Original Article

Comparative evaluation of crestal bone levels following placement of implant in delayed implant bed: An *in vivo* clinical study

ABSTRACT

Background: Restoring lost dentition using dental implant is one of the most promising treatment modality, for both complete and partially dentulous situation. In order to have more predictable outcome, the quest for coming up with a surgical protocol has been never ending. Keeping the same in mind the present study was conducted to place implant in delayed implants beds, i.e., 14 days after the osteotomy site was prepared.

Materials and Methods: For the purpose of the study, ten implants measuring 4.2 mm   10 mm were placed in ten healthy individuals with missing mandibular first molars in site prepared 14 days before actual placement of implants, i.e., delayed implant beds.

Results: The study revealed that, on evaluation of the bone levels at the time of placement of prosthetic loading revealed, a bone gain was maximum after 3 months of prosthetic loading.

Conclusion: A significant bone gain with a mean of 0.8 mm makes this technique of placing implants in delayed implant beds a more predictable technique than conventional protocol.

Keywords: Enhancement of alveolar binding capability, implant bed preparation, surgical protocol

INTRODUCTION

Tooth loss is multifactorial, complex interaction of multiple comorbidities which when left unresolved may progress to edentulism. Dental implants have taken over the contemporary dental treatment as a substitute of missing teeth that involve the use of titanium or titanium alloys for tooth root replacement (dental implant fixture) to support fixed and removable oral prosthesis which are meant to restore the missing tooth. The objective of placing an implant is to achieve a successful prosthetic restoration.

Branemark (1969) published a landmark research, documenting the successful "bone to implant" interface of an endosseous dental implant. This is a widely accepted fact, thus enabling dental implants as a treatment modality for the replacement of missing teeth. He coined the phrase "bone to implant interface" which is now known as the term "osseointegration."

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Attempts to shorten the overall treatment time have focused on approaches such as early or immediate loading following implant placement, immediate implant placement in fresh extraction sites, and immediate implant placement with early or immediate loading.[1]

Studies with immediate implant placement have recommended that the extraction sites are thoroughly debrided of infected

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material before implant placement, followed by postoperative systemic antibiotics. In such situations, implant bed preparation along with the extraction, followed by a waiting time of 2 weeks for delayed implant placement can ensure complete elimination of the remaining infection at the implant site.[1]

Heat was reported to impair the overall activityof the bone tissue by causing hyperemia, necrosis, fibrosis, osteocytic degeneration, and increased osteoclastic activity. Studies have stated that temperatures ranging from 56°C to 70°C are deleterious because of alkaline phosphatase (AP) in bone tissues which get denaturated at that level. Eriksson, Albrektsson, demonstrated that bone is more sensitive to heat and it will withstand a threshold temperature ranging from 44°C to 47°C for only 1 minute without impaired bony regeneration., Eriksson *et al* also concluded that temperatures below the denaturation point of AP (53°C) could be considered harmful to the reparative capability of bone, as burning and resorption of fat cells together with sluggish blood flow. Eriksson and Albrektsson also reported that heating up to 47°C was considered the finest limit that bone can withstand without necrosis. From a mechanical viewpoint, heat was reported to cause disruption in the structure lattice of hydroxyapatite mineral, to the extent that microscopic deformation (creep) of compact bone could be observed.[2]

According to Anil *et al*., osteotomy followed by delayed implant placement allows for implant placement into an environment that is more conducive to healing and osseointegration and allows bone to recuperate from surgical damage.[1]

Recent research advocates that the precise preparation of the implant bed and adequate primary implant stability are the vital factors for the enhancement of bone implant interface in order to facilitate immediate loading.[3]

According to a histological study by Ogiso *et al*., maximum bone resorption occurs at the margins of the bone defect by the 2nd week, and rapid formation of new trabecular bone starts by the 3rd week in an attempt to restore the defect. Thus, offering a relaxed healing implant bed structured to accept a fixture is preferable to inserting a fixture in a traumatized and heated site for obvious reasons, thus proving its potential in enhancing the alveolar binding capability before implantation.[4]

MATERIALS AND METHODS

The present study was conducted to evaluate the proximal crestal bone level around implant, using standardized intraoral periapical radiograph at three different intervals in delayed implant bed (i.e., 14 days following osteotomy). The study was approved by the institutional ethical committee.

A detailed medical and dental history was taken, followed by intraoral examination to assess the condition of edentulous spaces for hard and soft tissues. Baseline hematological investigations were conducted. Preoperative cone-beam computed tomography (CBCT) scan following standard operating protocol was done to evaluate the bone level and distance from the vital structures and quality of bone at edentulous site. Patients with partially edentulous mandibular arch with missing mandibular first molar (Kennedy's Class III) were included in the study. Patients were explained about the procedure, and a consent was taken for the same. Maxillary and mandibular arch diagnostic impression was made for fabrication of surgical stent for accurate implant placement as planned with the help of the CBCT scan. Implant bed was prepared using standard surgical protocols for the placement of the Adin-root form, threaded collar Implant, with internal hex 4.2 mm in diameter and 10 mm in length in the mandibular first molar region for all the subjects.

Surgeries were completed following the standard aseptic protocols. A full thickness flap was reflected, and the implant osteotomy site was marked using the [Figure 1] pilot drill with the help of surgical stent [Flowchart 1]. Sequential osteotomy was performed according to the implant size planned for the patients. The site was sutured to achieve primary closer. Postoperative instructions were given to the patient. The patient was recalled for the suture removal after 5–7 days, and the implant placement was done on the 14th day from the day of implant bed preparation. Following the standard sterile protocols, the osteotomy site was relocated using the previously fabricated surgical stent which was used at the time of surgery initially. Reopening of the site was done

Figure 1: Pilot drill through stent

by tissue punch (3.5 mm diameter). The implant was then placed at the level of the crestal bone at the osteotomy site using a calibrated Ratchet at a torque >35N, which was confirmed by the radiovisiography (RVG) at the time of ostetomy, taken following the standardized paralleling technique using a positioner parallel to the long axis of the implant and perpendicular to the X-ray tube head. The image was stored for future comparison [Figure 2].

After 10 weeks of uninterrupted healing, Stage II surgery was performed. The cover screw was removed and gingival former placed at a torque of 20 Ncm to achieve the gingival cuff, self-cleaning area, emergence profile, and the patients were recalled after 10 days. On the 10^{th} day, following the second stage surgery, closed tray implant level impressions were made using an elastomeric impression material. Porcelain fused to metal restorations were fabricated [Figure 3] and evaluated for passive occlusal contacts in centric and no contact in eccentric position. At the time of implant loading, the measurements were taken from the implant abutment junction considering it at the level of crest of the alveolar bone following the previously mentioned protocol to evaluate the crestal bone level using RVG [Figure 4], and the image was saved for the future comparison with the bone levels at the time of implant placement. After 3 months of conventional loading, the patients were re-evaluated for crestal bone level [Figure 5]. It was done following the previously mentioned protocol using RVG and the values then obtained for all the subjects.

RESULTS

The present study was undertaken to evaluate the effect of crestal bone levels around implants placed in delayed implant sites prepared 14 days before placement of implants, using digital radiography (RVG). For the purpose of the study, implants measuring 4.2 mm (Diameter) ×10 mm (Length) were placed in ten individuals with missing mandibular first molars selected, and the crestal bone levels were evaluated at three intervals viz.

1. At the time of placement of implants

Figure 2: Baseline bone level evaluation

Figure 3: Occlusal view of prosthesis

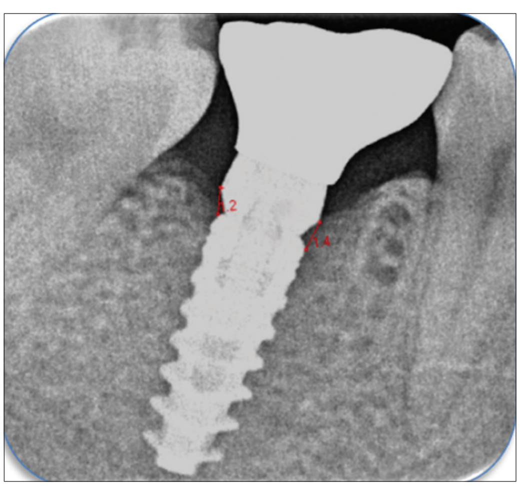


Figure 4: Evaluation of bone level at the time of prosthesis placement

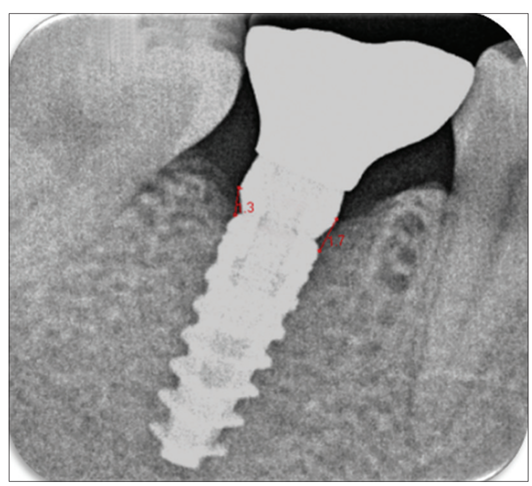
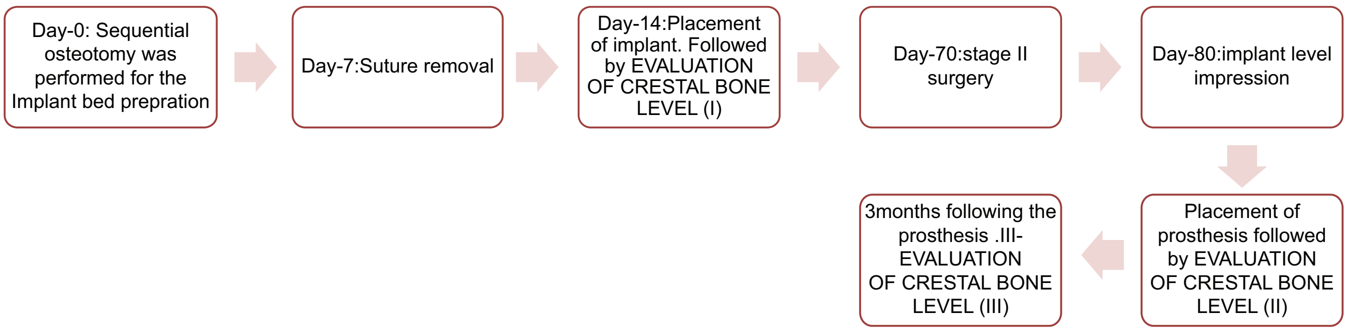


Figure 5: Bone level evaluation 3 months after the functional loading

Table 1: Comparative analysis of bone levels at 3 time intervals i.e., at the time of placement of implants, at the time of placement of prosthesis i.e., 2 months from the time of implant placement, and 3 months after of the prosthetic loading

	n	Baseline	At the time of prosthetic loading	Three months after the prosthetic loading	*P*
Mesial	10	0	0.79±0.40	0.85±0.43	<0.001
Distal	10	0	0.70±0.32	0.75±0.28	<0.001
Mean	10	0	0.73±0.35	0.78±0.35	<0.001



Flowchart 1: Methodology

2. At the time of placement of prosthesis, i.e., 2 months from the time of implant placement
3. After 3 months of the prosthetic loading.

After data assimilation, the same was subjected to statistical analysis using SPSS 22 (Version: 1.0.0.1406, Operating System: Windows, Mac, Linux, Developer Name: IBM), and a $P < 0.05$ was considered statistically significant.

Table 1 Graphs 1 and 2 illustrates the crestal bone levels observed at three intervals, i.e., at the time of implant placement; at the time of placement of prosthesis (i.e., 3 months from the implant placement); and after 3 months of the prosthetic loading. It was evident that a definitive bone gain was observed from the placement of implant till the final observations were recorded radiographically, and the maximum bone gain observed 3 months postfunctional loading with a mean of 0.8 mm.

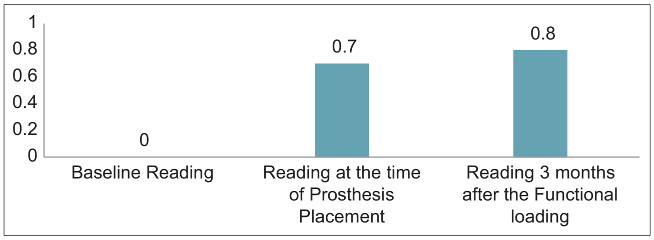
DISCUSSION

It is a well-established fact that, during the preparation of implant bed, excessive surgical trauma and thermal injury might lead to osteonecrosis and result in fibrous encapsulation around the implant.[1] According to Eriksson *et al*.[5] on thermal injury to bone, temperature over 47°C for 1 min causes "heat necrosis" in the bone and without irrigation, drill temperatures above 100°C are reached within seconds during the osteotomy, thereby necessitating adequate cooling with the internal and external saline irrigation to minimize the thermal injury to the implant bed. Surgical trauma includes thermal injury and mechanical trauma that may cause microfracture of bone during implant placement, which may lead to osteonecrosis and possible fibrous and granulation tissue encapsulation around the implant.

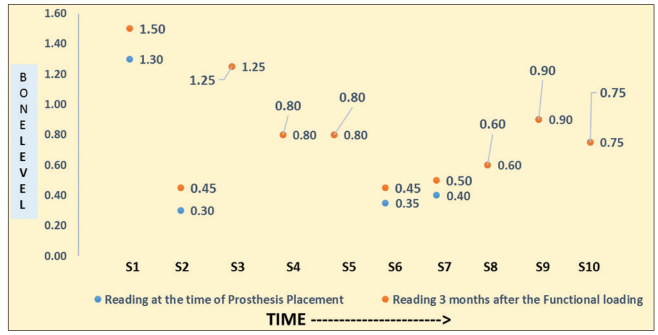
Studies by Sharawy *et al*.[6] have advocated that bone-cutting procedures produce a local rise in temperature due to frictional heat. Even with saline irrigation, temperature adjacent to the drills may often reach 60°C and above. It is generally agreed that temperatures above 56°C–60°C are deleterious to the bone tissue as they give rise to the denaturation of hard tissue proteins.

Misch *et al*.[7] through a review came to a conclusion that the temperature in the bone was affected by the rotations of the drill as 2500 rpm produced the least heat, and maximum temperature increase was observed at 1250 rpm. The effect was revealed by early formation of granulation tissue and early resorption of the margins of the bony defect. Accordingly, controlling heat generation will help avoid thermal bone necrosis that in turn influences bone healing. Another detrimental factor affecting crestal bone levels in future is the mechanical stress which might lead to alteration in bone quality and architecture, leading to a distinct reaction within the bone cells at the bone–implant interface, proceeding to a metabolic turnover of the bone based on the changes in osteocyte responses around the implant, resulting in altered bone remodelling.[8]

Appositional bone formation occurs when osteoblasts produce bone on existing bone surfaces. For example, appositional bone formation occurs in the periosteal enlargement of bones during growth and remodeling. Histological studies have shown that woven bone formation



Graph 1: Comparative evaluation of the mean crestal bone level at the time of implant placement, at the time of prosthesis placement and three months following the functional loading using digital radiography



Graph 2: The graph Illustrates the readings of THE observed crestal bone levels

by appositional growth only begins to form by the 2nd week after implant insertion, at a rate of 30–50 μ per day.[8] The bone to implant contact is weakest and at the highest risk of overload at approximately 3–5 weeks after implant placement (Strid, 1985).[9] The phenomenon of direct bone to implant contact by deposition of new bone around the implant is known as osseointegration which is defined as the apparent direct bone attachment or connective tissue of osseous tissue to an inert, alloplastic material without intervening fibrous connective tissue. It generally follows three stages: incorporation by woven bone formation, adaptation of bone mass to load (lamellar and parallel-fibered deposition), and adaptation of bone structure to load (bone remodeling) (Schenk and Buser, 1998).[8]

The conventional method of placing implant in an edentulous site is by sequential osteotomy of the edentulous site, followed by implant placement immediately and commencing the procedure. As a consequence of the surgical placement, organized, mineralized lamellar bone in the preparation site becomes unorganized, less mineralized woven bone of repair next to the implant.[9] At 4 months, the bone is still 60% mineralized and is organized lamellar in configuration. Lamellar and woven bones are the primary bone tissues types found around a dental implant. The lamellar bone is organized and highly mineralized. It is the strongest bone type and has the highest modulus of elasticity. Thus, it is described as load-bearing bone.[9]

On the other hand, woven bone is unorganized, less mineralized, of less strength, and more flexible (lower modulus of elasticity). Woven bone may form at a rate of up to 10 μ per day. The two-stage surgical approach of dental implants permits the bone repair around the implant avoiding the early loading response by 3–6 months. The surgical process of the implant osteotomy preparation and implant insertion cause a regional accelerated phenomenon of bone repair around the implant interface.[9]

The success of an implant depends on atraumatic preparation of the implant site so as to have vital bone adjacent to the implant that is placed. The temperature during drilling for implant site frequently exceeds, which results in osteocytic destruction due to frictional heat, mechanical vibration, leading to capillary destruction, resulting in ischemia that might be a potent cause of delay in osseointegration.

Despite the use of the surgical modifications, bone injury does occur. In an attempt to allow bone to recover from surgical injury, thereby allowing implant placement into an environment more conducive to healing and development of osseointegration, a technique where in the implant was placed in the osteotomy site at a later date was proposed. In the present study, implants were placed after 14 days following osteotomy preparation, which in accordance with previous studies are considered to be peak time for formation of new trabeculae.[10]

In a recent study done by Kunnekel *et al*., implants were placed in rabbit femurs following the conventional and delayed (after 2 weeks) implant placement protocols. The implant stability quotient was quantified by resonance frequency analysis, and it was observed that the test group had the more rapid healing, characterized by faster deposition of woven and lamellar bone which could be the manifestation of the stimulatory effect for placing implants 14 days after the osteotomy.[11]

Another histomorphometry study compared the osseointegration of implants placed 14 days after implant site preparation with that of immediately placed implants in rabbit femurs. On one side, the implants were placed 14 days after osteotomy, and the other side received implants immediately after osteotomy. Healing was assessed by microcomputed tomography and histomorphometry. The delayed implants (placed 14 days after osteotomy) showed better osseointegration than the immediately placed implants. Bone-to-implant contact and bone volume, as assessed by histomorphometry and microcomputed tomography, were significantly higher for the implants placed after 14 days.[1] Futami *et al*.[12] suggested that a microspace between the host bone and the implant placement enabled the migration of osteogenic cells from the bone marrow toward the implant surface, thus favoring rapid and extensive osteogenesis.

According to Luthra S, *et al*.,[13] delayed method of implantation appeared to enhance trabecular bone formation with spongiosa rich in original trabeculae and numerous enlarged capillaries as revealed by histological observation around the implant. This was compared to the conventional implant placement where the histological examination demonstrated loose fibrous tissue with very few and thin capillaries. It was observed that delayed method of implantation could be an efficient method for promoting better and faster bone formation around the implant.

Luthra S *et al*.[13] reported that bone healing after osteotomy passes through three stages: Inflammation (granulation tissue), fibrous tissue formation, and maturation. The insertion time for an implant 2 weeks after the osteotomy is preferred because the collagen formation and neoangiogenesis represent an acceptable implant bed configuration that enhances the surrounding tissue to its maximum level, therefore enhancement of the alveolar bone binding is at a faster rate within this protocol.

In the present study, ten implants were placed in ten different individuals in the mandibular first molar region following the delayed implant bed protocol and were loaded within the 6–8 weeks, thereby following the early loading protocol (ITI consensus 2009).[14]

For the purpose of the study, all implants were placed equicrestal in order to have a baseline reference for future evaluation of bone levels as affected by the surgical protocol followed in the study. The subjects were recalled for the prosthesis placement after an interval of 2 months, and the crestal bone levels for all the subjects were re-evaluated the data thus obtained revealed bone gain in all the subjects at the time of prosthetic loading, with a mean of 0.7 mm which was found to be statistically significant from the day of surgery. Then, the patients were re-evaluated 3 months after the functional loading, and it was observed that either it was a bone gain (four subjects) or the bone levels were stable (remaining six subjects) with a mean of 0.8 mm which was statistically insignificant from those obtained at prosthetic loading but was significant from those as observed on the day of surgery.

Nagarajan *et al*.[15] conducted a prospective study to evaluate the crestal bone levels before loading by placing implants equicrestal and subcrestal. The implants placed equicrestal showed crestal bone levels (1.31 ± 1.04 mm and 0.68 ± 1.08 mm on mesial and distal surfaces respectively) that was apical to implants placed subcrestal (0.49 ± 0.49 mm and 0.025 ± 6.06 mm on mesial and distal surfaces respectively) with a *P* value of crestal bone level for both the groups being 0.12 and 0.07, respectively, which was statistically insignificant. They concluded that the implants placed at subcrestal and equicrestal level did not show difference in crestal bone loss before prosthetic loading. On the contrary, Adell *et al*.[16] reported that there is an average of 1.2 mm marginal bone loss from the first thread during healing and the 1st year after loading.

The results of the present study substantiated the fact that placing implants in delayed implant beds has a positive influence on the osseointegration due to enhanced trabecular bone formation with spongiosa rich in original trabeculae and numerous enlarged capillaries. This physiological environment not only lead to bone gain but also the bone formed as a result might be lamellar in nature which is highly mineralized and organized in structure making it capable of withstanding majority of the load around an implant which ultimately lead to maintenance of the bone levels even after prosthetic loading to almost similar levels which however is not experienced when a conventional protocol is followed.

CONCLUSION

A significant bone gain was observed (mean = 0.8 mm) which remained constant even after prosthetic loading as evident from observations made after 3 months of loading. The bone formed by following the above mentioned technique is expected to be lamellar in nature, as is evident from the levels of crestal bone levels and bone gain as recorded at three intervals. Thus, placing implants in delayed implant bed can be recommended over the conventional techniques for more predictable results in terms of bone implant contact, osseointegration, and maintenance of bone levels throughout their use in oral cavity.

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Conflicts of interest
There are no conflicts of interest.

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