

Crestal Bone Preservation in Implantology: A Review of Current Treatment Concepts

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Abstract

Dental implants have become the globally accepted treatment for replacing single or multiple missing teeth, aiming to restore optimal function and esthetics. Implant-supported prostheses have gained significant patient acceptability and have shown to improve quality of life. The success of implant prosthodontics relies on precise decision-making and protocols, including diagnosis, treatment planning, implant design, surgical approach, and maintenance. A critical factor for long-term success is the integration between implant components and oral tissues, particularly the preservation of crestal bone surrounding the implant. Maintaining marginal bone height is essential for the durability of dental implants. With advancements in implant design and surface characteristics, modern implants have improved osseointegration, enhancing treatment efficiency and predictability. Several strategies, such as platform switching, non-submerged approaches, implant design modifications, and immediate implant placement, have been proposed to preserve crestal bone. When applied meticulously, these techniques improve bone implant contact and soft-tissue profiles, minimizing crestal bone loss and contributing to the overall success of implant rehabilitation. This literature review aims to explore clinically relevant methods for preserving crestal bone, offering prosthodontists strategies to ensure predictable and successful implant-supported rehabilitation.

Keywords: Crestal bone loss, External hex connection, Flapless surgery, Implant thread geometry, Implant-abutment connection, Internal hex, Microthreaded collar, Morse taper, Platform switching, Polished collar, Progressive loading, Submerged implant.

INTRODUCTION

In contemporary prosthodontics, dental implants are universally recognized as the preferred treatment strategy for replacing single or multiple missing teeth. The success of implant prosthodontics relies on meticulous decision-making protocols, which encompass accurate diagnosis, treatment planning, implant design, surgical techniques, hard- and soft-tissue response, impression making, prosthesis fabrication, and maintenance phase.

The longevity of dental implants is highly dependent on the integration between implant components and oral hard and soft tissues. A critical factor in this integration is the preservation of the crestal bone since the initial breakdown of implant-tissue interface begins at the crestal region in successfully osseointegrated dental implants. This leads to loss of marginal bone termed as “crestal bone loss.”^[1]

The first report in the literature to quantify the early crestal bone loss (CBL) was a 15-year retrospective study evaluating implants placed in edentulous jaws. In this study,

Adell *et al.* reported an average of 1.2 mm marginal bone loss from the first thread during healing and the 1st year after loading. In contrast to the bone loss during the 1st year, there was an average of only 0.1 mm bone lost annually thereafter.^[2] Based on these findings in sub-merged implants, Albrektsson *et al.* and Smith and Zarb proposed criteria for implant success.^[3]

Albrektsson criteria

1. The individual unattached implant should be immobile when tested clinically
2. The radiographic evaluation should not show any evidence of radiolucency

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Received: Mar. 05, 2025; **Accepted:** Apr. 12, 2025; **Published:** Apr. 29, 2025

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How to cite this article: Mistry S, Panikker S. Crestal Bone Preservation in Implantology: A Review of Current Treatment Concepts. J Res Adv Dent 2025;16(3):1-6.

Access this article online

Website:
www.jrad.co.in

DOI:
<https://doi.org/10.53064/jrad.2024.16.3.670>

3. The vertical bone loss around the fixtures should be <0.2 mm per year after 1st year of implant loading.
4. The implant should not show any signs of pain, infection, neuropathies, paresthesia, violation of mandible canals, and sinus drainage.
5. The success rate of 85% at the end of 5 year and 80% at the end of 10 years.

A lifetime successful treatment for a patient requires osseosufficiency, that is, the harmonious relationship between the host, the implant, and the clinician.

With advancements in diagnostic procedures, implant macro- and microtopography, and improved treatment protocols, implantology has now entered an era where the clinician's aim is not limited to just minimizing bone loss to preserve the crestal bone, but to achieve the status of "Zero bone Loss."^[4]

The Zero Bone Loss concept by Tomas Linkevicius is a scientifically driven approach to implant dentistry that aims to eliminate marginal bone loss by optimizing biological and biomechanical factors. The concept is based on key principles, including the importance of maintaining a thick peri-implant mucosa (≥ 3 mm) to prevent crestal bone remodeling, the strategic use of subcrestal implant placement to enhance tissue stability, and the application of prosthetic designs that minimize excessive mechanical load and bacterial infiltration. In addition, linkevicius highlights the critical role of platform switching, soft-tissue augmentation when necessary, and the avoidance of microgap exposure at the crestal bone level. By integrating these evidence-based strategies, the Zero Bone Loss concept seeks to improve long-term peri-implant health, enhance esthetic outcomes, and maximize the predictability of implant success.^[4]

Achieving zero bone loss around dental implants is a challenging goal, as various patient-specific and clinical factors can influence marginal bone levels. While the Zero Bone Loss Concept by Tomas Linkevicius provides strategies to minimize bone loss, current evidence indicates that completely eliminating marginal bone loss may not always be feasible. Factors such as implant-abutment connection type, implant design, surgical technique, and patient-specific variables play significant roles in peri-implant bone stability. However, despite advancements in implant design and surgical protocols, a certain degree of marginal bone remodeling is commonly observed, suggesting that while the goal of zero bone loss is ideal, it may not be entirely attainable in all clinical scenarios.

A thorough understanding of the treatment concepts that help preserve crestal bone is indispensable in rendering successful implant therapy as a prosthodontist. The various treatment concepts that influence the preservation of crestal bone around dental implants are as follows.

IMPLANT DESIGN MODIFICATIONS

Increasing the functional surface area of an implant will better distribute the axial and non-axial loads, resulting in lesser

force concentration at the crest. The use of threaded implants rather than cylindrical implants for crestal bone preservation has been documented in the literature.

Thread depth, thread face angle, and thread pitch are some of the varying geometric patterns that determine the functional thread surface and affect the biomechanical load distribution of the implant. The influence of threads can be easily understood as the greater the number of threads present as well as greater the depth of the threads, the more is the functional surface area available. It has been found that the shear force on a V-shaped thread face that is 30° is approximately 10 times greater than the shear force on square thread. Therefore, square-shaped threaded implants will concentrate lesser forces at crestal bone as well (Figure 1).^[5]

Implants with microthreads in the collar region enhance bone implant contact and engage crestal bone more effectively than those without microthreaded collars. In the presence of an inadequately prepared osteotomy, microthreads around the neck of the implant can improve the stability of the initially placed implant. This would lead to greater primary stability, and would, in turn, accelerate the healing process, thus facilitating preservation of crestal bone (Figure 2).^[6]

Increasing the implant length and width increases the surface area but it has been found that implant width is more important for crestal bone preservation than the implant length as stress

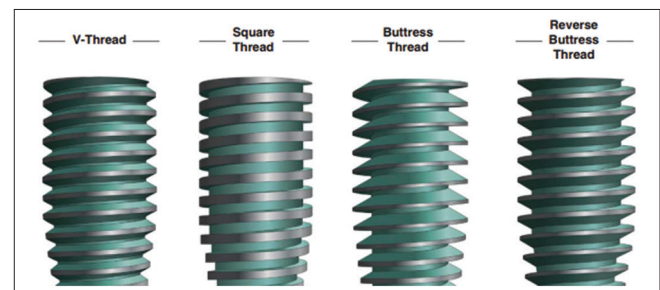


Figure 1: Variation in implant thread geometry



Figure 2: Polished collar and microthreaded collar design

values and concentration areas decrease for cortical bone when implant diameter is increased.^[1,7]

Tada *et al.* conducted a finite element analysis in which they found that highest cortical bone stresses in all types of bone are located around the implant neck, but strain distributions around the cancellous bone showed some differences.^[8]

In type 1 and type 2 cancellous bone, highest stresses were found around the implant neck, but in type 3 and type 4 cancellous bones, the threads of the implants effectively reduced the degree of stress, generating moderate strain in bone around thread crests and evenly distributed low strain in other regions. They concluded that increasing implant width is more beneficial for type 1 and type 2 bones and increasing implant length is more beneficial for type 3 and type 4 bones.^[8]

IMPLANT ABUTMENT CONNECTION AND CONCEPT OF PLATFORM SWITCHING

The advent of widediameter dental implants in the late 1980s created a situation where mismatched standard diameter abutments were used due to the scarcity of commercial availability of components that match the widediameter implants. Coincidentally, it was found that these implants exhibited less than expected initial CBL. Several early clinical reports demonstrated enhanced soft- and hard-tissue responses to these platform switched implants, leading many commercially available implant companies to incorporate platform-switching into their implant systems even for narrowbody implants.^[9,10]

- The concept of “platform switching” explains the use of a smaller-diameter abutment on a larger-diameter implant collar. The mechanism by which this stepped effect produced by platform switching may contribute in maintaining the crestal bone height can be attributed to four main reasons:^[1]
 - Shifting of the inflammatory cell infiltrate inward and away from the adjacent crestal bone
 - Maintenance of biological width and increased distance of implant-abutment junction (IAJ) from the crestal bone level in the horizontal direction
 - The possible influence of microgap on the crestal bone is reduced
 - Decreased stress levels in the peri-implant bone.

Implant–abutment interface is a very important criterion for implant success. Platform switching increases the distance between IAJ and the crestal bone, thereby increasing the micro-gap to crestal bone distance, hence preserving the crestal bone, but it does not affect the width of the micro-gap (Figure 3).^[11]

From the existing body of scientific literature,^[12-14] it is possible to draw the inference that internal implant-abutment connections and conical (Morse Taper) implant-abutment connections show lesser microleakage than external implant-abutment connections. The external connections, of which the external hexagonal connection is the most common, provide a short and narrow connection with the abutment and provide for

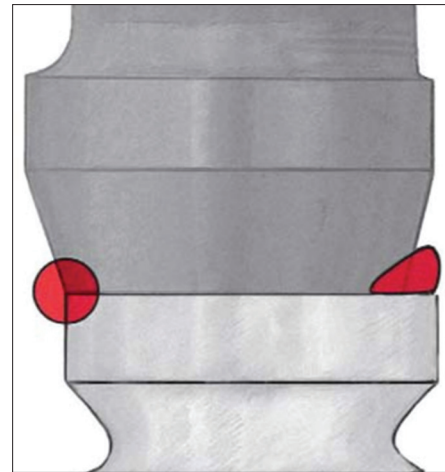


Figure 3: Platform switching repositions the implant abutment interface away from crestal bone and locates the inflammatory infiltrate $<90^\circ$ instead of $<180^\circ$

only limited screw engagement and a short fulcrum arm, which together allow for frequent screw loosening. The instability of the external connection leads to open micro gaps.

Lateral forces are distributed deep within the implant, and the long internal wall engagement within the implant shields the abutment screw and buffers vibrations. Internal connections are therefore, less prone to micromovements, and opening of the implant-abutment connection. Conical connections, specifically, have the advantage of the smallest inherent micro gaps due to frictional fit of the abutment into the implant, virtually removing any gap between the two.^[15]

Hence, the introduction of a combination of morse taper connection and platform switching have shown to preserve crestal bone around implants and can be a boon to implant dentistry.

Repeated screwing and unscrewing of components such as healing abutment and impression coping leads to risk of microbial contamination of the microgap due to ingress of saliva, and hence, this must be minimized. Recent advances like one abutment 1 time concept help reduce the stresses and microbial contamination at the microgap. This protocol involves placement of the final or definitive abutment at the time of implant placement, as opposed to placing a cover screw or healing abutment, therefore overcoming the need to repeatedly change the prosthetic components after delivery of the final prosthesis.^[16]

TIME OF IMPLANT PLACEMENT

Misch defined immediate implant placement as a placement of a dental implant at the time of tooth extraction, into the extraction socket. Immediate implant placement is one of the contributing success factors for implant longevity in compromised bones. Placing immediate implants after tooth extraction helps preserve the denser cortical bone and prevents atrophy resulting in less loading of the marginal bone.^[17,18]

The crestal bone surrounding the immediate and delayed placed implants was compared in a study by Schwartz-Arad *et al.*, they stated that after an average of 3.5 years, the immediate implants had less CBL, with an average loss of 0.61 mm as opposed to the delayed implants, who had a loss of 0.89 mm.^[19]

In an investigation by Tadi *et al.*, the crestal bone levels around implants were measured at different points in the time immediately, after 1 month, after 3 months, and after 6 months to assess how much the levels had changed during the first 6 months. They came to the conclusion that in comparison to conventional implant placement, immediate implant insertion displayed much less bone resorption.^[20]

FLAP DESIGNS FOR IMPLANT PLACEMENT

Cortical bone is poorly vascularized and has very few blood vessels running through it, in contrast to marrow bone. When soft-tissue flaps are reflected for implant placement, blood supply from the soft tissue to the bone (supraperiosteal blood supply) is severed, thus leaving poorly vascularized cortical bone without a part of its vascular supply, prompting bone resorption during the initial healing phase.

The regeneration of the periosteum results in the restoration of the blood supply. The underlying trabecular/cancellous bone supplies the crestal bone, in addition to the periosteum, with nutrients. Reflecting the flap for the placement of an implant is a wellknown conventional approach, whereas the flapless technique is now an evolving technique. The advantage of the flapless implant placement is intact periosteum and blood supply, which could be the reason for reduced loss of crestal bone. It gives a favorable healing environment for the hard and soft tissue (Figures 4 and 5).^[21-23]

A recent systematic review and meta-analysis published in 2022 by Lahoti *et al.* that included 23 studies concluded that flapless technique of dental implant placement has significantly less CBL compared to the flap technique.^[24] The use of a guided or freehand approach of flapless surgery both showed less CBL compared to flap surgery; however, significant results could not be obtained.

DEPTH OF IMPLANT PLACEMENT

It has been stated that a certain width of peri-implant mucosa is required to enable a proper epithelial-connective tissue attachment and, if this soft-tissue dimension is not adequate, crestal bone resorption will occur to ensure the establishment of attachment with appropriate biological width. Recent studies have shown that for all two-piece implants, the bone crest level changes appeared dependent on the location of the microgap. Thus, scientific literature has stressed up on the use of a non-submerged approach.^[25,26]

The non-submerged approach is for a 2piece implant system, the implant, and the abutment are placed during the first stage of the surgery. The second stage is not required. According to studies, periimplant mucosa must be 2–3 mm in width to allow

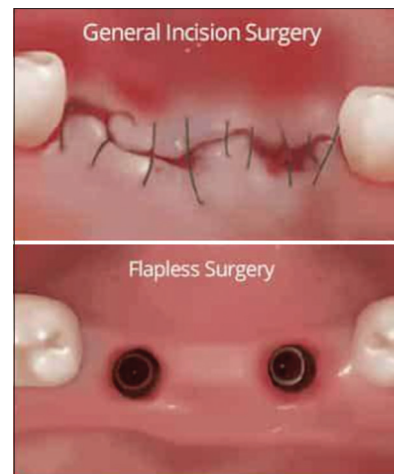


Figure 4: Conventional flap surgery and flapless surgery

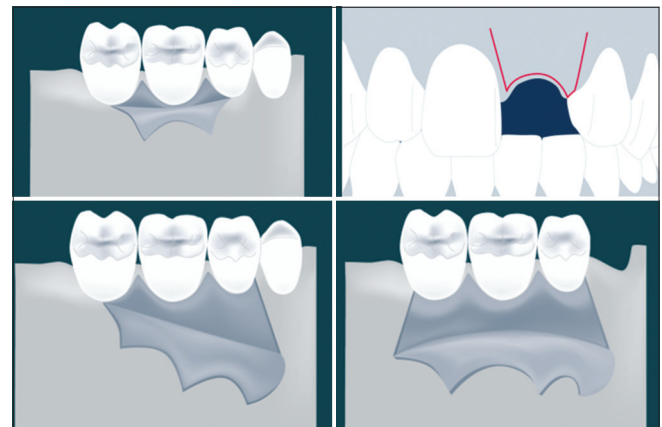


Figure 5: Flap designs

for an appropriate epithelial-connective tissue attachment. If these dimensions are insufficient, crestal bone resorption will take place to assure the establishment of an attachment with the proper biological width (Figure 6).^[26]

In their study, Finne *et al.*,^[27] found that one-piece implants have a better ability to protect both soft and hard tissues than two-piece implants in maintaining marginal bone levels. This approach eliminates the second stage of surgery which would disrupt the biological width. The width is maintained because the micro gap is positioned far from the marginal bone.

The reasons for reduced crestal bone loss in non-submerged approach which have been cited in the literature are the following:^[1]

- Elimination of the apical migration of junctional epithelium during second-stage surgery which could disrupt the biological width
- Maintenance of biological width as microgap is placed away from the crestal bone
- The additional advantage of one-piece non-submerged approach is the absence of microgap and micromovement which will maintain the biological width, thereby preserving the crestal bone.

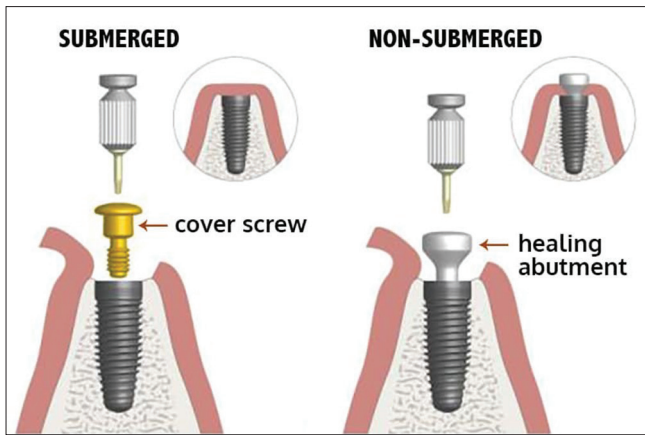


Figure 6: Submerged and non-submerged approach of implant placement

LOADING PROTOCOLS

Progressive loading is a technique that allows the bone to respond to increasing levels of biomechanical stress. As a result, instead of overloading the bone-implant interface directly, techniques that gradually increase the tension are advantageous. Bone is slightly overloaded and reacts by increasing its formation, growing denser and improving its quality.

This protocol uses transitional prostheses made of acrylic resin that minimally interfere with the integration of the implant-bone interface during the healing phase.

Furthermore, progressive loading may help to prevent CBL. When stresses are greater, or the bone is softer, a longer healing interval between stages I and II is recommended. Before the implant bodies are subjected to the screw load, this period allows for additional bone mineralization and a more mature lamellar bone interface to develop adjacent to the implants.^[1]

According to a study by Manz,^[28] the amount of CBL following adequate bone integration was positively correlated with bone density. The implant may fail if the forces applied to it are greater than the physiological limits of the surrounding bone density. Density is increased by a slow and progressive rise in stresses during prosthetic manufacturing. Crestal bone will be effectively maintained as a result, especially in Types 3 and 4 bones.

The effectiveness of progressive loading techniques on maintaining crestal bone height and enhancing periimplant bone density around maxillary implants was established by Appleton *et al.* The average values of crestal bone height decrease for implants that were gradually loaded at 12 months were 0.2 mm and for implants that were loaded conventionally, they were 0.59 mm and 0.27 mm, respectively.^[29]

CONCLUSION

While certain approaches to crestal bone preservation have become widely accepted as standard practices, it is essential for clinicians to move beyond rigid dogmas and adopt a

flexible, evidence-based approach to implant therapy. Success in implant treatment requires a comprehensive, patient-centric strategy that integrates accurate diagnosis, careful treatment planning, and adherence to appropriate surgical and prosthetic protocols tailored to the unique demands of each clinical case. Ultimately, the responsibility lies with the clinician to continually refine their approach, ensuring predictability and optimal outcomes through a holistic understanding of both the biological and technical aspects of implantology.

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