclastic resorption, potentially contributing to increased early crestal remodelling **[16].** Similar findings were reported in a study published in the Journal of Contemporary Dental Practice, where no statistically significant difference in crestal bone loss was observed between immediate and delayed implant placement groups over a 6-month period, despite minor variations in measured values. This suggests that timing of implant placement may not critically influence early crestal bone changes under controlled clinical conditions **[19].** Radiographic assessment of CBL was performed using both intraoral periapical radiographs (IOPAR) and cone-beam computed tomography (CBCT). Radiographic evaluation remains the gold standard for monitoring peri-implant bone levels **[20]**. Researches further highlighted that etiologic factors for CBL include surgical trauma, implant design, occlusal overload and peri-implant inflammation **[21]**. CBCT provided three-dimensional assessment of mesial, distal, buccal and lingual bone levels, aligning with recommendations for precise implant evaluation. CBCT should be justified based on clinical need due to radiation exposure considerations. The omission of CBCT at the 3-month interval in this study reflects adherence to these guidelines **[22, 23]**. Soft tissue parameters, including probing depth and bleeding on probing (BOP), improved over time in both groups. The peri-implant mucosal maturation between 6 and 12 weeks, characterized by epithelial barrier formation and collagen fiber organization. This biologic maturation may explain the reduction in probing depths observed in the present study **[16]**. In agreement with these findings, the JCDP study showed progressive improvement in peri-implant soft tissue parameters over time, with significant differences in esthetic scores favoring immediate implants, while delayed implants still showed acceptable healing outcomes, indicating that both approaches support soft tissue maturation **[19].** Studies reported that soft tissue thickness significantly influences crestal bone stability, with thicker mucosa associated with reduced bone loss. Although mucosal thickness was not directly measured in this study, its potential influence on CBL cannot be disregarded **[24]**. The role of prosthetic loading and design also merits consideration. Early loading protocols require adequate primary stability and controlled occlusal forces. Excessive stress at the implant–abutment interface may contribute to marginal bone remodeling **[15]**. Prosthetic factors such as screw-retained versus cement-retained restorations can influence peri-implant health, highlighting biological complications associated with residual cement. Although prosthetic variables were standardized in the present study, occlusal stresses after loading may have contributed to minor increases in CBL in both groups **[25]**. Radiographic bone changes must also be interpreted alongside clinical parameters. In this study, BOP values at 6 months post-loading remained low in both groups, suggesting favorable peri-implant tissue health. The findings align with previous literature indicating that early marginal bone remodeling within acceptable thresholds does not compromise implant survival **[21]**. Overall, the relaxed implant bed technique demonstrated comparable clinical outcomes to the conventional approach within the 6-month follow-up period. Although animal studies suggest enhanced osseointegration with delayed placement, the present human clinical findings indicate that both techniques yield predictable short-term results when executed under controlled surgical and loading conditions **[17, 18]**.

Conclusion:

The conventional implant placement technique showed slightly less crestal bone loss than the relaxed implant bed technique, though the difference was not statistically significant. Both techniques showed similar probing depth, bleeding index and plaque index outcomes, indicating comparable soft tissue responses. Overall, both approaches are clinically effective, though further research may refine the relaxed implant bed technique.

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