Review Article

The implant-abutment connection and its impact on prevention of peri-implant diseases and crestal bone stability—an academic and clinical evaluation of the literature

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Abstract: The crestal bone stability and the long-term presence of bone crest at the level of the implant platform to achieve implant success and esthetic outcomes is of paramount importance. The paper presents an academic and clinical evaluation of the literature on the characteristic features of the implant-abutment connection, the main characteristic of an implant collar and platform to control the microgap and bacteria proliferation leading to prevention of crestal bone loss. In addition, the role of the abutment-disconnection, the size of the horizontal mismatch, and last but not least the importance of the Morse-tapered connection has been discussed as fundamental requirements for improvement of implant success and long-term successful esthetic outcomes. The author presents also clinical and histological information on the implant abutment connection, which is beneficial for the bone stability. All this scientific information must be critically analyzed in the modern implant dentistry when new implant surfaces and implant-abutment connections are developed to improve strategies for better osseointegration and sustainable crestal bone stability.

Keywords: Crestal bone loss; platform switching; prevention

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The crestal bone stability and the long-term presence of bone crest at the level of the implant platform to achieve implant success and esthetic outcomes is of paramount importance. Therefore, clinicians and manufacturers have tried over the years to develop a variety of implant collar designs with the presence of threads and micro-threads (1), absence of a microgap, implant-abutment connections allowing lack of micromovements and a better sealing against bacteria (2,3), as well as a development of one-piece (tissue level) implants (4).

Implant collar characteristics

Different studies showed that micro-threads might be an avenue for crestal bone stability (5-7), but there is no confirming information about this design feature as a requirement for all implant designs. Although even a recent systematic review showed less crestal bone loss with dental implants that had a micro-threaded neck design than with machined-surface or conventional rough-surface dental implants (8), most implant manufacturers today develop implant designs without micro threads and present radiologically excellent crestal bone levels.

However, this marginal bone stability is required when patients have compromised bone qualities and systemic conditions (9).

The implant-abutment joint and how to minimize the gap

Early studies evaluated the implant-abutment interface and

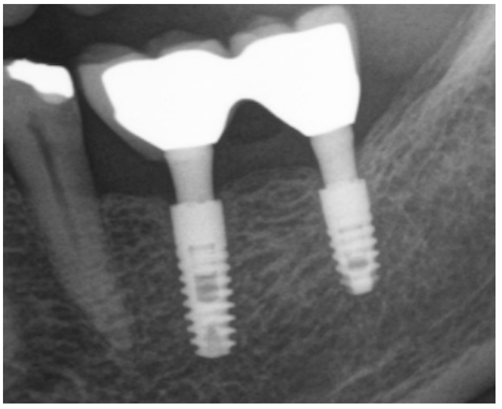

Figure 1 Subcrestal and epicrestal implant placement in the same patient after 3-month healing and one-abutment concept. This radiograph presents the crestal bone stability 25 years after loading.

its impact on implant stability. Binon (10) showed a direct correlation between the implant-abutment joint misfit and screw joint loosening. A rotational misfit of under 2 degrees provided the most stable and predictable screw joint. Therefore, there is a need to eliminate this misfit in rotations during the function to avoid screw-loosening leading to abutment loosening (11).

Previous studies from the University of Gothenburg demonstrated the association between peri-implant soft tissue inflammatory reaction and microgap in butt-joint implant-abutment connections (12). The impact of the microgap on the crestal bone level was firstly investigated by Hermann *et al.* (13), in canines. The studies showed that significant crestal bone loss occurs in two-piece implant designs even with the smallest-sized microgaps (<10 microns) combined with possible movements between implant components. In addition, further studies demonstrate that the rough/smooth implant interface, as well as the location of the microgap, have a significant effect on marginal bone formation. Bone remodeling occurs rapidly during the early healing phase after implant placement for non-submerged implants and after abutment connection for submerged implants (14).

However, studies by Weng *et al.* (15,16) with unloaded implants in dogs showed that different microgap designs cause different shapes and sizes of the peri-implant ('dish-shaped') bone defects in submerged placed implants both in equicrestal and subcrestal positions (16). Subcrestal positioning of an external butt-joint microgap may lead to faster radiographic bone loss before implant loading (16).

Recent studies by Sasada and Cochran (17) showed that implants without micro-threads and absence of a microgap (one-piece implants) have the best prognosis in the long term. However, it is difficult to place one-piece (tissue level) implants in specific clinical conditions. For instance, when angulations are needed, clinicians are challenged to place implants parallel to each other. In addition, in case of crestal bone loss in the esthetic zone, visualization of the implant neck might compromise esthetics, and therefore all these limitations reduce the selection of one-piece implant designs in daily practice. Two-piece implants were developed to find solutions to clinical problems with the aim of reducing or eliminate the issues of the microgap. First implant designs having reduced diameter of abutment neck compared to the diameter of the implant were developed in the 80s. In 1985, Thomas Driskell introduced the first unique sloping shoulder concept designed to help maintain crestal bone height and interdental papillae with the name "Bicon®" implant system (18). Almost the same time Nentwig and Moser (19) illustrated the design of a concept with reduced diameter abutment neck, and a progressive thread design for better stability and apical load transfer, which was introduced in the German market (NM®-implant system, Krupp Co.) and was modified slightly later (Ankylos®-implant system Dentsply Co.). Due to the difference in the load transfer towards the apical part of the implant (20), this implant design showed promising clinical outcomes in the conjunction between teeth and implants using cement-retained fixed restorations (21).

The absence of a microgap is also possible in systems with a tight and rigid interface between implant and abutment, which creates a "virtually" one-piece implant due to lack of micromovements and bacterial accumulation (bacterial seal). In general, the type of mechanical connection is associated with micromovements under loading conditions. Conical (Morse-cone) connections present stability under loading (22,23) and are beneficial in clinical settings. Recent systematic reviews, comparing conical versus non-conical implant-abutment connection systems in their *in vitro* and *in vivo* performances, demonstrated that the Morse-connection provides a better abutment fit, stability, and seal performance (24). Therefore, more implant systems today move towards these developments and improvements.

A retrospective clinical study showed crestal bone stability around implants with Morse-tapered (conical) connections when these implants have been loaded after healing without abutment disconnection (*Figure 1*).

In addition, the design features of the implant-abutment

Figure 2 Soft tissue stability 12 years after implant loading on an implant with Morse tapered connection and platform switching.

Figure 3 Peri-implant soft tissue stability 6 years after implant loading demonstrating the papilla formation due to platform switching and Morse-tapered implant-abutment connection.

connection allow soft-tissue stability (*Figure 2*) and papilla formation due to the presence of supported bone crest (*Figure 3*).

The data of this study present long-term crestal bone stability (13 years post-op) for subcrestally and epicrestally placed implants (25) with PS. Also, studies from another scientific group confirm this concept using the same implant design. The marginal bone level changes around platform-switched implants with the same geometry were not affected by the epicrestal or subcrestal location of the implant platform (26) within an 18-month loading period. Additional studies evaluating implants placed in different apico-coronal positions (at the bone level or 2 mm subcrestally) showed similar clinical outcomes three years after prosthetic loading in both groups of implants, but less peri-implant marginal bone loss group of subcrestal placed implants (27).

The role of abutment-disconnection

Furthermore, there is evidence that implants, which have been connected and disconnected with the healing abutments present an apical migration of the peri-implant long junctional epithelium and crestal bone loss (28). The findings from these studies performed in beagle dogs indicate that the dis- and subsequent reconnections of the abutment (5×) compromised the mucosal barrier and resulted in a more "apically" positioned zone of connective tissue in the peri-implant tissues. Thus, the additional marginal bone resorption observed due to abutment manipulation may result from marginal tissue reactions to establish the proper "biological width" of the mucosal-implant barrier.

Even studies by Abrahamsson *et al.* (29) showed a similar composition around dental implants with different implant designs (i.e., Astra, Nobel and Straumann), the examined implants with conical implant-abutment connections and PS (Astra system) presented a shorter long junctional epithelium. In addition, when plaque-induced inflammation was initiated after placement of ligatures around implants with different types of implant-abutment connections, the level of peri-implant soft tissue infiltrate was evaluated and showed a statistically significant difference in the inflammatory reaction, with less inflammation around implants with PS (Astra design). However, the authors concluded that the marginal bone levels, measured from the abutment/fixture border, did not differ between the three systems (30).

Figure 4 Marginal crestal bone stability around implant with Morse-tapered connection and platform switching (monkey). There is lack of space at the implant-abutment interface under loading conditions in the histological specimen to be observed, which proves the sealing at the implant-abutment interface.

Also, repeated (2×) dis-/re-connection at four and six weeks (test) around titanium and zirconia implants in dogs with a horizontal mismatch of 0.4 mm presented dimensional changes of peri-implant soft and hard tissues (31).

The one-abutment concept, which was proven in monkeys showed lack of micromovements under loading conditions and a seal in the implant-abutment interface when conical implant-abutment connections were used (*Figure 4*). The clinical impact of the Morse-tapered connections was also confirmed clinically by other investigators, showing a longitudinal stable soft tissue dimension (32).

Advanced surgical protocols with immediate loading of dental implants placed in healed ridges and implants placed in fresh extraction sockets and restored with the final abutments without removal were documented and showed excellent success after many years of function (33,34).

Degidi *et al.* (35) confirmed the concept of one-abutment in a clinical study with a 2-year follow-up period. The authors showed that non-removal of abutments placed at the time of surgery improves the stability of healed soft and hard tissues around the immediately restored, subcrestally placed tapered single maxillary implants in fresh extraction sockets. In addition, mandibular immediately loaded implants in partially edentulous patients successfully used the one-abutment concept (36).

Further animal and clinical studies with immediately loaded implants using the same abutment from the time of implant placement (without disconnection) concluded to similar clinical outcomes (37). Specifically, the prosthetic restoration was fabricated after the impression of the abutment without disconnection, and the prosthesis was cement-retained (38-40). In addition, it was shown in heavy smokers, no significant difference in the clinical outcomes when implants are loaded immediately (41,42). Human histological autopsy report from a heavy smoker presented an excellent osseointegration with soft and hard tissue stability around immediately loaded implants (43).

In all these studies, implants with a narrow abutment neck diameter than the implant diameter (platform shifting) were used following a concept of abutment placement and without removal. The strategies and treatment approach to accomplish soft and hard tissue stability were recently published (44).

Size of the horizontal mismatch

The reduced diameter of the abutment neck compared to the implant diameter, so-called "platform switching" (PS) was introduced in the international literature by Gardner (45) and later by Lazzara and Porter (46) confirming the maintenance of the crestal bone level for platform-switched implants based on human histological evaluation (47).

Quantitative analysis based on seven systematic reviews with meta-analysis indicated positive peri-implant bone preservation for implants restored with an implant-abutment mismatching (48). This study suggested that marginal bone level alterations could be related to the extent of implant/abutment mismatching. Furthermore, marginal bone levels were better maintained at implants restored according to the PS concept.

In a previous evaluation of the literature on PS, seven studies reported that implants placed according to this concept did not minimize crestal bone loss compared with non-platform switched (NPS)-implants. Three-dimensional (3D) implant positioning, the width of alveolar ridge, and control of micromotion at the implant-abutment interface are the more critical factors that influence crestal bone levels than PS (49). In addition, canine studies with PS- and NPS-implants showed that the bone remodeling was minimal in both groups and that the PS may not be of crucial importance for the maintenance of the crestal bone level (50).

However, in a relatively new investigation, the crestal bone resorption was also evaluated around implants with platform-matched and platform switched interfaces. Implants with platform-matched abutment groups demonstrated a higher amount of metal ion release and more surface damage. In contrast to these findings, the PS concept reduces the tribo-corrosion products released from dental implants, which may minimize the adverse tissue reactions leading to peri-implant bone loss (51). These findings highlight the positive effect of PS due to reduced osteoblast viability and secretion of cytokines (52) controlling further corrosive phenomena at the implant-abutment interface.

The horizontal mismatch between the abutment neck and implant platform was evaluated in a dog study (53). It showed that a mismatch of 0.85 mm between the implant and abutment yielded more coronal levels of bone-to-implant contact and a reduced height of the peri-implant soft tissue (biologic width), especially at the buccal aspect, if the implant shoulder was placed at the bone level.

However, the design of the transmucosal component can influence the establishment of the peri-implant biologic width on implants with PS. Specifically, flat, and wide emergence profiles (45° angulation with implant long axis compared to narrow emergence profiles with 15° angulation with implant long axis) induced an apical displacement of the peri-implant biologic width and more crestal bone loss (54).

Studies also in canines showed that independent of the shape of the horizontal mismatch (concave or no, mimicking the currently marketed bone-level implant from Straumann implant design), implants with concave abutment neck present thick, soft tissue around the neck and, therefore thicker transmucosal component as a protective barrier against bacteria. However, a crestal bone loss was observed except if the implants are fabricated as one-piece implants with concave transmucosal portion. The study promoted the concept of one-piece dental implants (55).

Further studies by Cochran *et al.* (56) confirmed that the bone loss around implants with non-matching implant-abutment diameters was significantly less (five- to six-fold) than that reported for bone-level implants with matching implant-abutment diameters (butt-joint connections).

Without doubt the studies in canines are fundamental but clinical evidence is required in the future using this type of designs.

The morse-tapered connection

There are many implants in practice today using conical implant-abutment interfaces, but the degree of angulation impacts mechanically the anti-rotational stability. In engineering the taper angle of the Morse taper varies somewhat with size but is typically 1.49 degrees. Specifically, from the mechanical engineering perspective, the clamping force in conical connections originates a large frictional resistance. In addition, the manufacturer has included a non-rotational interconnection (like a hex) to add rotational stability for an accurate placement of the prosthetic abutment/restoration.

It was also shown that the 11-degree Morse taper demonstrated better resistance to microbial leakage than the butt-joint connection (57). A misfit of the implant-abutment interface leads to abutment overload, screw loosening, incorrect force transmission to the implant body and the peri-implant crest of bone and bacterial proliferation, and potential risks for implant fracture.

It must be considered that a complete fit of the abutment with the internal taper of the implant (or only a small amount at the top of the abutment connection) is of importance to provide mechanical interlocking, abutment stability and bacterial sealing. The Morse locking tapered connection is shown to leave a gap, which is smaller than 1 micron, whereas the smallest bacterium measures approx. 1.5 microns.

In finite element studies Yao *et al.* (58) showed that the design optimization and is the 5.7-degree Morse-tapered connection not only reduces the possibility of abutment fracture but also increases the longevity of implant therapy (59) and overall patient satisfaction (60).

Today, there is only one clinical study comparing two implant systems with different implant-abutment connections and PS placed in the same patient and splinted together with a fixed prosthesis. The butt-joint and the Morse-tapered connection were compared in this prospective clinical study. The implants were placed with platforms at the bone level and restored with the final abutment at day of implant placement for immediate function. It was shown that 70% of the implants with the butt-joint connection presented more than 2 mm crestal bone loss in contrast to the implants with Morse tapered connections (11%) (61).

The study also showed a significant difference in terms of bacteria presence at the implant-abutment interface (62). Specifically, the abutments were removed after 2 years of loading for bacteria analysis. In addition, chlorhexidine (CHX) was used to potentially decontaminate the implant-abutment interface. There is evidence that butt-joint connections are not well sealed and presented periodontal-pathogenic bacteria infiltration, which was no found in the conical connections (62). In addition, the efficacy of the CHX was minimal.

Thus, the type and design of the implant-abutment interface seem to have a fundamental difference in terms of bacteria penetration, preventing or allowing peri-implant inflammatory reactions and potentially establishing the resorption of the crestal bone. Based on this data, it can be concluded that when the crest of bone in the anterior mandible must be reduced to create sufficient interocclusal space for the prosthetic restoration using hybrid type of prostheses, or when implants even with PS are placed in the atrophic bone, there is an expectation of bone resorption independent on the implant-abutment connection and absence of micromovements (when implants are splinted).

Furthermore, the gentle bone preservation, especially in the anterior mandible, as well as the soft tissue thickness and presence of keratinized peri-implant mucosa, have shown to have an impact on crestal bone stability (63,64).

Summary

In summary, there is a pantheon of components that must be considered and synchronized by clinicians based on knowledge and experience in understanding these sensitive and fundamental topics in implant dentistry. Specific implant design features provide important information for clinicians and manufacturers to create a better future for dental implants, especially if the host response changes over time. Biology and technological improvements must be considered when clinicians are placing implants especially in compromised sites and patients with systemic diseases. All these developments must be critically analyzed when new implant surfaces and implant-abutment connections are developed to improve strategies for better osseointegration and crestal bone stability.

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