

Surgical, biologic and implant-related factors affecting bone remodeling around implants

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Placement of implants in the alveolar process elicits a sequence of healing events, which includes necrosis and subsequent resorption of the traumatized bone around the titanium surface while new bone formation takes place.¹

Whereas the initial mechanical stability of the implant owes to direct contact and friction between the implant surface and the bone, the long-term maintenance of this stability requires a biological attachment between the foreign body and the surrounding tissues. The peri-implant bone adjusts its architecture in relation to its functional loading bearing, and the strains induced by these loads affect the bone remodeling process.

Soft tissue stability around dental implants is crucial for the predictable and routine restoration of single teeth and partially edentulous patients. In turn, the soft tissues are supported by the underlying alveolar crest.

Early crestal bone loss of about 1.5 mm is frequently observed during the first year after implant loading, followed by a yearly bone loss of about 0.2 mm in the following years. Crestal

bone loss produces changes in soft tissue arrangement and vice versa. Possible etiologic factors associated with this initial bone loss are:

- Surgical factors
- Biologic factors
- Implant-related factors

Surgical factors

Surgical trauma has been regarded as one of the most commonly suspected etiologies for early implant failure. Elevation of the periosteal flap, heat generated at the time of drilling, and excessive pressure at the crestal region during implant placement may contribute to implant bone loss during the healing period. The questions that will be addressed are the following:

- Is surgical trauma determined by periosteal detachment during second stage surgery considered a cause of bone resorption?
- Is it possible to reduce the surgical trauma during implant site preparation using a piezosurgery insert?

Periosteal elevation has been speculated as one of the possible contributing factors for crestal implant bone loss (Figs 1 and 2).

The tooth (root) in function and its supporting tissues (cementum, periodontal ligament and bundle bone) play a crucial role in the maintenance of the dimensions of the alveolar process and that the absence of a tooth per se will reduce the demand for tissue support at that site. The removal of the root from its socket involves a pronounced mechanical trauma to the periodontal ligament and its blood vessels as well as to the bundle bone and the bone of the alveolar process.

An animal study from Araujo et al² confirmed that the removal of a single tooth (root) during healing caused a marked change in the edentulous ridge. It was also observed that similar amounts of bone loss occurred during healing irrespective of the procedure used for tooth removal, ie, flapless or following flap elevation. Fickl et al³ studied tissue alterations after tooth extraction performed in either a flapless or a flap procedure in the beagle dog. Healing was studied 2 and 4 months after tooth extraction using volumetric measurements made on casts. In other words, the measurements included both soft and hard tissue components. The authors concluded "leaving the periosteum in place decreases the resorption rate of the extraction socket." A more detailed analysis of the data illustrated that both extraction techniques resulted in loss of tissue volume, but also that the model used in the experiment did not distinguish between soft and hard tissue components. Blanco et al⁴ examined ridge alterations fol-

lowing immediate implant placement in fresh extraction sockets in a dog model.

The teeth were removed either in a flapless or in a flap elevation procedure. In biopsies obtained after 3 months of healing following implant (Straumann Implant System) installation it was observed that the buccal bone crest (BC) was located on average 4.13 mm (flap) and 3.62 mm (flapless) from the shoulder of the device. In other words, the difference between the flapless and the flap group after 3 months amounted to about 0.5 mm at the buccal aspect. One important difference between the Araujo et al² study and the experiment by Blanco et al⁴ is the length of the healing period, ie, 6 vs 3 months. It has been shown by eg, Schropp et al⁵ that dimensional changes following tooth extraction are not completed after 3 months but that between 3 and 12 months additional resorption and reduction will occur. The data from the present experiment therefore suggest that the 0.5 mm difference between the flap and the flapless group observed in the Blanco et al⁴ study may disappear after longer healing periods.

The extent of reduction of the supporting bone is apparently related to the thickness of the bone at the surgical site.⁶⁻⁸ Thus, the thinner the bone wall, the greater the crestal resorption becomes.

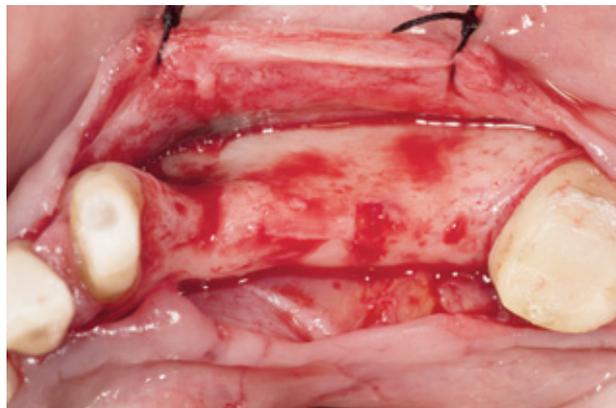
Covani et al⁹ showed that immediate implants with and without a mucoperiosteal flap elevation can be successfully used even in the presence of bone defects requiring augmentation procedures.

It was also noted that the bone regenerated reached a higher coronal level in the group with flap elevation than in the group without flap elevation.

Wilderman et al¹⁰ reported that the mean horizontal bone loss after osseous surgery with periosteal elevation is approximately 0.8 mm and the reparative potential is highly dependent upon the amount of cancellous bone existing underneath the cortical bone. Bone loss at the second stage surgery is generally vertical and it has been measured to be between 0.2 mm and 1.3 mm.¹¹ This resorption occurs only around the implant and is characterized by “saucerization”; the surrounding bone is not affected, even though all the bone is exposed during the surgery.

In 1984, Eriksson and Albrektsson¹² reported that the critical temperature for implant site preparation is 47°C for 1 min. or 40°C for 7 min. Overheating may be generated by excessive pressure at the crestal region during implant surgery. It has been demonstrated¹³ that temperature elevation was influenced more by the force applied than by drill speed. However, it was found that, when both drill speed and applied force were increased, no significant increase in temperature was observed due to efficient cutting.¹⁴

The introduction of an ultrasonic surgical device^{15,16} has paved the way to new possibilities in performing osteotomies without generating high temperatures. Currently, the effect of piezosurgery is being widely investigated in various fields of medicine. In orthopedics, for example, they are used to accelerate healing of bone fractures and ligament damage by promoting cell proliferation and bone matrix synthesis.¹⁷⁻¹⁹ Other experimental studies have postulated that piezosurgery influence in promoting angiogenesis²⁰ and in stimulating odontoblasts to produce reparative dentin, si-



Figs 1 and 2 Mucoperiosteal flap elevation has been speculated as being one of the contributing factors of bone resorption.

multaneously activating dental pulp stem cells to differentiate into odontoblasts.²¹ Moreover, two recent animal pilot studies concluded that piezosurgery appears to be more effective than drills in favoring bone healing in periodontal and implant surgery: an ultrasonic cut induces an earlier increase in BMP-4 and TGF- β 2 levels, controls the inflammatory process,

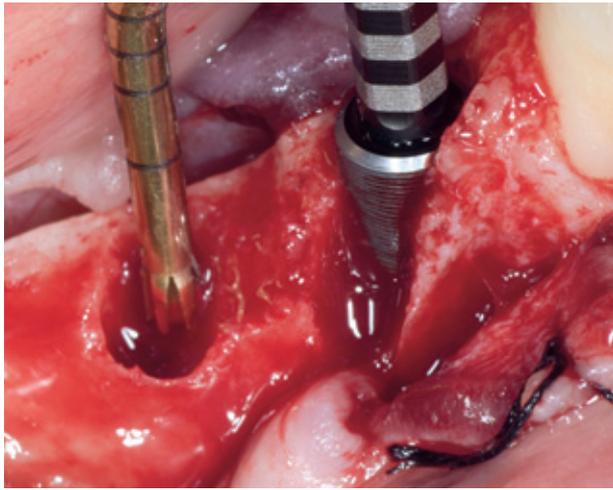


Fig 3 Piezosurgery implant site preparation could promote a more rapid osteointegration.

and stimulates faster bone remodeling (Fig 3).^{22,23} A possible interpretation of these results could derive from the cleaning effect of piezosurgery: microvibration and the cavitation effect of saline solution could result in effectively removing bony debris and tissue remnants deriving from site preparation, exposing marrow spaces and favoring a rapid migration of osteoprogenitor cells into the fresh wound. The reduced cell necrosis and the more rapid cellular activity could reduce the inflammatory process and bone remodeling during the healing phase, increasing peri-implant bone stability.

In summary, the signs of bone loss resulting from surgical trauma and periosteal flap elevation are not commonly observed at implant stage II surgery; furthermore, the pattern of bone loss in implants is more likely to be vertical than horizontal. Hence, the hypothesis of the surgical causes of early implant bone loss remains to be determined.

Biologic factors

Biologic width (biological seal)

In natural teeth, the dento-gingival junction consists of three components: the gingival sulcus, the epithelial attachment, and the connective tissue attachment. The dimensions of the dento-gingival apparatus were studied in human skulls by Gargiulo et al²⁴ and Vacek et al²⁵. The former reported that the average value of sulcus depth was 0.69 mm, and the average values for the epithelial attachment and connective tissue attachment were 0.97 mm and 1.07 mm, respectively. The biologic width (BW), which includes only the epithelial and connective tissue attachments, was therefore found to be 2.04 mm. The values found by Vacek et al were similar to Gargiulo's findings, and were 1.14 mm for the epithelial attachment and 0.77 mm for the connective tissue attachment. Both studies concluded that the most consistent value between individuals was the dimension of the connective tissue attachment.

An epithelial attachment and connective tissue attachment also exist around dental implants. They comprise the biologic seal that acts as a barrier against bacterial invasion and food debris ingress into the implant-tissue interface. The epithelial attachment in both implants and natural teeth is composed of hemidesmosomes and basal lamina, whereas collagen fiber direction in the connective tissue attachment is different, being parallel to the implant surface and perpendicular to the natural root (Table 1).²⁶ The questions that will be addressed are the following:

- Does implant placement above or below the boney ridge have an influence on the degree of peri-implant bone resorption?
- Does a mismatched implant influence the linear distribution of the biologic width or even the tissue compartment distribution?

Cochran et al²⁷ performed a study on loaded and unloaded non-submerged titanium implants and found that the dimensions of the implant-biologic width remained constant over time up to 12 months after loading. After 12 months of loading, the values were 0.16 mm for the sulcus depth, 1.88 mm for the junctional epithelium, and 1.05 mm for the connective tissue attachment. The biologic width reported in the study was 2.93 mm.

The dimensions of the peri-implant biologic width are not always the same, but they are subject to interindividual variations from patient to patient and from implant to implant.²⁸ It follows, then, that inter-individual variations also occur in postrestorative peri-implant bone levels, influencing the esthetic outcome. Her-

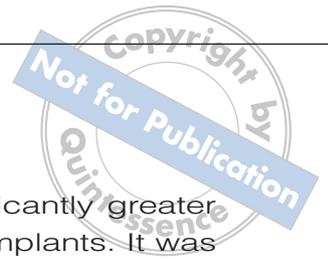
mann et al²⁹ histometrically evaluated the dimensional change of the biologic width around non-submerged implants. They observed that each dimension of sulcus depth, epithelial attachment and connective tissue attachment changed over time, but within the overall biologic width dimension.

The dimensions of the biologic width around submerged implants have also been reported (Table 2).^{30,31}

Berglundh and Lindhe³² studied the dimension of peri-implant mucosa in a beagle dog model. Prior to abutment connection, the ridge mucosa of the test side was surgically reduced to about 2 mm or less, while the contralateral (control) side remained intact (2 mm). Following 6 months of plaque control, animals were sacrificed for microscopic observation. The results illustrated that wound healing in the test sites consistently included bone resorption in order to establish about 3 mm of implant/soft tissue interface (biologic seal). In the control side, the distance between the BC and the outer surface of the peri-implant oral epithelium, was on average 3.65 ± 0.44 mm.

Table 1 Comparison between teeth and implants

	Tooth	Implant
Connection	Cementum, bone, PDL	Osseointegration, functional ankylosis
Junctional epithelium	Hemidesmosomes and basal lamina	Hemidesmosomes and basal lamina
Connective tissue	Perpendicular fibers	Parallel fibers
Vascularity	More	Less
Probing depth	≤ 3 mm in health	2.5 mm to 4 mm (dependent on soft tissue depth)
Bleeding on probing	More reliable	Less reliable



Hämmerle et al³³ studied the effect of subcrestal placement of the polished surface of non-submerged implants on marginal soft and hard tissues in 11 patients. At test sites, the apical border of the polished surface was placed about 1 mm below the alveolar crest, while, in control sites, the junction between rough and polished surface was located at the crest. After 1 year of function, the average crestal bone loss was 2.26 mm in the test group and 1.02 mm in the control group. The study suggested that, during the first year of function, the biologic seal is established 1 mm apical of the rough portion at the expense of the crestal bone independent of an initially increased implant depth.

In another study³⁴ comparing healed tissues in submerged and non-submerged unloaded dental implants in dogs, it was found that the apical extension of the epithelial attachment in submerged implants was located below the

microgap and was significantly greater than in non-submerged implants. It was speculated that this greater apical extension in submerged implants might be due to microbial leakage at the microgap after abutment connection at stage II surgery. However, there was no significant difference between the 2 groups: the distance between implant top and first bone-implant contact was 2.92 mm in submerged and 2.95 mm in non-submerged implants. The study hypothesized that the extent of epithelial downgrowth was not related to the amount of bone resorption occurring after surgery, but to microbial leakage at abutment microgap and that connective tissue appeared to fill that space. Wallace³⁵ emphasized the significance of biologic width in dental implants and stated that, if the ultimate location of the epithelial attachment following phase two surgery is on the implant body, this “is of clinical significance to the implant

Table 2 Biologic width measurements around natural teeth and dental implants

	Natural teeth		Dental implants		
			Non-submerged	Submerged	
	Gargiulo et al ¹⁶	Vacek et al ¹⁷	Cochran et al ¹⁹	Berglundh et al ²²	Abrahamsson et al ²³
Sulcus depth (SD)	0.69 mm	1.34 mm	0.16 mm		2.35–1.64 mm
Junctional epithelium (JE)	0.97 mm	1.14 mm	1.88 mm	2.14 mm	1.64–2.35 mm
Connective tissue attachment (CT)	1.07 mm	0.77 mm	1.05 mm	1.66 mm	0.50–0.62 mm
Biologic width (BW)	2.04 mm (JE+CT)	1.91 mm (JE+CT)	2.93 mm (JE+CT)	3.80 mm (JE+CT)	2.14–2.97 mm (JE+CT)

surgeon since it will in part determine the amount of early post-surgical bone loss.”

Based upon these findings, it is apparent that early implant bone loss is due, at least in part, to the processes involved in establishing biologic width. However, the amount of this bone loss may be influenced also by soft tissue thickness, position of the junction between rough and polished surfaces in non-submerged implants, and location of the microgap in submerged implants.

In a recent histological animal study,³⁶ a difference in the dimension of the biologic width was found between implants placed flush with the bone with a mismatched abutment and those with a matched abutment. The former had a shorter BW of 1.97 ± 1.20 mm, with a connective tissue compartment of 1.21 ± 0.96 mm and an epithelial attachment of 0.83 ± 0.92 mm. The control implant presented an average BW of 3.20 ± 0.33 mm, with a connective tissue compartment of 1.29 ± 0.53 mm and an epithelial attachment of 1.91 ± 0.71 mm. The results of the present experiment suggest beneficial effects of mismatched (0.25 mm) abutments at implants, where the shoulder had been placed flush with the level of the alveolar crest. These effects include the preservation of approximately 0.5 mm crestal bony height concomitant with a shortening of the epithelial attachment of 1.1 mm and a maintained dimension of the supracrestal connective tissue compartment.

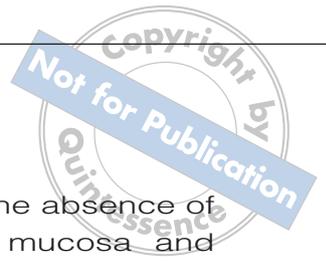
Keratinized mucosa

It has been suggested that the presence or absence of keratinized mucosa (KM)

may alter the resistance of the peri-implant region to plaque-induced tissue destruction. As a matter of fact, Warrer et al³⁷, using an animal model, reported that the absence of keratinized mucosa around dental endosseous implants increases the susceptibility of the peri-implant region to plaque induced tissue destruction. Therefore, the question that will be addressed is:

- What influence does the keratinized mucosa have in the preservation of marginal peri-implant bone?

There is a limited number of clinical studies evaluating the influence of keratinized mucosa on marginal bone level changes. Mericske-Stern et al³⁸ followed for 5 years 66 ITI implants placed in the mandible of 33 edentulous elderly patients. The implants served as overdenture anchorage. Approximately 50% of the implants had been installed into the lining of the mucosa. The peri-implant mucosal tissue was maintained healthy during the whole observation period, and no or minimal loss of attachment was observed. Wennström et al³⁹ evaluated the soft tissue conditions at implants in relation to the width of masticatory mucosa. The results showed that 24% of the sites were lacking masticatory mucosa, and an additional 13% had a width of less than 2 mm. Mobility of the facial marginal soft tissue (ie, lack of an attached portion of masticatory mucosa) was observed at 61% of all implants. No differences in the clinical parameters examined were found between sites with and without an “adequate” width of masticatory mucosa. Multiple regression analyses revealed that neither the width of masticatory mucosa nor the mobility



of the marginal tissue had a significant influence on (i) the standard of plaque control, or (ii) the health condition of the peri-implant mucosa, as determined by bleeding on probing. Hence, the study failed to support the concept that the lack of an attached portion of masticatory mucosa may jeopardize the maintenance of soft tissue health around dental implants.

Bengazi et al⁴⁰ evaluated alterations in the position of the peri-implant soft tissue margin, occurring during a 2-year period after insertion of the fixed dental prostheses. Apical displacement of the soft tissue margin mainly took place during the first 6 months of observation. Lingual sites in the mandible showed the most pronounced soft tissue recession, decrease in probing depth, and decrease of the width of masticatory mucosa. The statistical analysis revealed that lack of masticatory mucosa and mobility of the peri-implant soft tissue at the time of bridge installations were poor predictors of soft tissue recession occurring during the 2 years of follow-up. It was suggested that the recession of the peri-implant soft tissue margin might be the result of a remodeling of the soft tissue in order to establish “appropriate biological dimensions” of the peri-implant soft tissue barrier (ie, the required dimension of epithelial-connective tissue attachment in relation to the facio-lingual thickness of the supra crestal soft tissue).

The role of keratinized mucosa in peri-implant disease was studied by Roos-Jansåker et al,⁵¹ who examined 218 patients treated with titanium implants. A multivariate analysis of potential explanatory variables for peri-implant mucositis and peri-implantitis was made, where

no association between the absence of keratinized peri-implant mucosa and peri-implant disease was found.

From animal experiments there is limited evidence demonstrating differences regarding the soft tissue seal between masticatory and lining mucosa. Evidence from longitudinal retrospective and prospective clinical trials shows that, with adequate plaque control, there is no difference in the prognosis for maintaining a healthy functioning soft tissue seal as judged by clinical measures. A recent systematic review⁴² suggested that the presence of at least 1 to 2 mm wide keratinized mucosa might be beneficial in decreasing plaque accumulation, tissue inflammation, mucosal recession as well as loss of clinical attachment. There is a trend, but not statistically significant, to have more bone loss in the narrow KM group related to a wide KM group.

Soft tissue thickness

It has been suggested that peri-implant bone loss may be due more pronounced in thin soft tissue biotype sites. Therefore, the question to be answered is:

- What influence does soft tissue thickness have on the preservation of marginal peri-implant bone?

Data regarding the relationship between mucosal thickness and marginal bone loss around implants are sparse. Strub et al,⁴³ in an animal model, failed to find differences in peri-implant soft tissue recession or bone loss between sites with or without KM following plaque-induced breakdown. On the other hand, ligated implants in monkeys with minimal or no KM demonstrated significantly more

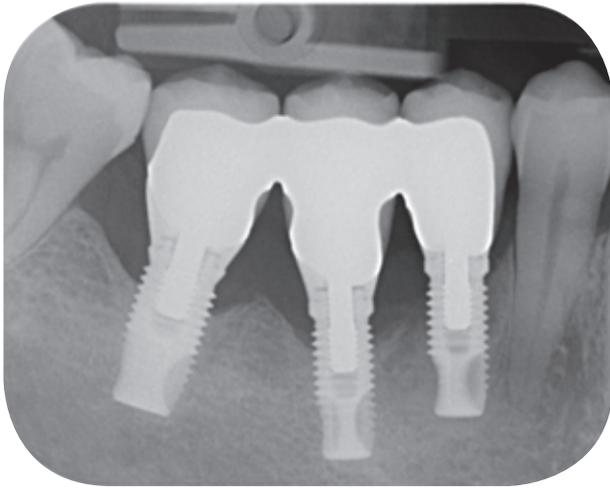


Fig 4 Implants surrounded by thin mucosa may be more prone to bone resorption with angular defects.

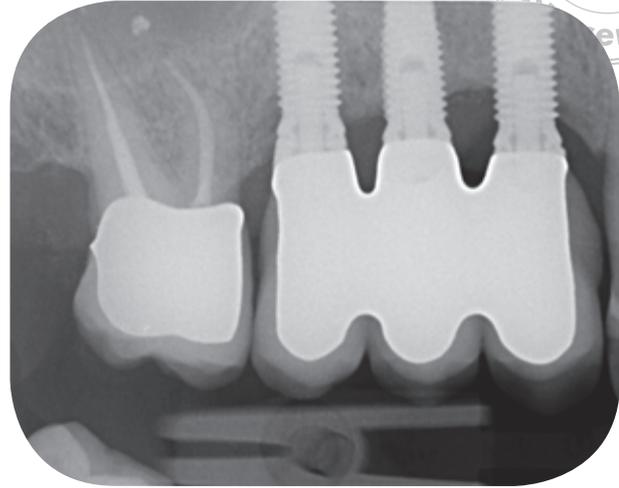


Fig 5 Implants surrounded by thick mucosa may display more horizontal bone loss.

recession than those surrounded by KM.^{44,45} The presence of KM around an implant is strongly correlated with soft tissue health. In accordance with those studies that support the association between KM width and soft tissue health, a recent study⁴⁶ found a negative correlation between KM width, mucosal recession (MR) and periodontal attachment loss (PAL). Also, when grouped together, a narrow mucosal band (1 mm) was associated with three times greater MR (0.27 ± 0.52 vs 0.9 ± 0.78 , $P = 1/40.001$) and more periodontal attachment loss. Conversely, KM width was positively correlated to PD, whereby implants with a wider mucosal band (1 mm) presented a higher mean PD. The possible explanation for this phenomenon might be related to the fact that MR and thereby less pocket formation may be more common in areas with a narrower band of keratinized mucosa. KM thickness around implants might determine

the future dynamics of the soft tissues that may display either recession or the formation of pockets in areas where the mucosa is of a thin or a thick biotype, respectively.

In an animal experiment, Berglundh and Lindhe²⁴ reported that thin tissues can provoke crestal bone loss during formation of the peri-implant seal. Observations in another histological study showed that implants surrounded by consistently thin mucosa had angular bone defects, while at implant sites with an even alveolar pattern, a wide mucosa biotype prevailed.²⁵ However, the evidence provided by well-designed animal studies is limited, which in turn reduces the generalization of the aforementioned results to clinical practice.⁴⁷ In addition, clinical research regarding the effects of tissue thickness on bone stability around implants is lacking (Figs 4 and 5). Consequently, the question remains whether gingival tissue thickness

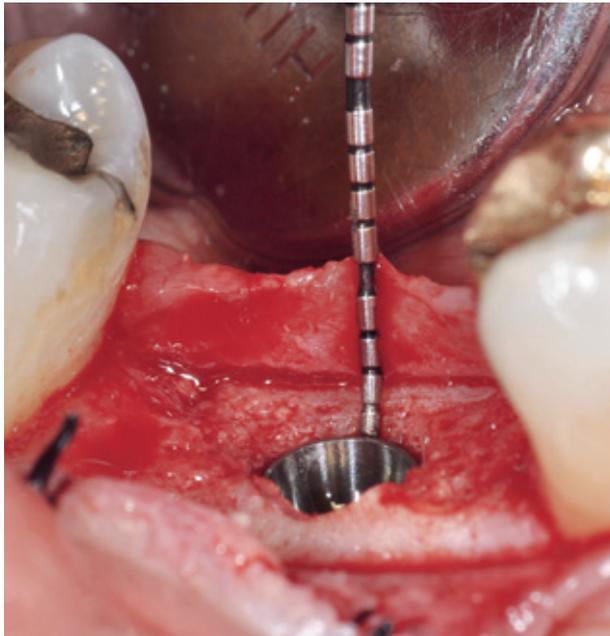


Fig 6 The initial tissue thickness may be an important factor in peri-implant bone stability.

plays a role in the etiology of early crestal bone loss.

A recent clinical human study by Linkvicius⁴⁸ indicated that thin mucosal tissues can cause crestal bone loss after implant placement and up to 1 year *in situ*. If the initial tissue thickness is less than 2.5 mm, bone loss up to 1.45 mm can be expected in the first year of function. In thick tissues (2.5 mm or more), significant marginal bone recession could be avoided if the implant-abutment junction is positioned approximately 2 mm above the bone level; in these cases, a negligible amount of bone loss (around 0.2 mm) would occur. Therefore, the authors recommended avoiding supracrestal placement of implants if a thin mucosal biotype is present (Fig 6).

Implant-related factors

One-stage vs two-stage implants

One-stage implant surgery contemplates the placement of a healing abutment following implant installation that remains exposed to the oral cavity following suturing of the mucoperiosteal flap. In contrast, in a two-stage implant surgery, a cover screw is placed following implant installation and the implant is completely submerged by the sutured flaps. Three to six months later, the implant is uncovered with a second surgical procedure and a healing abutment is placed allowing the peri-implant mucosa to heal.

The question to be answered is:

- Is there a difference on peri-implant bone stability between one-stage and two-stage implants?

The effect of one-stage and two-stage implant surgery on peri-implant mucosa and crestal bone level changes have been evaluated in both experimental and clinical studies.

Abrahamsson et al,²³ in an animal study, compared the morphology and the composition of the transmucosal tissue for 3 different implant systems (Astra Tech, Brånemark, and Straumann), using either a two-stage (Astra Tech, Brånemark) or one-stage technique (Straumann) over a six-month period. The epithelial and connective tissue components had similar dimensions and composition. All 3 groups exhibited bone loss of around 0.5 mm; the epithelium height was around 2 mm (slight variation among groups, 1.6–2.3 mm) and the connective tissue was roughly 1 mm. These histological observations

suggested that the soft tissue seal has the same characteristics using these implant systems. Similarly, in a later study,⁴⁹ no histological and radiographic differences were found between implants of the same system (Astra Tech) placed with different techniques (one-stage vs two-stage).

Although there is a large number of clinical studies and reports for implants placed with one-stage or two-stage surgical techniques, there are few studies which directly compare these two techniques. Åstrand et al,⁵⁰ in a split-mouth clinical study, compared implants placed with one-stage (ITI, TPS solid screws) and two-stage (Brånemark) surgical techniques supporting maxillary screw-retained fixed partial dentures for 3 years. No statistically significant differences were found among the implants studied regarding bone level changes and survival rates, except for the frequency of peri-implantitis, which was higher for the ITI implants. Similar findings were reported in another clinical study comparing implants placed with one-stage (ITI, TPS hollow screws) and two-stage surgical technique (Brånemark) supporting mandibular fixed partial dentures over a 3-year time period.⁵⁰ After 3 years, the cumulative success rates were 97.9% and 96.8% for the Brånemark and ITI systems, respectively. Kempainen et al,⁵¹ with a parallel group design study, compared for 1 year Astra Tech implants placed with a two-stage surgical technique vs ITI hollow cylinders placed with a one-stage surgical technique for single tooth replacement. Again, there were no statistically significant differences in failures and marginal bone level changes

between the implant systems and surgical protocols after 1 year of function (mean marginal bone loss was 0.13 mm for Astra Tech implants and 0.11 mm for ITI implants).

It appears that using one- or two-stage surgical techniques has no clinically significant effect on success rates, survival rates and marginal bone levels. However, one has to consider that the one-stage technique has less morbidity for the patients since it involves a single surgical procedure, while the two-stage surgery might offer greater potential for soft tissue management (Figs 7 and 8).

Macro-design of the implant collar

Functional activities produce bone strains that either directly or indirectly play a role in a bone's cellular adaptation.⁵² Maintenance of the osseointegration depends on continued remodeling activity of the bone surrounding the implant.⁵³ Carter et al⁵⁴ found that bone has an extremely poor fatigue strength. A bone stress fracture is believed to result from accumulation and coalescence of microdamage occurring when bone remodeling is insufficient to mend it as it is formed. In the light of this finding, it was suggested that a dental implant should be designed in such a way that the peak bone stresses resulting from the loads applied are minimized. As a matter of fact, load transfer characteristics of the implant may be dependent on the size and design of the implant neck.

Therefore, the questions that will be addressed are the following:

- Can implant macrogeometry influence peri-implant bone stability?

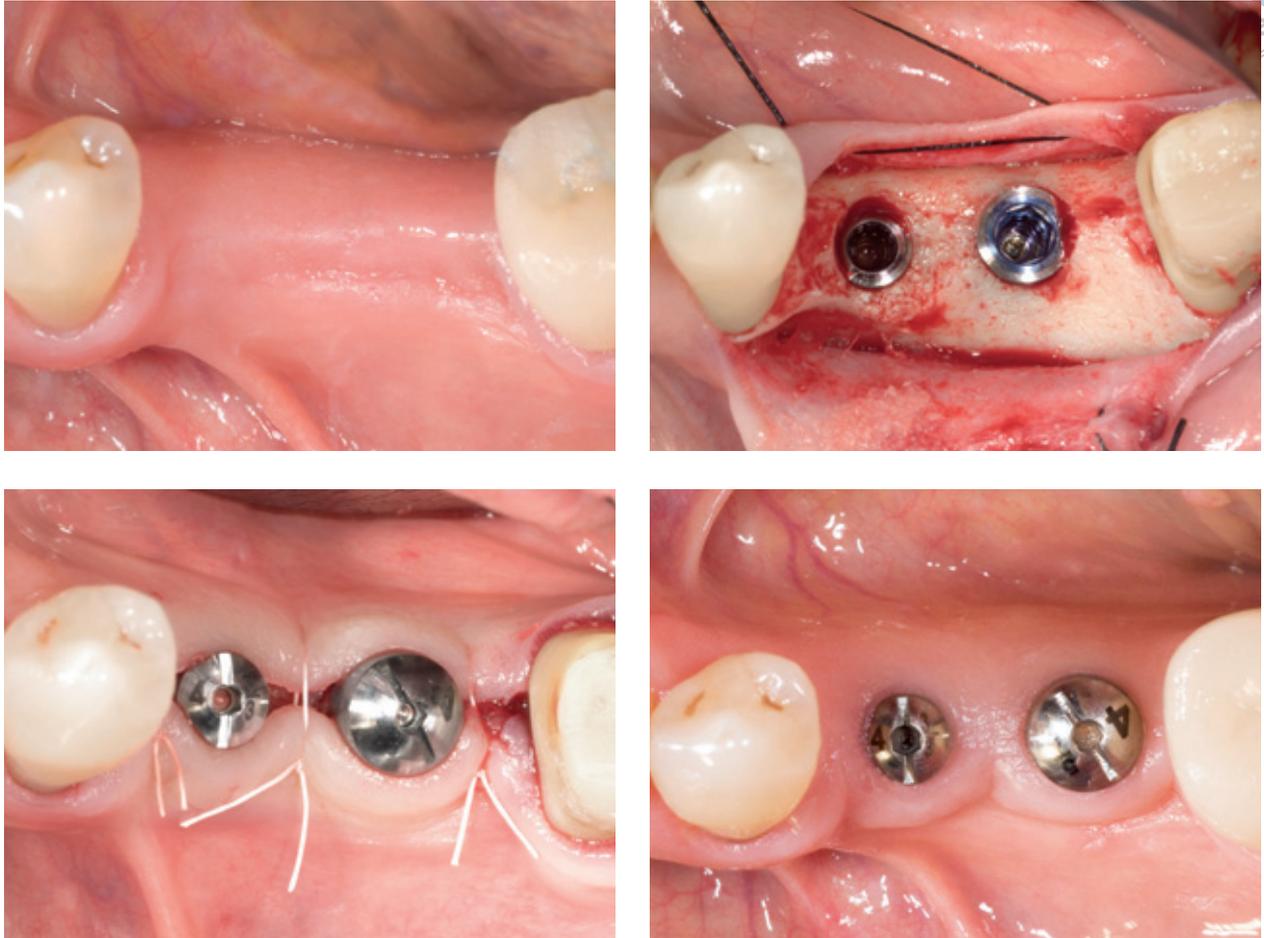


Fig 7 One-stage implant placement procedures reduce patient morbidity without compromising peri-implant bone architecture.

- What's the rationale for using a smooth implant neck?
- Do microthreaded collars promote bone stability more than smooth necks?

The load on an implant can be divided into vertical and horizontal components. Stoiber⁵⁵ and Mailath⁵⁶ found that the peak bone stress resulting from a vertical load on the implant was located at the top of the marginal bone, as did the

peak bone stress resulting from a horizontal load. This meant that bone stresses of two different origins spatially coincided and, thus, had an additive effect. In order to avoid these stresses in the marginal bone, both Stoiber and Mailath recommended a smooth endosseous implant neck, which is thought to allow a sliding motion between implant and bone, so that the marginal bone resists horizontal load components while vertical loads are managed by the underlying

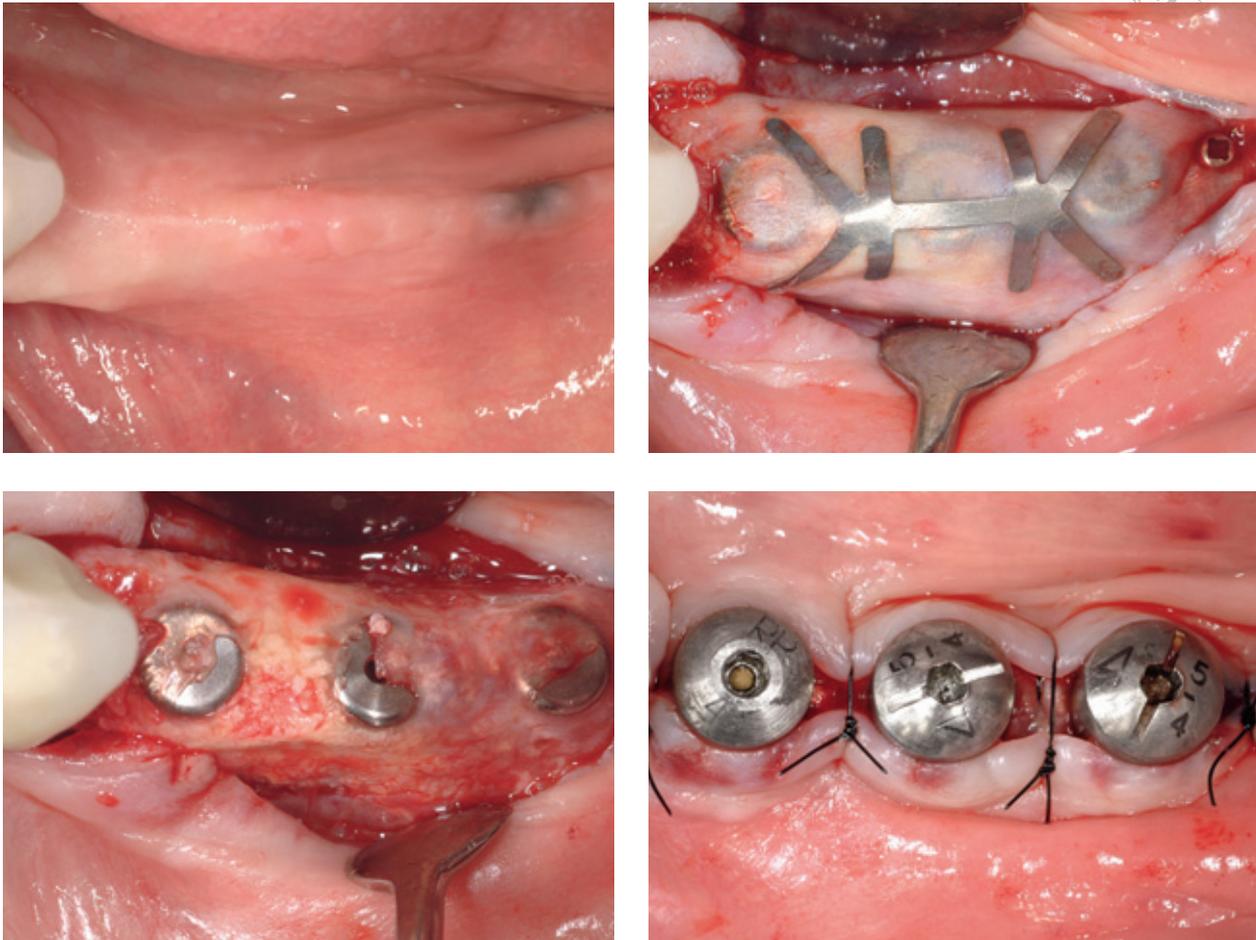


Fig 8 Two-stage implants placement procedures should be performed whenever an insufficient peri-implant bone volume is detected and a GBR procedure is required.

ing bone. The rationale for this recommendation was that the peak stresses caused by horizontal load components should be spatially separated from the peak stresses caused by vertical load components. However, smooth necks are far from preventing marginal bone resorption; as a matter of fact, they promote it (Frost's theory).

Bone loss can also be the consequence of insufficient mechanical stimulation. Hansson⁵⁷ found that the

location of the peak bone-to-implant interface shear stress depends on the design of the implant-abutment interface. With a "flat to flat" implant-abutment interface at the level of the bone, the peak stress was located at the very top of the marginal bone. With a conical interface, the peak stress had a more apical location.

According to a study on the mechanical properties of bone,⁵⁷ bone is most resistant when a compressive



load is applied, 30% less resistant under tensile stresses and 65% less resistant against shear loads. Therefore, to minimize bone loss, the application of a crestal module design, which can decrease the shear force on the crestal bone, is important. This clinical advantage could be obtained by a macro-geometry modification, which introduces a microthread in the cervical area of the implant. In order to analyze the influence of these microthreads on peri-implant bone stability, a comparative histological and radiographic study between two different implants with and without microthreads was performed in an animal model⁵⁹ and human model⁶⁰. The conclusion of the studies were that implants with microthreads demonstrated a better bone performance relative to implants without microthreads (BIC 81.8% vs 72.8%)(0.14 ± 0.11 vs. 0.28 ± 0.19 , respectively).

A recent human radiographic controlled study⁶¹ with a median follow-up time of 1.9 years (range: 1.9–2.1) showed that marginal bone levels adjacent to a machined-neck or rough-surfaced microthreaded implant underwent minimal changes in crestal bone levels during healing (stress-free) and under functional loading. The machined-neck group had a mean crestal bone loss of 0.5 mm (range: 0–2.3) after the healing period, 0.8 mm after 6 months (range: 0–2.4), and 1.1 mm (range: 0–3) at the end of the follow-up. The rough-surfaced microthreaded implant group, instead, had a mean bone loss of 0.1 mm (range: 0.4–2) after the healing period, 0.4 mm (range: 0–2.1) after 6 months, and 0.5 mm (range: 0–2.1) at the end of the follow-up.

In traditional implants, the role of the first thread is to transform the shear force between the implants and the crestal bone into the compressive force to which bone is the most resistant.⁶² Compared to threads of standard dimensions, small threads give the additional advantage of increasing the axial stiffness of the implant bringing about an additional reduction of the peak interfacial shear stress.⁶³

Another macrogeometry modification that could influence peri-implant bone resorption has been analyzed in a recent 5-year study.⁶⁴ In this study, the effect on crestal bone height of implant geometry and collar macrostructure was evaluated. Implants with a straight collar had less bone loss than implants with stepped collars. The bone position was also affected by the different collars. Rough collars has -0.61 ± 0.16 mm and it was -1.55 ± 0.10 mm for smooth collars group in both straight and steeped collar implants. Another study⁶⁵ confirms that implants with rough surface and microthreads have an improved bone response compared to smooth-collar implants. In this study, it was also pointed out that platform switching by itself was not sufficient to reduce bone loss and that additional design changes should be considered for the implant neck.

Previously published studies^{66,51} focused on the presence or absence of microthreads and, thus, did not provide insight into the effect of the microthread location on peri-implant marginal bone. Therefore, it is possible that the microthread location might also have the same effect on the stabilization of marginal bone levels. In a recent study,⁶⁷ the average bone loss around implants

with microthreads placed 0.5 mm below the top of the neck (group B) was greater than that observed around implants in which the microthreads were placed at the implant top (group A). One possible explanation is that implants with microthreads placed below the top lacked retentive features above the microthread level and, therefore, lacked the ability to distribute stress concentrated at the implant neck. Thus, these implants may have transferred this stress to the peri-implant marginal bone. If such stress exceeds the threshold that the peri-implant marginal bone can withstand, fatigue microdamage occurs, leading to bone resorption. Therefore, microthreads, which act to distribute stress, placed at the level of the marginal bone exert optimal effects for maintaining peri-implant marginal bone stability.

In conclusion, a modified implant macrogeometry with minute threads seems to reduce the peak stress values in the bone, particularly when combined with a conical implant abutment connection located under the level of the marginal bone. The benefits of a microthreaded collar compared with a smooth neck in terms of established bone-to-implant contact and maintained marginal bone levels are well documented.

Implant-abutment microgap location and bacterial contamination

The connection interface between implant and abutment has been investigated intensively during the last 10 years. More than the surgical technique (submerged or non-submerged), there is evidence that the crestal bone changes are dependent upon the presence or

absence as well as the location of the implant-abutment interface (microgap).⁶⁸

At the time of insertion, implant surfaces are devoid of indigenous microbiota. However, they can be colonized once the implant is exposed to the oral cavity. A pattern and a sequence of microbiota succession quite similar to the one described for tooth surfaces was observed.⁶⁹ Many studies^{70,71} have shown that component interfaces or microgaps are contaminated with bacteria. Initially, bacterial products stimulate an innate immune response and eventually an acquired immune response that stimulates and enhances the recruitment of more inflammatory cells. This inflammatory process can result in the recruitment of osteoclast precursors, an increase in the RANKL/OPG ratio and osteoclastogenesis, leading to bone resorption. Inflammatory cells (B and T cells) produce receptor activator of nuclearfactor-kappa B-ligand (RANKL), thus increasing its ratio to osteoprotegerin (OPG), its natural decoy receptor. Such a relationship between bone loss and inflammation has been recognized since the 1970s with concepts such as Waerhaug's⁷² "extended arm" of gingival inflammation that could result in osteoclastic bone resorption and Garant's "effective radius of action of locally produced bone resorption stimulators."⁷³

It has been proposed that the likely source of the microorganisms at the implant-abutment interface is due either to contamination during the abutment insertion or to their apical migration from the sulcus after prosthetic placement.⁷⁴ Because the extent of the peri-implant inflammatory infiltrate is directly influenced by the amount and composition

of the submucosal biofilm, a correlation between the submucosal microbiota and the amount of bone resorption has been hypothesized.

Therefore, the questions that will be addressed are the following:

- Where do microorganisms come from in the implant-abutment interface?
- Does the type of internal connection, internal octagon/hexagon vs conical seal provide better biologic seals and minimize/prevent bacterial leakage?
- Is there a difference in microgapping between different connections and what are the biologic consequences as far as microbial colonization, inflammatory cellular infiltrate, and bone resorption are concerned?
- Does the size of the butt joint vertical gap have an influence on the amount of peri-implant bone loss?

Ericsson et al⁷⁵ showed that the bone resorption at the implant-abutment junction (IAJ) was caused by an inflammatory cell infiltrate that formed a 1.5 mm semispherical zone around the IAJ.

A recent animal study⁷⁶ showed that, when implants are placed with the implant-abutment interface even with the bone, the average crestal bone loss 6 months after loading ranged from 0.15 for the submucosal group to 0.47 mm for the transmucosal group. These values are much smaller compared to a similar animal study⁷⁷ using matching implant abutment diameters. In that study, the marginal bone loss after abutment connection was about 2 mm.

Since the microgap influences the level of crestal bone, it is possible that

the size of the microgap and subsequent bacterial invasion between implant and abutment may exert a profound effect upon crestal bone levels. A longitudinal radiographic study⁷⁸ was conducted to determine whether the size of the interface or the microgap between the implant and abutment influences the amount of crestal bone loss in unloaded non-submerged implants. The conclusion of the study was that the size of the butt joint (range 10 to 100 μm) did not influence the amount of bone loss observed around the interface. This finding implies that implant configurations incorporating interfaces will be associated with biological changes regardless of interface size (Fig 9).

A recent study⁷⁹ compared the microbiota around implants restored with the platform switching approach and those restored with a standard protocol. The results of this study cannot support the hypothesis that the reduced bone loss around implants restored with the platform-switching approach was associated with lower levels of subgingival species or a less pathogenic submucosal microbiota. This finding suggests that this clinical phenomenon might be explained by a greater availability of an exposed horizontal implant surface for biologic width reestablishment or by creating a greater distance between the peri-implant inflammatory infiltrate and the bone surface as previously proposed.

On the other hand, in implants with solid abutments and no central opening that would allow migration of microorganisms, smaller inflammatory lesions were occasionally identified in the connective tissue compartment adjacent to the abutment implant borderline. Such

lesions were the result of a single contamination during the connection procedure rather than of a constant bacterial growth between components.⁸⁰

The different design and geometry of the two implants may have an influence on the bone remodeling following surgical therapy. Recent experiments demonstrated that the position of the implant-abutment interface defines the degree of inflammatory reaction and contributes directly or indirectly to the extent of alveolar bone loss.^{81,82}

From a hypothetical point of view, the subcrestal placement of the implant could produce a large space in which the blood clot can form and in sequence, woven bone can develop.^{83,84}

The influence of different vertical microgap locations on the peri-implant bone morphology has been investigated in two different implant-abutment connection types.⁸⁵ Three months after tooth extraction, on one side two internal Morse taper connection implants (Anki-los) were inserted, while the contro-lateral side received two oxidized screw external hex implants (Tiunite). It was concluded that a vertical bone resorption of 0.5 to 1 mm can be expected. The first bone-to-implant contact was found closer to the implant shoulder if the implant was placed 1.5 mm subcrestally compared with an equicrestal insertion and the “dish-shaped” defect configuration was more pronounced in a non-conical butt joint connection without horizontal offset. The observation that bone was maintained on the smooth collar part of the Ankylos implants might indicate that differences in the implant-abutment connection type have a more pronounced influence on the bone-to-

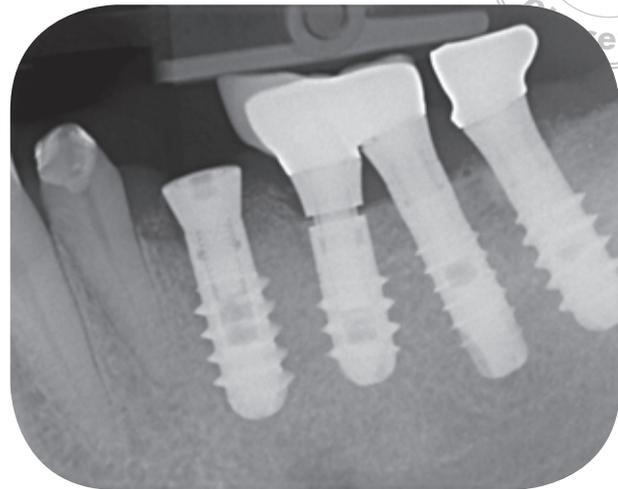


Fig 9 The presence and size of the implant-abutment gap does not influence the amount of bone loss observed around the implant.

implant contact than the roughness of the surface per se.

Screw loosening can favor contamination of the components' internal parts by microorganisms. This leakage is higher when the abutment screw is tightened and loosened repeatedly. Many years ago, the principle of Morse taper for the implant-abutment connection was introduced in oral implantology. Morse connection is based on the principle of “cold welding” obtained by high contact pressure and frictional resistance between the surface of the implant and the abutment. The connection is called “self-locking” if the taper angle is 5 degrees. Morse taper can resist eccentric loading complexes and bending moments, ensuring mechanical stability and reducing the incidence of prosthetic complications at the implant-abutment interface.⁸⁶

Morse connection could provide an efficient seal against microbial penetration, significantly reducing the microgap

(1 to 3 μm) dimensions at the implant-abutment interface, and contributing to a minimal level of peri-implant tissue inflammation.⁸⁷ With Morse taper connection, the gap is closed so tightly that the abutment and the fixture behave like a single piece; for this reason, there is no microgap and no bacterial leakage. Even with this seal, a recent study⁸⁸ found bone resorption where the bone level of the fixture was situated 0.89 and 1.10 mm from the reference point, after the first and sixth year of functional loading, respectively.

Even in implant systems having tight and stable implant-abutment joints (Astra vs Ankylos), some studies⁸⁹ reported the occurrence of microleakage of very small molecules (ie, endotoxin). Ankylos showed endotoxin contamination from all samples within 5 min of agitation. Significantly less molecular microleakage was observed for Astra implants at every time point when compared to Ankylos implants. The reason may be due to the smaller gap size reported at the conical implant-abutment junction for Astra implants (1–2 μm) compared to that for Ankylos (4 μm).

The fact that peri-implant bone was able to grow over the microgap only in the Morse taper connection-type implants may mean that either microbial contamination or micromechanical movement or the combination thereof is reduced in such implants. The angulation of the peri-implant bone defect was only half as big in the Morse group as in hexed group. For both groups the bone angle was 10 to 20 degrees smaller when a subcrestal insertion mode was chosen compared to an equicrestal insertion mode.⁹⁰

From the radiographic and histological studies reviewed, it can be concluded that:

- The radiographic bone to implant contact develops 2 mm from the microgap irrespective of the vertical location of the microgap.⁹¹
- The histological bone to implant contact maintains a distance of 1.3 to 2.6 mm from the microgap depending on the location of the microgap relative to the surrounding bone level.⁹²
- The microgap size itself does not influence the amount of peri-implant bone resorption, unless micromovement becomes an additional factor.
- The healing mode (submerged or non-submerged) does not influence the amount of the peri-implant bone resorption during the healing phase of an implant.⁹³

Abutment platform switching

One approach that has been proposed to minimize bone loss at the implant-abutment interface is to alter the horizontal relationship between the implant diameter and the abutment diameter. The platform switching (PS) concept was introduced in the literature by Gardner in 2005.⁹⁴ A reduced abutment diameter displaces the implant abutment interface further away from crestal bone and, possibly, the subsequent inflammatory reaction (Fig 10).

The questions that will be addressed are:

- Does PS minimize bone loss at the implant-abutment interface?
- If so, by which mechanisms?
- Could PS be more prone to long-term bacterial infection?

A recent systematic review⁹⁵ analyzed the effect of PS on preserving implant marginal bone. Only nine studies met the inclusion criteria, three were prospective comparative studies and six were RCTs. The conclusions of the study were that, based on the current evidence, the use of PS seems to exert beneficial effects on peri-implant marginal bone. Some confounding factors, such as the apico-coronal position of implants in relation to crestal bone, the presence of various implant microtexture, the degree of PS and the reliability of examination methods, should be considered when interpreting the results.

A 5-year clinical study⁹⁶ reporting data of an implant with an abutment that had a reduced diameter relative to the implant diameter, showed a mean marginal bone loss of 0.06 mm in the first year of function. A long-term prospective study⁹⁷ with a follow-up of 11 to 14 years suggests that PS implants are effective in preserving crestal bone level, even though a control group was not included. In a prospective controlled clinical trial,⁹⁸ reported a positive effect of PS on bone preservation after 1 year; at 5 years, the marginal bone change was insignificant compared to that seen at 1 year around both PS and non-platform switching implants. These results suggest that under normal circumstances, the pattern of marginal bone loss associated with PS implants was identical to that of conventional implants, where the greatest amount of bone changes occurred between surgery and crown/abutment placement, after which the changes were minimal.

Several theories have been suggested to explain this phenomenon. According

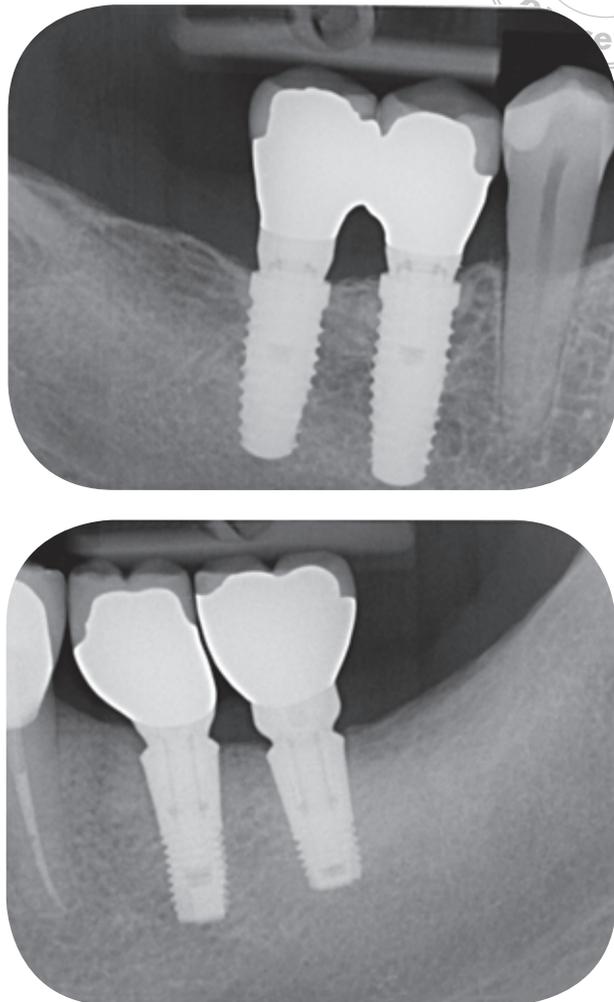


Fig 10 A reduced abutment diameter displaces the implant abutment interface further away from crestal bone and, thus may reduce the effects of the associated inflammatory reaction.

to the biomechanical theory, connecting the implant to a smaller-diameter abutment may limit bone resorption by shifting the stress concentration zone away from the crestal bone-implant interface and directing the occlusal forces along the implant axis.⁹⁹ Focusing on this last

aspect, Chang et al¹⁰⁰ compared the implant-bone interface stresses around PS and matching implants using 3D finite element analysis (FEA). They confirmed that the PS technique reduced the stress concentration in the area of compact bone and shifted it to the area of cancellous bone.

Although it was demonstrated that bone resorption is correlated to mismatching with a linear inverse correlation,¹⁰¹ some studies have suggested that peri-implant bone resorption is also dependent on fixture diameter. It has been demonstrated with finite element analysis that increasing the implant diameter results in stress reduction at the peri-implant crestal bone.¹⁰² This positive behavior could be related to an increase of both implant diameter (decreasing stress on the implant/bone environment) and the mismatching (decrease the negative impact of implant/abutment microgap infection on vital bone). To test this hypothesis, a prospective randomized controlled matched-paired trial was run to evaluate hard tissue responses around implants with different platform diameters restored according to the PS concept with the same implant/abutment mismatch.¹⁰³ At the end of the study, no statistically significant differences were found. The authors concluded that biological and microbiological factors are prevalent in the formation of peri-implant bone remodeling compared to biomechanical factors.

As a matter of fact, the other theory to explain bone behavior around PS implants assumes that marginal bone resorption may be minimized by the shift of the implant-abutment connec-

tion toward the center of the implant which moves the location of the biologic width.^{104,105} This biological advantage of the PS could have a clinical reflection in the inter-implant distance and between implant and teeth.

Even if the previous review studies^{106,107} advance the hypothesis that platform-switching may preserve the crestal bone level and maintain the soft tissue level in the esthetic zone, a more recent literature review¹⁰⁸ stated that the radiographic marginal bone level is a surrogate measurement for the esthetic outcome.

In a recent study¹⁰⁹ of a platform shifted implant system, the mean peri-implant bone resorption measured from the implant-abutment interface was 0.36 ± 0.26 in the horizontal axis and 0.46 ± 0.37 mm in the vertical axis. The results of this study suggest that a PS implant can be placed 1 mm from the adjacent tooth and still maintain the adjacent bone peak. These results are in agreement with a previously published study that suggested that a 2 mm distance between adjacent platform-switched implants was able to maintain the inter-implant bone peak¹¹⁰ even after 6 to 48 months of loading.

Vertical bone resorption at the interimplant area of around 0.68 and 0.92 was obtained for the equicrestally (ECL) implants group and 0.37 and 0.49 mm for the subcrestally (SCL) implant group.¹¹¹ Another study¹¹² found different values between 2.03 and 1.98 mm for the same parameter in ECL groups. The difference could be explained, at least in part, by the surface treatment of the implant collar: in the previous investigation, a rough collar was used, while in that by

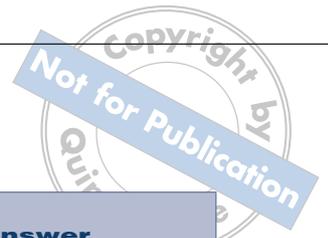
Papalexio et al, a smooth collar was instead placed.¹¹²

Some authors have stated that the horizontal implant/abutment mismatching following this prosthetic concept could be more prone to bacterial infection, thus compromising peri-implant attachment levels in long term.

In order to investigate the inflammatory response to platform switching, it was suggested to measure the levels of metalloproteinase. Enzymes of the matrix metalloproteinase (MMP) family are involved in the breakdown of extracellular matrix physiological processes, tissue remodeling, as well as in disease processes, while MMP-8 in particular has been shown to be one of the key mediators in periodontal and peri-implant tissue destruction. A recent study of PS implants after 3 years of loading that used this analysis¹¹³ tends to refute the hypothesis that implant/abutment mismatching predisposes to enhanced inflammation over time (2.7–3.6 ng/ml were recorded). A possible explanation could be that PS always presents a fibrotic ring overlaying implant platform not covered by the abutment. Such tissue is supposed to seal the horizontal step following implant/abutment mismatching, creating a similar environment to that present in traditionally restored implants. It is also possible that changes in this local habitat will take a longer period of time to occur. (Healthy crevicular fluid samples present less than 14 ng/ml of active MMP-8, while inflamed sites show values higher than 14 ng/ml).

Since the first systematic treatment with dental implants that started in the late 1970s, much has happened clinically, as well as market wise, regarding products,

clinical measures and indications. During the first years, the systematic and well-controlled dental implant treatment was mainly confined to the Brånemark System (Nobel Biocare) and the Straumann Dental Implant System (Institute Straumann). Criteria for survival and success were introduced based on systematic scientific documentation of treatment outcome.¹¹⁴⁻¹¹⁶ However, since then, several other implant systems have been launched, surgical and prosthetic techniques have improved, and the demands for more sophisticated functional and esthetic solutions have increased. Thus, new implant brands and new surfaces, different connections between implant and superstructure, and different time frames between surgical installation procedures and the start of prosthetic loading have continuously been introduced. Based on previous postulations, it is widely accepted that a marginal bone loss in the order of 1 mm during the first year of service, that is, during the first year after initiation of prosthetic loading, and an annual bone loss thereafter not exceeding 0.2 mm, is a natural feature and consistent with successful treatment. A meta-analysis¹¹⁷ was carried out to compile and compare data on peri-implant marginal bone level changes from prospective studies that have recorded the peri-implant marginal bone level radiographically at the time of prosthetic connection and after 5 years of follow-up. Forty prospective studies were identified. Three implant systems met the inclusion criteria of having at least two independent studies: Astra Tech Dental Implant System® (Astra Tech), Brånemark System (Nobel Biocare), and Straumann Dental Implant System (Institute Straumann). The pooled mean marginal



bone level change amounted to -0.24 mm (95% CI -0.345, -0.135) for the Astra Tech System, 0.75 mm (95% CI -0.802, -0.693) for the Brånemark System, and 0.48 mm (95% CI -0.598, -0.360) for the Straumann System, with a statistically significant difference (P .01) among the systems. Based on the results of the present analysis, it becomes evident that marginal bone loss around these dental implants, under favorable conditions, is comparable with that of natural teeth.¹¹⁸⁻¹²¹

Discussion on surgical, biologic and implant-related factors affecting bone remodeling around implants

Hannes Wachtel

Many variables could influence the peri-implant bone stability during function. In order to make this discussion useful, we will attempt to answer some questions related to the topics analyzed during the presentation. There will be two options for each single question: the first will be related to the scientific evidence and the second will be based on the clinical evidence.

Question	Answer
Does surgical trauma produced by flap elevation during the first stage surgery cause bone resorption?	Yes, on the basis of scientific and clinical evidence

Question	Answer
Does surgical trauma produced by flap elevation during the second stage surgery cause bone resorption?	Yes, on the basis of scientific evidence, but the clinical evidence is nonconclusive

Matteo Capelli

According to the literature, particularly the teeth's literature, each time we elevate a full thickness flap, we can cause bone resorption. The amount of bone resorption is related to many factors like the patient's periodontal biotype, the anatomical area that we are dealing with, and the thickness of the cortical bone. In order to reduce the amount of bone resorption during the first stage surgery, we should reduce the amount of flap trauma by avoiding elevating a flap.

Giano Ricci

Particularly when we are dealing with thin bone, the important thing is to preserve the periosteum. Therefore, in the first stage surgery, whenever possible, we should raise a partial thickness flap instead of a full thickness flap.

Matteo Capelli

If there is enough bone volume and keratinized mucosa around the implant, we can avoid raising a flap, but, if a graft has to be placed, of course, that will not be possible.

Franck Bonnet

What is the evidence in the literature regarding bone resorption around im-

mediate post extraction implants and implants placed in a healed bone crest? I think that these are completely different situations. When we raise a flap in a healed crest, do we have some degree of bone resorption?

Hannes Wachtel

In some situations, bone resorption is not so significant, but in extraction sockets it is relevant. What about during second stage surgery: should we always perform a split thickness approach?

Matteo Capelli

The answer for me is yes even if we don't have conclusive evidence in the literature because there aren't many studies. It has been reported that, after second stage surgery, there is vertical bone resorption around implants, but not between the implants. So, there must be other contributing factors.

Tidu Mankoo

The issue here is the soft tissue thickness. From clinical experience, where do we see more bone remodeling? We see it in the posterior areas of the mandible because the soft tissue there is thin. So, vertical remodeling takes place independently from which implants are being used. How do you eradicate the other confounding factors? In other words, is it the flap elevation or the thin tissue establishing a biological seal? You cannot separate the two because they happen simultaneously.

Ueli Grunder

Whether raising a full thickness flap during the second stage surgery is really relevant depends on whether we can

bring together the two flaps. If we cannot adapt the flaps perfectly, we could have a secondary healing between the implants, and that could have an influence from a clinical point of view.

Matteo Capelli

But in the majority of the second stage surgeries we make an apically repositioned flap with a secondary healing. We do that in order to increase the keratinized mucosa. So, we have the opposite situation. Of course, if we have enough KM, we can do just a mucosa punch.

Kony Meyenberg

For the patient it is much better if we don't raise a flap, but it depends on whether we want to increase the soft tissue quality and quantity.

Ueli Grunder

This is very interesting because we should ask ourselves if we should increase the amount of KM before any implant surgical procedure and, afterwards, doing a punch without raising a flap anymore or if we should perform this procedure at the second stage surgery. We don't know what is the best surgical procedure.

Nitzan Bichacho

We cannot give a conclusive answer to a question that is completely clinically oriented. In order to obtain an ideal amount of KM, we should consider how many surgical procedures a patient should undergo. The aim of our procedures is to reduce the patient's morbidity and, thus, we could accept even a sub-optimal situation with a minimum peri-implant soft tissue recession especially in the posterior area.



Giano Ricci

As far as bone resorption is concerned, from the experience of periodontal surgery, we know that bone resorption occurs regardless of whether we keep the periostium or not. Regarding the issue when to increase the KM, if during the first or the second stage surgery, I think that it is much easier to do it during the second stage surgery and this doesn't affect the amount of bone resorption.

Nitzan Fuhrer

Is there any evidence in the literature for any surgical procedure, like BMP of grafting, which could compensate for the bone resorption?

Matteo Capelli

No, there isn't a strong literature evidence for some surgical compensation procedure for bone resorption. There is a "clinical feeling" that if you graft you could obtain a better clinical situation, particularly for esthetic cases.

Ueli Grunder

There's an interesting study from Covani et al⁹ who showed that, after you raise a flap for immediate implant placement, you lose bone and the same thing happened even after he raised a flap for late implant placement. Whatever we do, we know that we will lose bone. So, if we raise a flap, we should compensate for bone resorption. We have to differentiate between horizontal and vertical bone resorption. This makes a big difference. Many studies talk about the buccal aspect and never talk about the height.

Question	Answer
Is it possible to reduce the surgical trauma during implant site preparation using piezosurgery inserts?	Yes, on the basis of scientific evidence, but the clinical evidence is nonconclusive

Matteo Capelli

Piezosurgery implant site preparation could have some potential for a faster and better osteointegration. This was investigated in a human histological study where the authors concluded that the main difference between the use of the classical burs and that of piezosurgery for implant site preparation could be noted only in the first weeks after implant position. There is no literature evidence that this faster osteointegration and minor bone trauma could have a long-standing influence on the peri-implant bone resorption.

Tidu Mankoo

How did they compare piezosurgery to burs? Did they use internal or external irrigation?

Matteo Capelli

External irrigation, but keep in mind that we obtain a faster integration and a better bone wound healing only in the first few weeks and that, after that period, we don't have any advantages.

Nitzan Bichacho

We have been using circular implants only for one reason: not because they support the anatomy better or because they support the crown better, but be-

cause we cannot make it in any other way since, when you drill, you obtain a circular hole. I think that there is some indication, especially when there is a narrow ridge and we don't want to do any bone regeneration procedure, to use a noncircular implant like the blade, which has been used for many years, with the same concept but with improved design. With piezosurgery, we could perform a noncircular osteotomy that allows different implant configurations. Some people utilizing piezosurgery claim that the immediate healing response for the patient is less uncomfortable when compared to a traditional osteotomy.

Hannes Wachtel

There is some potential base upon literature for a more favorable bone healing compare to burs.

Ueli Grunder

If you use piezosurgery, don't forget that you need more time and the longer the surgery, the more bone resorption you will see. Think about the speed of the different techniques as well.

Question	Answer
Does implant placement above or below the ridge have an influence on the degree of peri-implant bone resorption?	Yes, on the basis of scientific and clinical evidence

Matteo Capelli

From the literature and from the clinical standpoint, we can conclude that there

is strong evidence that a different apical-coronal implant position influences peri-implant bone resorption.

Tidu Mankoo

There are many variables that could influence the amount of bone resorption, not only the vertical implant position. It depends on the configuration of the implant, the kind of abutment connection, the design of the implant, its macro-design, if a flap is raised or not, if you graft or not, and so on.

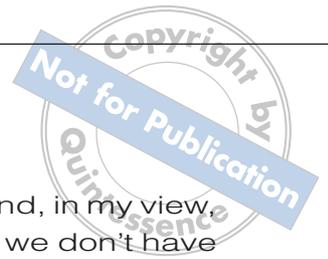
Hannes Wachtel

It is clear that there are a lot of factors, but we were looking for a specific one. We can conclude that implant position related to the bone crest has an influence on the degree of peri-implant bone resorption.

Question	Answer
Does keratinized mucosa influence the preservation of peri-implant marginal bone?	Yes, on the basis of scientific evidence, but the clinical evidence is nonconclusive

Matteo Capelli

Different longitudinal retrospective and prospective clinical trials of machined implant surfaces showed that, with adequate plaque control, there is no difference in the prognosis for maintaining a healthy functioning soft tissue seal as judged by clinical measurements. Even if the literature speculates that the presence of peri-implant keratinized mucosa does not have such a strong relevance



for long standing implants outcome, there is clinical evidence that the lack of this kind of mucosa could influence the clinical results.

Hannes Wachtel

The literature has not provided clear evidence. There were a lot of clinical studies with the old implant surface that are not conclusive.

Tidu Mankoo

Can we really draw any conclusion from the old studies using machined implant surfaces compared to what we do today? So much is different in the clinical behavior of both soft tissue and bone.

Ueli Grunder

The important aspect is that we need stable attached KM. In the posterior area in the mandible, 1 mm of attached KM could be enough to stabilize the peri-implant soft tissues.

Kony Meyenberg

I agree with this concept and I would like to remind you of a very interesting study from Comut et al¹²² in a dog model where they analyzed bone resorption in presence of KM and the difference was between mobility or not of the peri-implant mucosa.

Giano Ricci

Even if from the literature we know that the lack of KM and attached gingiva around teeth is not so detrimental, we can see in our daily practice that we need attached KM around teeth. Another very important aspect is that, more than the height of the peri-implant mucosa, the width has a primary role. I transfer this concept from

natural teeth to implants and, in my view, we can affirm that, even if we don't have strong scientific evidence, the clinical evidence tells us that we do need attached KM around implants.

Question	Answer
Does the soft tissue volume have an influence on marginal peri-implant bone resorption?	Yes, the clinical evidence suggests it does, but the scientific evidence is nonconclusive

Matteo Capelli

There are very few and recent human studies that have measured the soft tissue thickness around implants. They suggest that the thicker is the soft tissue, the more predictable could be the peri-implant bone stability. From the Linkevicius study⁴⁸ it seems that with 2.5 mm or more of soft tissue thickness, significant marginal bone recession could be avoided if the implant-abutment junction is positioned approximately 2 mm above bone level. In these cases, a negligible amount of bone loss (around 0.2 mm) will occur. One of the limitations of this study is that the authors reported only supra-crestal soft tissue thickness, but there isn't an indication of the vestibular soft tissue.

Tidu Mankoo

Nozawa et al¹²³ have investigated the relationship between the height and width of buccal supraimplant mucosa based on the physiologic mucosal form surrounding the implant. These findings indicate that peri-implant soft tissue augmentation procedures resulting in an av-

erage biologic height-width ratio of 1:1.5 may provide a stable buccal cervical line around the implant superstructure, even for thin periodontal biotypes. The clinical evidence is that, each time we place an intramucosal component, we have to thicken the soft tissues surgically.

Question	Answer
Is there a difference in peri-implant bone stability between one stage and two stage implants?	No, on the basis of scientific and clinical evidence

Matteo Capelli

From both scientific and clinical aspects, there is strong evidence that there isn't any difference in peri-implant bone stability between one-stage and two-stage implants.

Question	Answer
Can implant macrogeometry influence bone architecture?	Yes, the clinical evidence suggests that it does, but the scientific evidence is non conclusive

Matteo Capelli

From the limitations of the studies, we can state that there isn't any conclusive scientific evidence about the influence of the implant's macrogeometry on bone architecture. From a clinical standpoint, instead, there is a feeling that the implant macrogeometry does influence bone architecture.

Ueli Grunder

The main problem is that clinically we cannot isolate a single variable and, thus, we don't know which is the most influential factor on bone stability.

Question	Answer
Does a microthread collar promote long-term bone stability when compared with a smooth neck?	Yes, on the basis of scientific and clinical evidence

Matteo Capelli

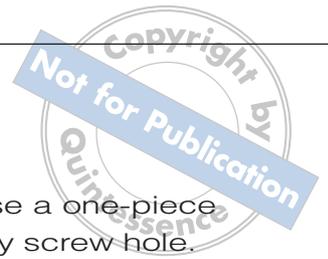
According to the literature, we can conclude that microthreaded collars have a better performance for long-term bone stability as compared to smooth implant collars.

Kony Meyenberg

We know that if we place a smooth implant collar in contact with the bone, we don't obtain any osseointegration. The apico-coronal implant position has a determinant influence on the amount of bone resorption. Vertical implant position should be differentiated on the basis of the type of implant (smooth vs rough/microthread collar) that we are dealing with.

Ueli Grunder

I would like to underline that the question says "long-term bone stability". Do microthreads have a better long-term performance than smooth collars? This question could be very provocative if we come to the conclusion that for bet-



ter long-term bone stability we need a smooth collar instead of a rough surface.

conclusion could be to use a one-piece solid abutment without any screw hole.

Question	Answer
Does the size of the micro-gap have an influence on the amount of peri-implant bone loss?	Yes, on the basis of scientific and clinical evidence

Question	Answer
Does platform switching minimize bone loss at the implant-abutment interface?	Yes, on the basis of scientific and clinical evidence

Matteo Capelli

From the scientific and the clinical standpoints, there is a strong evidence that the size of the microgap does not have any influence on the amount of peri-implant bone loss.

Matteo Capelli

The literature review suggests that PS could contribute to minimize bone loss at the implant-abutment interface.

Question	Answer
Do we have clear evidence where microorganisms come from in the implant-abutment interface?	Yes, on the basis of scientific and clinical evidence

Ueli Grunder

Standardized digital or conventional periapical radiographs were used to evaluate marginal bone loss in all included articles. The limit is that they control the mesial and distal bone levels only. Wennstrom et al¹²⁴ showed that about 44% of the subjects and 48% of the implants had experienced no bone loss when compared with baseline data. Furthermore, during the 5-year follow-up, five subjects (14%) and five implants (13%) exhibited a bone level reduction that was ≥ 1 mm. In the Norton¹²⁵ study, the frequency of implants losing more than or equal to 1 mm of bone from the microgap was 25% in the maxilla and 36% in the mandible. The question that could arise from these data is: how predictable is PS? From our own clinical experience we concluded that PS is not a predictable procedure. For 80 % of our cases we can obtain a very good result, but some cases we do not have a predictable bone results.

Matteo Capelli

Yes, we have clear evidence that microorganisms at the implant-abutment interface come from the oral environment.

Nitzan Bichacho

The more precise the fit between the abutment and the internal implant connection, like the Morse taper connection, the less bacterial contamination can be found around the implant. The majority of the contamination is due to the inability to seal the screw hole properly. A practical

Hannes Wachtel

When we look into the long-term follow-up studies there are some factors that override PS. It could be patient related.

Nitzan Bichacho

Another aspect that we don't know from the literature is whether the better bone performance of PS is related to the abutment shift or to an improved fit of the abutment.

Ueli Grunder

We should ask ourselves what we want from PS. Can we increase the implant diameter in order to obtain PS and decrease by 0.5 mm bone resorption? Inter-implant proximity is a bigger disadvantage that creates inter-implant bone loss than the PS advantage. Is there a real advantage in a single anterior implant? Maybe on the buccal side yes, but there is no 3D peri-implant bone analysis in the literature. The only clinical indication for PS may be when there are two adjacent implants like a central and a lateral incisor. Almost it doesn't make sense clinically.

Question	Answer
Is PS more prone to long-term bacterial infection?	It is not known

Matteo Capelli

Some authors have stated that the horizontal implant/abutment mismatching following this prosthetic concept could be more prone to bacterial infection, thus compromising peri-implant attachment

levels in long term. Both from scientific and clinical evidence, it seems that PS helps maintaining the attachment levels in the long term (3-year). For a stronger scientific and clinical evidence, we need more studies with longer follow-ups.

Question	Answer
Has PS less connective infiltrates?	No, on the basis of scientific and clinical evidence

Matteo Capelli

A recent study⁷⁹ compared the microbiota around implants restored with the platform switching approach and those restored with a standard protocol. The results of this study cannot support the hypothesis that the reduced bone loss around implants restored with the platform-switching approach is associated with lower levels of subgingival species or a less pathogenic submucosal microbiota. It seems that, if the quantity and the quality of submucosal microbiota remain the same, the immunologic connective infiltrates should remain at the same level.

Question	Answer
Does PS cause a different spatial distribution of the biologic width?	Yes, on the basis of scientific and clinical evidence

Matteo Capelli

Animal and human histological studies have concluded that the prevalent



advantage of PS is related to a spatial distribution of the biologic width. A recent animal histological study³⁶ has advanced the hypothesis that PS could not only promote this spatial advantage, but even a histomorphometric advantage with a shorter biologic width related to a shortening of the epithelial attachment and a maintained dimension of the supracrestal connective tissue compartment.

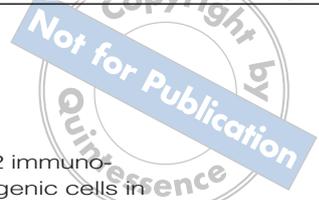
Question	Answer
Are the old implant bone resorption parameters still valid to evaluate implant success?	No, they should be reevaluated on the basis of the new scientific and clinical evidence

Matteo Capelli

This question is very important because the implant success parameters proposed from Albrektsson et al in 1986,¹¹⁴ were introduced at the beginning of the implant era and, since then, surgical as well as prosthetic techniques have improved, and the demands for more sophisticated functional and esthetic solutions have increased. New implant configurations and new surfaces, different connections between implants and superstructures, and different time frames between surgical installation procedures and the beginning of prosthetic loading have continuously been introduced. On the other hand, a 5-year follow-up meta-analysis study¹¹⁷ has concluded that less than 1 mm of bone loss could be expected.

Ueli Grunder

I don't think that 1 mm of bone loss around an implant should not be considered a failure. The main aspect is if this amount of bone loss remains stable in the long-term follow-up.

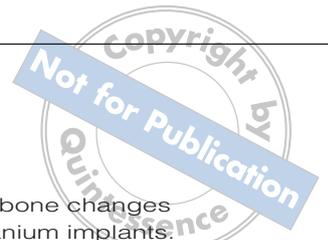


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