REVIEW ARTICLE

Crestal bone preservation: A review of different approaches for successful implant therapy

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ABSTRACT

The level of bone crest surrounding the implant is of utmost significance to determine osseointegrated implant success, as preservation of marginal bone height is highly important for long-term dental implant survival. Various approaches have been described in the literature to prevent the crestal bone loss, including platform switching, non-submerged approach, scalloped implants, implant design modifications, progressive loading, immediate implant placement, etc. The purpose of this paper is to review all the possible methods to preserve the crestal bone, when each method should be used and their success rates in an attempt to address this complex problem of crestal bone resorption. “PubMed” and “Google Scholar” were used to find out any studies involving platform switching concept from 1990 up to 2009. Twenty-four studies involving methods for preservation of crestal bone were evaluated, which included 26% studies on platform switching, 22% on non-submerged approach, 17% on scalloped implants, 13% on progressive loading and 22% on immediate implant placement. Crestal bone preservation should be thought of starting from the design of the implant to be placed. The technique to be followed in a given case will depend upon the density of bone, force factors by the patient, bone volume and amount of soft tissues, etc. The best possible method or the combination of the methods should be used to preserve the crestal bone for the long-term success of the implants.

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Initial breakdown of implant–tissue interface begins at the crestal region in successfully osseointegrated endosteal dental implants. Adell *et al.*[1] were the first to quantify and report marginal bone loss. Their study indicated greater magnitude and occurrence of bone loss during first year of prosthesis loading, averaging 1.2 mm with a range of 0–3 mm. Years subsequent to the first showed an average of 0.05–0.13 mm bone loss per year. Albrektsson *et al.*[2] proposed the criteria for implant success, including vertical bone loss less than 0.2 mm annually following implant’s first year of function.

Crestal bone loss can lead to increased bacterial accumulation resulting in secondary peri-implantitis which can further result in loss of bone support leading to occlusal overload and again crestal bone loss.[3] This will end up in a vicious cycle, ultimately causing implant failure. Apart from this, resorption of marginal bone will affect the marginal soft tissues in implants. Tarnow *et al.*[4] conducted a study to find the correlation between crest of the bone and the presence or absence of interproximal papilla in humans. They concluded that the presence of crestal bone peak is very important for papilla preservation. Because of all these reasons, crestal bone preservation has become a very important factor for the success of the implant. This paper reviews all the possible methods to preserve the peri-implant crestal bone, when each method should be used and their success rates, in an attempt to address this complex problem of crestal bone resorption.

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PLATFORM SWITCHING

The concept of “platform switching” explains the use of a smaller-diameter abutment on a larger-diameter implant collar. This connection shifts the perimeter of the implant–abutment junction (IAJ) inward toward the central axis (i.e., the middle) of the implant.

In 1991, Implant Innovations, Inc. (3i, Palm Beach Gardens, FL, USA) introduced 5- and 6-mm diameter implants with seating surfaces (i.e., restorative platforms) of the same dimensions. After a 5-year period, the typical pattern of crestal bone resorption was not observed radiographically in cases where platform switching was utilized. Lazzara and Porter[5] theorized that this occurred because shifting the IAJ inward also repositioned the inflammatory cell infiltrate and confined it within a 90° area that was not directly adjacent to the crestal bone. But it was thought that further investigation is needed to prove the real advantages of this technique.

Baumgarten *et al.*[6] described the platform switching technique and its usefulness in situations where shorter implants must be used, where implants are placed in esthetic zones, and where a larger implant is desirable but prosthetic space is limited. They also stated that a sufficient tissue depth (approximately 3 mm or more) is necessary to accommodate an adequate biological width. They concluded that platform switching helps in preventing the anticipated bone loss and also preserves crestal bone.

Gardner[7] discussed the changes that occur when an implant is placed in bone and presented a case study using platform switching implants. The main advantage of platform switching is that it is an effective way to control circumferential bone loss around dental implants, but he concluded that platform switching needs further investigation. Furthermore, he noted several potential disadvantages of this procedure such as the need for components that have similar designs (the screw access hole must be uniform) and the need for enough space to develop a proper emergence profile.

Calvo-Guirado *et al.*[8] evaluated the survival rates at 12 months of a platform switched implant placed in the anterior and premolar areas of the maxilla and immediately restored with single crowns. Crestal bone loss was also assessed. Mesial and distal bone levels were evaluated with digital radiography on the day after implant placement, 15 days later, and 1, 2, 3, 6, 8, and 12 months later. Primary stability was measured with resonance frequency analysis (RFA). The mean bone loss measured on the mesial was 0.08 mm. Mean distal bone loss was 0.09 mm. Over the course of 12 months, the mean RFA value between baseline and 12 months was 71.1± 6.2. They concluded that the implants remained stable over the course of 12 months and had an overall survival rate of 96.7%. Minimal crestal bone loss was recorded around the surviving implants.

Calvo-Guirado *et al.*[9] in their study noted the success of the placed platform switched implants after 8 months with minimal marginal resorption (less than 0.8 mm) and highly satisfactory esthetic results.

How does the platform switching reduce crestal bone loss: A critical analysis

The mechanism by which this stepped effect produced by platform switching may contribute in maintaining the crestal bone height can be because of four main reasons:-

- Shifting of the inflammatory cell infiltrate inward and away from the adjacent crestal bone.
- Maintenance of biological width and increased distance of IAJ from the crestal bone level in the horizontal way.
- The possible influence of microgap on the crestal bone is reduced.
- Decreased stress levels in the peri-implant bone.

Lazzara and Porter[5] first theorized that shifting the IAJ inward also repositioned the inflammatory cell infiltrate and confined it within a 90° area, thereby reducing the loss of marginal bone.

Maeda *et al.*,[10] in a 3D finite element analysis, found the biomechanical advantages of platform switching. They noted that this procedure shifts the stress concentration away from the bone–implant interface, but these forces are then increased in the abutment or the abutment screw.

Schrotenboer *et al.*[11] fabricated a two-dimensional model to analyze the bone–implant interactions under masticatory forces. Two abutment diameters, 4.5 mm representing platform switching and 5 mm representing a standard platform, were used in conjunction with a 5-mm diameter fixture. A 100 N force was applied vertically and obliquely to the abutments. Results showed that reduction of abutment diameter resulted in measurable but minimal effect on Von Mises stresses in the crestal region of cortical bone. However, it was concluded that further clinical trials are warranted before any firm conclusion is drawn.

Degidi *et al.*[12] evaluated the histology and histomorphology of three morse cone connection implants in a real case report and they explained that when there is zero microgap and no micromovement, platform switching shows no resorption.

Comparison of platform and non-platform switched implants

Markus Hurzeler *et al.*[13] compared crestal bone loss around platform switched and non-platform switched implants. They found the mean crestal bone loss in platform switched implants to be 0.22 mm and it was 2.02 mm for non-platform switched implants. They also concluded that reduction of the abutment of 0.45 mm on each side was sufficient to avoid peri-implant bone loss. An average of 1–2 mm of bone loss occurs in non-platform switched implants, while minimal bone loss occurs in platform switched implants.

Rodriguez *et al.*[14] by finite element analysis compared the biomechanical response of three types of implant–abutment configurations both before and after establishment of a new biological width. The three functional units studied were: a 5-mm implant platform connected with an external hexagon to a 5-mm-diameter abutment (type 1), a 5-mm implant platform connected with an external hexagon to a 4.1-mm-diameter abutment (type 2), and a 4.8-mm implant platform connected with an internal hexagon to a 4.1-mm-diameter abutment (type 3). The type 3 design, which combined platform switching with an internal connection, exhibited the smallest distortions in stress distribution after bone modeling, and the stress was distributed over the entire contact surface most smoothly and uniformly. Bone resorption following creation of the biologic width changes the biomechanical behavior of a restoration. The two implant–abutment designs featuring a smaller-diameter abutment on a larger-diameter implant platform achieved better results than the implant featuring implant platform and abutment of the same-diameter, even though their initial biomechanical load potential was lower.

Vela Nebot *et al.*[15] inserted abutments of a lesser diameter (4.1 mm) than the implant's platform (5.0 mm) to create a platform modification. The implants for the test group and the control group were placed at the same level as the alveolar crest. After abutment attachment, the implants were followed for 4–6 months to assess the bone loss radiographically. The mean value for bone resorption for the mesial measurement in the control group was 2.56 mm and for the study group it was 0.79 mm. The mean bone resorption for the distal measurement in the control group was 2.60 mm and it was 0.84 mm for the test group.

Thus, all the preliminary evidences in literature suggest that the anticipated bone loss that occurs around two-stage hexed implants may be reduced or eliminated when implants are restored with smaller-diameter abutments, a practice termed platform switching.

NON-SUBMERGED APPROACH

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.

Comparison of submerged and non-submerged implants – A literature review

There are basically three approaches for implant placement:-

- Submerged approach in which implant is placed below or at the level of the bone, requiring second surgery to place the abutment [Figure 1a].
- Non-submerged two-piece implants in which both the implant and abutment are placed during the first-stage surgery, eliminating the need for second surgery [Figure 1b].
- Non-submerged one-piece implants in which implant and abutment are there as one piece with no micromovement between implant and abutment and no microgap. Moreover, there is no need of second surgery [Figure 1c].

Ruggeri *et al.*[16] stated that their results from studies on the supracrestal collagen fibers around non-submerged implants disagree with the previous findings that submerged implants are necessary for implant survival.

Kaj Finne *et al.*[17] concluded in their study that stable marginal bone level is maintained with one-piece implants and they have a better capacity to preserve both hard and soft tissues compared to the two-piece implants.

Histological and radiographic studies by Herman *et al.*[18] have proven that a crestal bone loss of about 2 mm occurs with the submerged, two-pieces approach, dependent on the location of microgap, and minimal or no resorption occurs with non-submerged, one-piece implants. They demonstrated that a rough/smooth border on the surface of one-piece implants determines the crestal bone levels adjacent to such implants. All two-piece implants exhibited the crestal bone loss depending on the location of microgap. This was independent of whether the implants were placed by submerged or non-submerged technique.

Reasons for crestal bone preservation by non-submerged approach

The reasons for less resorption in non-submerged approach which have been cited in the literature are the following:

- 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.

The data obtained by David *et al.*[19] suggested that a biological width exists around unloaded and loaded non-submerged one-piece implants and this is a physiologically formed and stable dimension as is found around the teeth.

SCALLOPED IMPLANTS

The scalloped implant, a design by Noble Perfect™ (Noble Biocare AB, Zurich, Switzerland), enables the surgeon to

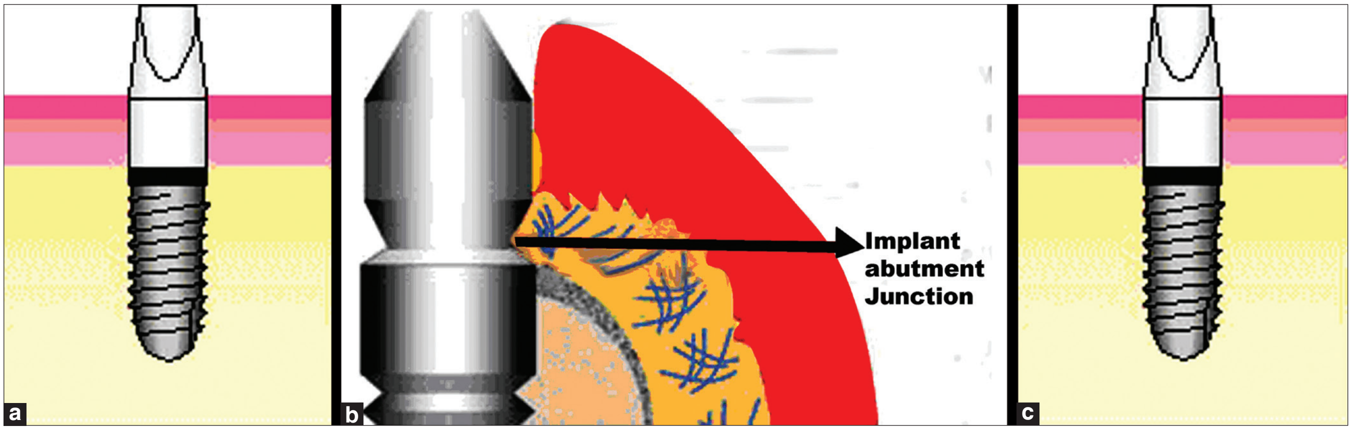

Figure 1: (a) Submerged approach; (b) two-piece non-submerged implants; (c) one-piece non-submerged implants

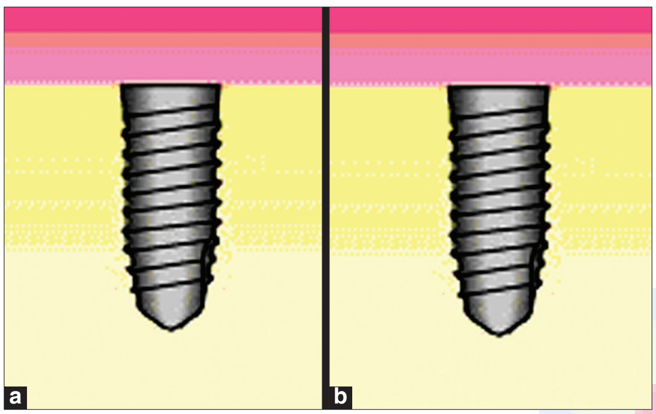

Figure 2: (a) Platform switched implant; (b) inward shifting of connective tissue maintaining biological width

place the implant in the residual bone which is characterized by remaining interproximal osseous peaks. The implant is designed such that interproximal peaks of the bone apposition area are in contact with interproximal peaks of the residual bone. It has been found that remodeling in such cases is significantly less when compared with flat prosthetic implant table.[20]

Literature review

Khatami *et al.*[21] described a case report in which a 22-year-old subject was treated with the Nobel Perfect dental implant system after avulsion of two maxillary central incisors. Implants were placed in the avulsion socket and provisional restorations were made and cemented immediately. All ceramic Procera crowns were cemented and followed for 1 year. At follow-up, no discernable clinical and radiographic changes in the soft tissue architecture and crestal bone profile were found.

McAllister *et al.*[22] performed a radiological study in which they found that use of scalloped implants enhances the interproximal bone levels as well as the esthetic outcome. Kan *et al.*[23] found that though favorable implant success rates and peri-implant tissue response can be achieved with scalloped implants in the esthetic zone, bone was not regularly maintained at the original levels around the scalloped area of the implants.

IMPLANT DESIGN MODIFICATIONS

Increasing the functional surface area of an implant will better distribute the stresses, resulting in lesser forces at the crest. Use of threaded implants than the cylindrical implants for crestal bone preservation has been documented in the literature.

Thread geometry

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 30º which is approximately 10 times greater than the shear force on square thread.[24] Therefore, square-shaped threaded implants will concentrate lesser forces at crestal bone as well.

Implant dimensions

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 values and concentration areas decreased for cortical bone when implant diameter is increased.[25]

Tada *et al.*[26] did 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. 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 screw type 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.

Winkler *et al.*[27] studied the influence of implant diameter and length on implant success rate. Their results on 3-year survival and stability of various implant lengths and diameters were 90.7% for 3–3.9 mm and 94.6% for 4–4.9 mm implants. Also, longer implants had significantly better survival rates as compared with shorter implants.

IMMEDIATE IMPLANT PLACEMENT

Immediate implant placement has become a major contributing success factor in compromised bones. Placing immediate implants after tooth extraction will help in preserving the denser bone and preventing the atrophy and results in less loading of the marginal bone.

More than 90% success rate for immediate implants has been well documented histologically as well as radiographically. Turkyilmaz *et al.*[28] discussed a case report to describe the placement of immediate implant and provisional restoration following minimally invasive extraction to preserve the anterior esthetics. The implant was placed immediately after extraction without any flap reflection. They concluded that this strategy preserves optimum gingival contours and papillary height by preserving the crestal bone and may be a viable option compared to fixed partial dentures. Smith *et al.*[29] studied 10 cases of immediate implant placement in which 100% survival rate was reported for a 6-year period of follow-up.

Comparison of immediate and delayed implants – A critical review

There are some studies which say that immediate implant placement preserves the bone better than delayed implants and some studies do not find any difference.

Schwartz-Arad and associates[30] compared the crestal bone resorption adjacent to immediate and delayed placed implants. They found that after an average of 3.5 years, the immediate implants had less crestal bone loss with an average of 0.61 mm compared to the delayed implants with the loss of 0.89 mm.

Yournis *et al.*[31] compared crestal bone remodeling following both immediate and delayed placement of titanium dental implants in the extraction sockets. The width and the depth of the defects located in mesial and distal sites of the implants were evaluated radiographically using computer software. The mean reduction of bone defects was 48% in the case of immediately placed implants, but it was only 17% in the case of delayed implants. They concluded that immediate implantation offers advantages of significant reduction in crestal bone resorption.

Block *et al.*[32] determined if there is a significant difference in the hard and soft tissue response, comparing immediate with delayed implant placement after tooth removal. The analyses showed no significant differences between the two groups in crestal interdental bone movement on either the implant or the adjacent tooth. There was a significant difference in the position of the facial gingival margin, with a more apical position of the facial gingival margin in the delayed group compared with the immediate group.

PROGRESSIVE LOADING

The progressive loading of implants was first suggested by Misch in 1980. A study by Manz[33] found that the crestal bone loss after successful bone integration was related directly to the bone density. An implant may fail if the stresses applied exceed the physiologic limits of the bone density present around the implant. A gradual and progressive increase in the loads during prosthetic fabrication stimulates an increase in density. This will result in definite preservation of crestal bone, particularly in type 3 and type 4 bone.

Literature review

Misch *et al.*[34] have found that Periotest values are significantly reduced in progressively loaded implants placed in D 4 types of bone. Similarly, Rotter *et al.*[35] by Periotest studies found that there was larger increase in implant rigidity for progressively loaded implants.

Appleton *et al.*[36] determined the effectiveness of progressive loading procedures on preserving crestal bone height and improving peri-implant bone density around maxillary implants. The mean values of crestal bone height loss at 12 months were 0.2±0.27 mm for the progressively loaded implants and 0.59±0.27 for the conventionally loaded implants. The peri-implant bone around progressively loaded implants demonstrated less crestal bone loss than the bone around conventionally loaded implants. The peri-implant density measurements of the progressively loaded implants showed continuous increase in peri-implant bone density by time.

DISCUSSION

Certain biological width is necessary to maintain the soft tissues and hard tissue. In platform switching, the IAJ is shifted inward [Figure 2]. This will not only shift the inflammatory infiltrate inward away from the crestal bone but also provides an additional horizontal biological width, thereby preserving the crestal bone. Also, at the same time, microgap is shifted away from the crestal bone, decreasing the probability of resorption. Another reason suggested for maintenance of marginal bone by platform switching is the decreased stresses around the implant neck, but the differences are very slight. So, decreased stresses may not be the only reason for the positive results shown by platform switching. Moreover, by decreasing the abutment diameter, more stresses are concentrated near the abutment, increasing the likelihood of abutment fracture. However, further studies in this area are warranted before any definite conclusion is made.

Scalloped implants can be used in the place of freshly extracted tooth where three-dimensional osseous morphology is maintained. The rise and fall of the osseous crest from midfacial to the interproximal position are most pronounced in the maxillary anterior region and decrease posteriorly. The scallops of cementoenamel junction and osseous contours have been found to be parallel to each other. The shape of the interproximal peak of the implant is important for bone maintenance in this region. Another indication is for the replacement of maxillary incisors where scalloped implants help in preserving crestal bone as well as maintaining the esthetics. In single tooth replacements, the use of conventional flat prosthetic table gives acceptable results as bone on the adjacent roots maintains the interproximal bone. But interproximal peaks resorb after the loss of adjacent tooth. Therefore, use of scalloped implants in the single tooth application helps in maintaining the interproximal bone even after loss of adjacent tooth.[21] In spite of these advantages, various studies have shown that bone is not maintained at the original levels. Therefore, though various companies have come up with scalloped contours of implants, still their clinical application is uncertain.

Immediate implant placement has been advocated to reduce the number of surgical procedures, to preserve the crestal bone as the density of bone is maintained and for esthetic reasons.

Non-submerged approach preserves the crestal bone as the implant and the abutment are placed in a single appointment. Due to this reason, apical migration of the junctional epithelium is minimized, thereby maintaining the crestal bone. Moreover, in non-submerged one-piece implants, there is no micromovement as well. But one-piece implants cannot be used in each and every case due to esthetic reasons.

CONCLUSION

The success of dental implants is highly dependent on integration between implant and intraoral hard and soft tissues. An understanding of the etiology of crestal bone loss is very important for the implant success. Once the clinician has identified the sources of forces on the implant system, the treatment plan should be designed to minimize the negative impact on the implant and the bone.

Crestal bone preservation should be thought of starting from the design of the implant to be placed. The various approaches to preserve the crestal bone have been reviewed in this paper. By reviewing 24 studies, we conclude that all approaches help in preserving the crestal bone. The mean crestal bone loss by using platform switched implant has been found to be 0.22 mm. The crestal bone loss by using non-submerged approach depends on the level of IAJ. Less crestal bone loss occurs as the distance between IAJ and the crestal bone increases. After reviewing four studies related to scalloped implants, it is concluded that these implants help in crestal bone preservation, but some studies say that bone levels are not maintained. So, further research is needed in this context. Immediate implant placement and progressive loading also preserves the crestal bone around the implants. The best technique to be followed will depend upon the density of bone, force factors by the patient, bone volume and amount of soft tissues, etc., and hence depends on the clinical situation as each technique cannot be applied to every clinical situation.

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