IMPLANT CONNECTION AND ABUTMENT SELECTION AS A PREDISPOSING AND/OR PRECIPITATING FACTOR FOR PERI-IMPLANT DISEASE: A REVIEW

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CONFLICT OF INTEREST

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Isabelle Laleman: concept/design of the article, collection of the articles to be analysed, drafting the article, approval of the final article

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ABSTRACT

Peri-implant mucosal integration is a critical aspect for long term implant health and can be triggered the selection of implant components. The aim of this review is therefore to investigate the evidence concerning implant connection and abutment characteristics (abutment materials, design, handling) as predisposing or precipitating factor for peri-implant mucositis and peri-implantitis.

Although the evidence that these features can directly predispose/precipitate peri-implant diseases is limited, there are -few- studies showing a potential role of the implant connection, trans-mucosal configuration, and handling in the development of early bone loss and/or peri-implantitis.

With bone level implants, conical internal connections (with inherent platform switching) might be preferred over internal flat-flat and external connections to decrease the risk of early bone loss and potentially the risk of peri-implant disease. Moreover, there is a trend suggesting moving the prosthetic interface coronally (to the juxta-mucosal level) as soon as possible to reduce the number of disconnections and to limit the risk of cements remnants. This can be achieved by choosing a tissue-level implant or to place a trans-mucosal abutment (one abutment-one time approach) to optimize the peri-implant soft tissue seal. In absence of evidence for the biocompatibility regarding several restorative materials, biocompatible materials such as titanium or zirconia should be preferred in the trans-mucosal portion. Finally, longer implants (≥2mm) with an emergence angle below 30° seem more favourable.

It should however be noted that some of this information is solely based on indirect information (such as early bone loss) and more research is needed before making firm recommendations about abutment choice.

SUMMARY BOX

What is known:

- There are several animal studies, clinical trials and even reviews available examining one specific abutment characteristic and its link with early bone loss.
- There are few animal studies, clinical trials and reviews available examining one specific abutment characteristic and its direct link with peri-implant diseases.

What this study adds: This narrative review aims to highlight recent concepts and the related evidence on these different implant trans-mucosal characteristics and their link with the risk to develop peri-implant diseases.

KEYWORDS

Peri-implantitis, peri-implant disease, dental abutment, dental implant-abutment design, materials science

INTRODUCTION

It is commonly accepted that implant patients with a history of chronic periodontitis, poor plaque control skills, and no regular maintenance care after implant therapy have increased risk of developing peri-implantitis [1]. In parallel with periodontitis there is thus an important role of the dysbiotic biofilm/plaque in the pathogenesis of peri-implantitis [2]. Additionally, there is also -limited- evidence linking peri-implant diseases to situations unique to the peri-implant environment, such as the presence of submucosal cement, the (mal)positioning of the implant and the poor quantity and/or quality of the soft tissues surrounding implants [1].

In health, the soft tissues around teeth and implants create a "soft tissue seal", preventing bacteria and their by-product to penetrate the deeper tissues. However, due to the typical anatomy of the peri-implant tissues, the interface with the implant component is less resistant when compared to the soft tissues around natural teeth. The most important difference is the orientation of the collagen fibres. Around teeth there is a firm relation between the connective tissue and the tooth due to the collagen fibres (periosteal Sharpey's fibres) inserting perpendicular in the cement. Around implants, these perpendicular fibres are lacking, the collagen fibres that are present run a course more or less parallel to the implant surface [3,4]. Another difference is the lower cellularity and vascularity of the peri-implant connective tissues [5]. Around natural teeth, the blood supply is provided by blood vessels originating from the supra-periosteal vessels lateral to the alveolar process and from the vessels of the periodontal ligament. Around implants, the latter are off course lacking [6,7]. These anatomical differences make peri-implant tissues more vulnerable.
To date it is suggested that the peri-implant soft tissue integration of the transmucosal portion of the implant(components) is a critical aspect for long term implant health. Several authors suggest that implant connection, prosthesis retention type and abutment characteristics (abutment materials, design) as predisposing or precipitating factor for peri-implantitis. However, as reported in a recent critical review, limited clinical evidence indicates the involvement of these in the development of peri-implant disease. It was concluded that the literature considering the potential effect of implant connection and abutment characteristics on the risk for peri-implantitis is inconclusive and that purpose-designed studies are required to clarify current observations[8].

Peri-implantitis is a common biological implant complication as one in five patients with implants will experience this sooner or later [9] and the clinical solutions for its management remain rather challenging. It is therefore from utmost importance to control the risk factors for this disease (history of periodontitis, no regular maintenance and poor plaque control). Moreover, nowadays a plethora of other predisposing or precipitating factors are being proposed. One of them is the soft tissue seal around implants and the trans-mucosal implant components selection and handling are suggested to play a role in predisposing and precipitating peri-implant disease, or at least early bone loss. This review aims to examine new concepts and the available evidence on the role of abutment selection and connection on peri-implant diseases.

IMPLANT-ABUTMENT CONNECTION

Since the first Brånemark implant was introduced [10,11], the number of implant systems has grown exponentially. Today there are countless different implant systems available to clinicians, each of them with their own implant-abutment connection.

For those who want to see the forest for the trees, we can roughly classify all these implant-abutment connections into three different categories: external connection, internal conical connection, and internal flat-flat connection (figure 1).

External connection implants are characterized by geometric features expanding above the coronal surface of the implant. The most used external connection is the external hex, where an external hexagon located above the implant neck ensures the abutment connection.

In internal connection implants the implant-abutment connection can be found below the coronal surface of the implant, into the body of the implant. A specific type of internal connection is the conical connection where the connection between the (conical) abutment and the implants walls are tapered [12].

Another concept important when speaking about implant-abutment connection is platform switching (figure 2). In platform-switched implants the diameter of the abutment is narrower than the diameter of the implant.

Finally, there are also implants on the market where the transmucosal segment is an integral part of the implant, the so-called soft tissue implants. With this type of implant, the implant-restoration margin is shifted to the soft-tissue level, away from the bone (figure 3).

Internal versus external connection

To our knowledge, there are no human studies available examining the effect of different abutment-implant connections on the prevalence of peri-implant diseases. Thus, examining this association, we can only consider indirect evidence. On one hand we can take into account studies examining the bacterial infiltrate at the implant-abutment interface and on the other hand we can consider studies examining the bone level around different implant-abutment connections.

Recently, Koutouzis and co-workers summarized the evidence about the bacterial infiltration at the implant-abutment interface [12]. Based on 23 in vitro studies they concluded that whatever implant-abutment connection was used complete prevention of bacterial penetration was impossible[12]. However, the bacterial load at the implant/abutment interface was less in conical connection implants compared to implants with external connections or internal clearance-fit connections[12]. These findings were confirmed by in vivo studies [12].

Two recent network meta-analysis examined the influence of implant-abutment connection on the bone level [13,14]. Camps-Font and co-workers showed that internal conical connections led to statistically significant less marginal bone loss compared to external connections or flat-flat internal connections 12 months after prosthetic loading [14]. Additionally, conical connections led to less prosthetic complications than external connections [14]. Few years earlier Caricasulo and co-workers came to practically the same conclusions [13]. However, in this systematic review an attempt was made to discriminate between internal connections with and without platform switch. They showed that there was significant more bone loss around external connection implants compared to conical connection implants. There was also significant more bone loss around internal connections without platform switch compared to conical connection implants. In contrast, this difference was not seen when comparing the latter with internal connection implants with platform switch.

Based on the available evidence, it therefore seems plausible that implants with a conical connection are less prone to peri-implant disease since they guarantee a better seal and less bone loss over time. However, we must be careful in translating the available evidence to this conclusion. Firstly, the evidence that early bone loss is a good predictor for peri-implantitis is scarce [15]. Secondly, these network meta-analyses compared very heterogeneous studies concerning implant-, patient-, surgery- and prosthesis-related factors. Factors that also could have influenced the bone level.

Platform-switching

There are several biological and mechanical hypotheses favouring platform-switching. Firstly, the lateral displacement of the implant-abutment connection shifts the inflammatory cell infiltrate seen at this junction laterally and thus away from the marginal bone [16]. Secondly, with platform switched abutments the collagen fibres are oriented circular around the abutment (figure 4). This circular organization stabilizes the connective tissue around the implant ensuring protection of the underlying bone[17]. A third hypothesis favouring platform switching is that it is more favourable mechanically, due to platform switching the mechanical stress concentration area could be shifted away from the cervical bone to the implant. But with as side effect, more stress on the abutment (screw) [18].

A recent publication combining two separate studies from the same group comparing a matching implant to abutment connection with platform-switched implants showed a more benign development of peri-implantitis for the latter during the experimental induction phase[19]. During the progression phase (after the removal of the ligatures), these differences disappeared [19]. It should however be noted that the results of this article could be influenced by its limited sample size, the fact that two subsequent, independent studies are analysed together and the experimental condition of the disease (which may be different from a naturally developed peri-implantitis). Furthermore, there is speculation that in platform switched implants the ligatures used to induce experimental peri-implantitis are blocked from moving more apically by the space between the abutment and the implant shoulder. In contrast, in matching implant to abutment connection this ligature could move more easily apically and thus easier cause bone loss.

In a study including 64 implants in 25 patients a trend was seen towards a lower prevalence of peri-implantitis for platform-switched implants compared to conventional implants (respectively 6.6% versus 15.6%)[20]. Additionally, systematic reviews examining the bone loss around conventional implants and platform-switched implants showed that the crestal bone is more stable around platform-switched implants [13,21–23].

Based on the available literature (direct evidence from an animal study and indirect evidence from human studies) there is emerging proof that platform switching may lead to a decreased prevalence of peri-implant diseases.

Soft-tissue level implants

Another alternative for the classic implant design are soft-tissue implants, shifting the implant-restoration margin to the soft-tissue level away from the bone. There is thus no microgap at the bone-level as seen in conventional implants.

Epidemiological cross-sectional studies showed that **peri-implantitis** is more prevalent in bone-level than in tissue-level implants[24–27]. Katafuchi and co-workers (2018) found a prevalence of peri-implantitis of 22.8% in the bone level group versus 7.5% in the tissue-level group [24]. A shortcoming of this study was that it was not examined if this difference reached statistical significance since this comparison was not the comparison of primary interest of this retrospective study. Additionally, a plethora of different implant system was examined (8 in total) in a fairly small sample (168 implants). Rokn and co-workers (2017) mention lower values of peri-implantitis prevalence and crestal bone loss in tissue- versus bone-level implants (respectively 4% and 0.28mm versus 15.10% and 1.37mm)[25]. These findings were confirmed by Yi and co-workers (2020) who found that the prevalence of peri-implantitis in bone level implants with external connection was 29.8% and in bone level implants with internal connection 17.5% versus 13.6% in tissue-level implants [26]. However, in this study only 22 of the 349 included implants (6%) were tissue level implants, there was thus an uneven distribution between bone- and tissue-level implants. Epidemiological data examining 600 patients in Sweden 9 years after implant placement showed lower odds for peri-implantitis for implants with transmucosal platforms compared to bone level platforms [27].

The data of all these retrospective studies are in contrast with the only prospective split-mouth study comparing tissue- versus bone-level implants in 20 patients. This study could not find any differences on the bone level, nor on clinical parameters after 24-months[28]. However, it should be noted that the follow-up of this study was only 24 months, and a rigid follow-up was carried out with monthly follow-ups for 9 months and 3-montly follow-ups afterwards. This is a scenario that may not reflect the everyday clinical practice.

In our knowledge, to date there are no studies available examining the effect of the location of the restoration margin on the treatment of (experimental) peri-implantitis. However, **peri-implant mucositis** is more effectively treated when the restoration margin is located supra-mucosal compared with submucosal margins. This was shown in a randomized clinical trial examining two anti-infective protocols as adjunct to non-surgical mechanical debridement in the therapy of peri-implant mucositis[29]. No differences were found between both protocols, however, it was found that implants with supra-mucosal restoration margins showed greater improvement following the treatment of peri-implant mucositis compared with those with submucosal restoration margins[29]. More recently, an experimental peri-implant mucositis study showed that the deeper the implant-restoration margin of a tissue level implant was located, the more difficult it was to resolve experimental peri-implant mucositis [30].

The available evidence seems to indicate that the location of the implant-restoration margin influences the prevalence of peri-implantitis and the treatment of peri-implant mucositis. Tissue level implants with implant-restoration margin located away from the bone crest seem more favourable.

ABUTMENT SELECTION

Abutment material

For a long time, titanium has been the gold standard for dental abutments. Over time, new materials were investigated and introduced to the market such as zirconia. More recently, restorative materials such as lithium disilicate or polymer-based materials are also often used in the trans-mucosal portion, usually bonded on a titanium base. Although these materials are frequently used in day-to-day implant practices, clinical studies describing their biocompatibility or their impact on peri-implant mucosal health are limited.

A recent systematic review examining the effect of different abutment characteristics on peri-implant soft tissue health showed less increase on bleeding on probing (BOP) for zirconia compared with titanium abutments [31]. It should however be noted that these findings were based on only three studies[32–34]. This systematic review explained the statistically significant difference in BOP by the lesser plaque retention and better quality of the soft tissues (more fibroblast) around zirconia compared to titanium abutments[31]. More research is needed to clarify this. The focus of this should be on the histology of the soft tissues surrounding abutments, since this has only been researched sparsely.

To date, clinical data concerning the effect of restorative materials on the peri-implant soft tissue integration is not available and their potential effect on peri-implant diseases occurrence is unknown. Based on in vitro studies, it appears that the biocompatibility (cell adhesion / proliferation) of titanium and zirconia is superior when compared to restorative materials such as lithium disilicate or polymer-based materials[35,36].

The influence on plaque retention according to the material surface topography has also been investigated in *in vitro* research [37,38]. Next to the material of the abutment, also the surface roughness of the chosen material seems to influence the biofilm formation and the cell behaviour at the abutment level [39,40]. In vitro studies showed that on smooth (polished) and machined surfaces (Sa = <1 μm) spreading of fibroblasts and keratinocytes was better compared with moderately rough surfaces (Sa = >1 – 2 μm)[41,42]. While rough surfaces (Sa > 2 μm) surfaces provided favourable properties in terms of cellular adhesion of fibroblasts but not of epithelial cells [43,44]. Rough surfaces also facilitate bacterial proliferation and biofilm formation more than smoother surfaces [40,45].

To optimise the peri-implant soft tissue seal and possible reduce the risk of peri-implantitis associated with the choice of abutment material, using a biocompatible material in the transmucosal portion of the implant might be recommendable. To date, the clinical evidence for peri-implant soft tissues integration applies for titanium oxide or zirconium dioxide. Additionally, machined or polished surfaces (Sa = <1 μm) should be preferred over rougher surfaces.

Abutment disconnection

When using bone-level implants, the healing abutment is removed several times before the final prosthesis is placed: for impressions taken, try-in of the metal framework, delivery of the abutments and final restoration. Disconnecting the healing abutment can rupture the adjacent epithelial and connective tissue cells form the underlying tissues, creating a wound exposing the underlying connective tissue (figure 5).

Although in 1997 Abrahamsson and co-workers showed that frequent removal and replacement of the abutment caused additional marginal bone resorption[46], this remains a controversial topic. In this study abutment disconnection was examined in beagle dogs[46]. A split-mouth study was caried out in 5 animals, where the abutment at one side of the mouth (the control) was never removed and the abutment at the other side (test) was reconnected 5 times within 6 months. At the end of the study, the beagle dogs were sacrificed. Histological examination of the surrounding peri-implant tissues showed that repeated disconnection can compromise the mucosal barrier and cause an apical displacement of the connective tissue attachment. Moreover, more marginal bone resorption was observed in this group [46].

Studies examining the association between abutment disconnection and peri-implantitis do not seem to be available in humans. The best evidence available today are systematic reviews studying repeated abutment disconnections and the impact on marginal bone loss[47,48]. The most recent systematic review with meta-analysis (2021) of Vatėnas and Linkevičius included four studies examining the effect on marginal bone level of three or four abutment disconnections/reconnections before definitive abutment placement in partially edentulous patients. In the group with the repeated abutment disconnections/reconnections there was 0.4mm more marginal bone loss compared to the test group.

To reduce the mechanical injury of the soft tissues associated with the repeated abutment disconnection, it seems relevant to minimize the number of abutment de-/reconnections and eventually consider a "one abutment (or one-base) -one time" concept aiming to leave the peri-implant soft tissue integration undisturbed.

Cement-retained implant restorations

A side effect of cement-retained restorations is cement residue. Moreover, this is a common side effect. For example, a 2009 study showed that 81% of cemented restorations contained excess cement. Residual cement is considered a local risk factor for peri-implantitis as the rough surface facilitates the attachment of the biofilm and hampers the biofilm removal [49]. Several observational studies seem to confirm excess cement as a possible risk factor for per-implant mucositis and peri-implantitis [1,50,51]. (Figure 6)

The prevalence of cement residue seems related to the soft tissue healing period and the location of the restoration margin[50,52]. Cement residues are more frequently detected when the soft tissue healing period is shorter than 4 weeks [50]. Moreover, the deeper the restoration margin, the greater the chance of cement remnants[52]. Linkevicius and co-workers showed that wherever the abutment margin was located, it was impossible to clean all excess cement, but especially when the margin was located 2mm or deeper subgingivally [52].

Peri-implantitis caused by excess cement seems even more manifest in periodontitis patients. Linkevicius and co-workers showed that in patients with a history of periodontitis 35 out of 39 implants with cement residue had peri-implantitis and 4 early peri-implantitis [53]. Of the 34 implants with cement overhang in patients with a healthy periodontium, only 3 had early peri-implantitis, 20 had peri-implant mucositis and 11 had healthy gums [53].

According to the existing data, cement remnants can be considered as a precipitating factor to develop peri-implantitis. To reduce the risk, it seems relevant to leave the soft tissues heal at least 4 weeks before the final restoration is cemented and to choose a abutment design were the margin is located at the mucosal margin to allow meticulous removal of excess cement [49,50].

Trans-mucosal profile

Several preclinical and clinical studies have explored the role of the abutment design (concave versus convex trans-mucosal profile) on the on peri-implant hard and soft tissue behavior. However, again, the outcome measures are radiographic marginal bone loss, which cannot be directly extrapolated to peri-implantitis.

In an animal model, flat and wide abutment emergence profile induced an apical displacement of the peri-implant biologic width and more bone loss [54]. Additionally, a histomorphometric dog study examining implants with a concave transmucosal design showed the formation of a soft-tissue O-ring seal in the area provided by the transmucosal concavity[55]. The presence of these circular collagen bundles is thought to reinforce the adhesion of the connective tissue to the transmucosal component of the implant, providing a firm soft tissue seal.

From a clinical point of view, two recent systematic reviews explored the effect of different abutment morphology (concave vs convex) on peri-implant hard and soft tissue behaviour [56,57]. Both concluded, based on four clinical studies, that concave/convergent implant transmucosal profiles result in less marginal bone loss. However, the existing evidence is moderate, as few RCTs were conducted, and follow-up periods were short.

Additionally, cross sectional studies suggested that a larger emergence angle (>30°) and a convex emergence profile is associated with a higher prevalence of peri-implantitis [24,26,58].

According to the limited evidence, convex abutment profile and wide emergence profile could increase marginal bone loss and potentially the risk of peri-implant diseases.

Therefore, it might be relevant to favour narrow and concave abutment trans-mucosal design with an emergence angle below 30°.

Abutment height

Several studies have explored the role of the abutment height on the marginal bone loss. However, again, studies with peri-implant diseases as primary outcome are lacking.

Retrospective cohort studies and prospective case series show that the marginal bone loss is influenced by the height of the abutment: short abutments induced more marginal bone loss than higher abutments[59–62]. However, it should be noted that we can assume that in these studies the abutment height was chosen based on to the soft tissue thickness. It is therefore not clear from these studies whether it is the abutment height per se or the vertical height of the soft tissues that determines the loss of marginal bone.

A recent review of Munoz and co-workers (2023) solely including randomized controlled trials confirmed these findings[63]. Additionally, they mention a threshold of 2mm, concluding that long abutments (≥2mm) play a protective role against marginal bone loss, allowing the establishment of the supracrestal mucosal adhesion when compared with shorter ones (<2 mm). Moreover, based on different randomized controlled trials this effect appears to be independent of soft tissue thickness[64,65]. However, in case of limited soft tissues thickness, it is important to place the implants subcrestally to allow for the establishment of supra crestal mucosal complex.

Different mechanisms are suggested how higher abutments seem more beneficial for marginal bone. Firstly, they allow more space for the formation of the supracrestal attachment [66]. Secondly, higher abutments allows the abutment-crown interface to be more coronally, away from the bone [66].

According to the existing evidence, abutments higher than 2 mm confine the marginal early bone loss and thus potentially the risk of peri-implant diseases.

SUMMARY FINDINGS

There is (limited) evidence that certain trans-mucosal implant characteristics may be associated with an increased risk of developing peri-implant diseases later in life.

Concerning bone level implants, conical internal connections (with inherent platform switching) might be preferred over internal flat-flat and external connections in to decrease the risk of early bone loss and potentially the risk of peri-implant disease. Moreover, there is a trend to suggest moving the prosthetic interface coronally (to the juxta-mucosal level) as soon as possible to reduce the number of disconnections and to limit the risk of cements remnants. This can be achieved by choosing a tissue-level implant or to place a trans-mucosal abutment (one abutment- one time approach) to optimize the peri-implant soft tissue seal. In absence of evidence for the biocompatibility regarding a number of restorative materials, biocompatible materials such as titanium or zirconia should be preferred in the trans-mucosal portion. materials such as titanium or zirconia should be preferred in the trans-mucosal portion. Finally, higher implants (≥2mm) with an emergence angle below 30° should preferably be selected. However, we must not forget that these choices should be driven by the patient's characteristics, especially in patient presenting an increased risk of developing peri-implantitis (patients with a history of chronic periodontitis, poor plaque control skills, smokers)[1].

In this review we tried to describe different implant-abutment characteristics separately. However, reality teaches us that these are often closely related and impossible to investigate separately. For example, it is difficult to distinguish between the type of connection and platform switching. Internal connection implants are often platform switched implants (e.g. platform-switching is inherent in conical connection implants) and external connection implants are often platform-matched implants. Studies examining platform-switching versus platform-matched implant with the same connection are scarce but do exist [67,68]. Additionally, when platform-switched versus platform-matched implants with the same connection are examined, there are often other differences that could influence tissue integration and health around implants. For example, in the study by Hsu and co-workers (2016) only internal connection implant are examined, but then the platform-switched ones have rough collars and the platform-machted ones smooth collars[67] .

One has, however, to keep in mind that the level of evidence where these recommendations are based on, is rather low. On the one hand, the link between peri-implant diseases and some of these implant characteristics has been investigated in clinical studies (and possibly summarized in systematic reviews): tissue versus bone level implants, abutment material and cement residue. On the other hand, there are also certain abutment characteristics where the only information one has is based on studies investigating (early) bone loss and/or animal studies: the type of abutment-implant connection, platform-switching and repeated abutment removal.

Since (early) bone loss does not necessarily mean peri-implant disease, the evidence for certain recommendations we did is therefore limited. Although, there is emerging evidence that the amount of early bone loss is a good predictor of later peri-implantitis[15], this disease is characterized by more than just bone loss. If researchers want to examen the relationship with peri-implantitis, they should therefore always bear the 2018 workshop definition in mind[2]. Studies examining peri-implantitis should therefore not only evaluate the bone level, but also the bleeding and/or suppuration on gentle probing.

We can conclude here with the well-known adagio: more research is needed to have more sound evidence about how specific abutment characteristics predispose/precipitate peri-implantitis. But, if we're honest, the question is whether this research will ever happen. On the one hand, so many new innovations are coming onto the market that it is difficult to substantiate their clinical success with thorough long-term studies. On the other hand, to clinically study a particular implant/abutment feature, the systems examined would have to be identical except for this feature, and this is virtually impossible.

CONCLUSION

The available evidence shows that the choice of the transmucosal interface of implants can influence the peri-implant mucosal integration and consequently dictate the risk of developing peri-implant diseases later in life. It seems more favourable in that light to opt for a conical internal connection instead of an internal flat-flat or external connection implant. It is also advisable to move the prosthetic interface as soon as possibly to the juxta-mucosal level by choosing a tissue-level implant or go for a one abutment-one time approach. Moreover, a biocompatible material, titanium, or zirconium, should be chosen. And finally, longer implants (≥2mm) with an emergence angle below 30° seem the preferred choice.

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FIGURES

Figure 1: Schematic of the three most common implant-abutment connections.

Figure 2: Matching platform versus platform switched implant.

Figure 3: A comparison between three tissue level versus two bone level implants

Figure 4: The use of a platform-shifting design allows the peri-implant connective tissue to organize in a circumferential manner around the implant. (a) The location of circumferential fiber formation at the implant-abutment interface is shown in red. Histology of (b) a soft tissue cross section showing circumferential fiber formation and (c) a longitudinal section showing horizontal thickness of peri-implant soft tissue (images provided by Dr. Peter Schüpbach).

Figure 5: A typical clinical case of removing an abutment and a temporary screw-retained (a) Disconnection creates a bleeding wound and exposed connective tissue. (b) Disconnection ruptured the epithelial cells adhering the abutment.

Figure 6: : A clinical case of a cement-retained prosthesis, where excess cement caused a rupture of the mucosal seal. (a) Radiograph showing peri-implant bone loss (b). (Images provided by Prof. Eric Rompen)