Prosthetic and biomechanical factors affecting bone remodeling around implants

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Bone remodeling and, consequently, soft tissue levels around osseointegrated implants may be influenced by many variables that are considered of prosthetic or biomechanical nature: implant-abutment connection type and geometry (external vs internal), timing of abutment connection (at uncovering vs delayed), abutment material (titanium vs gold vs ceramic), abutment shape and dimensions (convex versus concave, flush with the implant's collar versus narrower), abutment surface topography (smooth vs microgrooved), number of abutment removals and reconnections (single vs multiple), type of prostheses retention (screw vs cement), loading modality (axial vs off axis, dynamic vs static), parafunctional habits (none vs clencher/bruxer).

Many of these variables have been addressed in a previous EAED Closed Meeting by Happe and Körner.[1] Therefore, this review will be focused only on the consequences of abutment or reconstruction micromovement on bone and soft tissue stability. Micromovements may occur whenever the abutment screw loosens, or when a prosthetic protocol that contemplates repeated connections and disconnections is selected. These situations may create mechanical irritation of the tissues and pumping of the fluids with bacterial toxins contained in the implant cavities. Thus, they may have negative repercussions on the stability of the peri-implant hard and soft tissues.

The topics that will be investigated are:

- Implant-abutment connection geometry and its influence on screw stability.
- Abutment insertion protocol.

Implant-abutment connection geometry and its influence on screw stability

Stability of the implant-abutment connection is an important issue in the treatment of patients with osseointegrated implants whose outcome has to be reliable in the long term. If this connection is not stable, the complications that will ensue can cause inconvenience to the patient and the treating clinician and may contribute to a decreased survival of the implant-prosthetic unit.

Different variables have been implicated in screw loosening or fracture:

- implant connection configuration[2,3]
- abutment rotational misfit[4,5]
- abutment material[6,7]
- screw material[8]
- screw design
- screw preload[9-12]
- single vs splinted crowns[13,14]

The external hexagon was the most common configuration incorporated in the early implant systems, but, over the years, it demonstrated some drawbacks. Abutment screw loosening and fracture (Figs 1a–1c), along with marginal bone remodeling typically observed with these systems,[15-17] have been most commonly attributed to a geometric configuration with limited height that is not very effective when subjected to off axis loads.[18]

This is one of the reasons why implant systems with an internal connection, that is with a long internal wall engagement that may create a stiff, unified body, have been introduced (Fig 2). Internal connection implant systems are supposed to be characterized by:

- A higher resistance to joint opening (ie, reduction in the amplitude of micromovement).[19-24]
- Better-shielded abutment screws due to the distribution of lateral loading deep within the implant.[25]

Their presumed advantages are:

- A reduction in the stress transferred to the crestal bone,[25-28] since micromovements at the implant-abutment interface have been implicated with a stimulation of crestal bone resorption.[29]

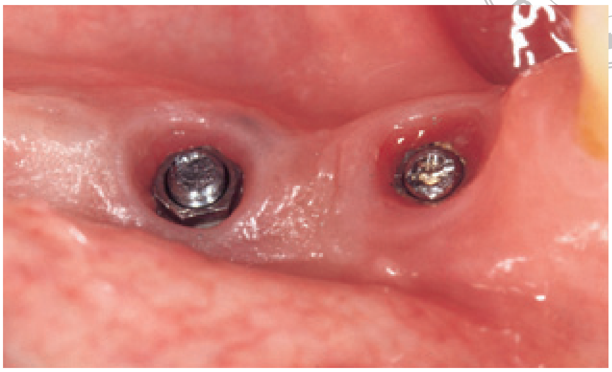

Fig 1a This patient fractured both abutment screws of a 2-unit prosthesis screw-retained to external hex implants after 5 years in service due to a bruxing habit.

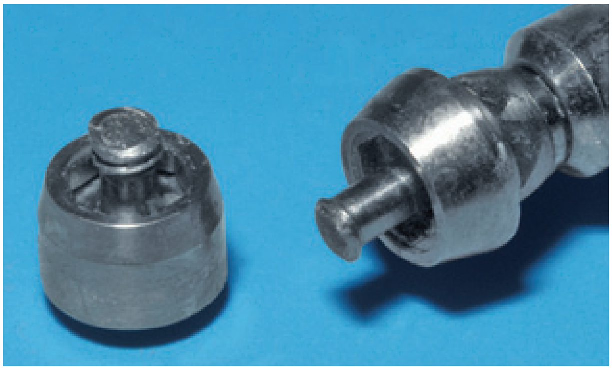

Fig 1b The broken titanium screws with the respective transmucosal abutments.

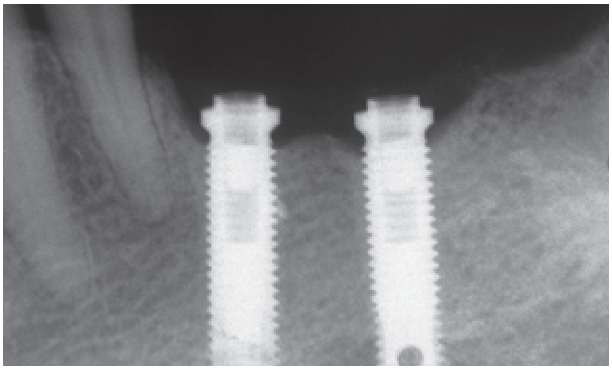

Fig 1c A periapical radiograph shows that the apical portions of the titanium screws were still in the internal chamber of the implants. These fragments were removed by unscrewing them with a tip of an explorer pressed upon the rough fractured surface. New gold alloy screws were then utilized after careful adjustment of the occlusion.

Fig 2 An example of an implant with an internal abutment connection configuration (left) and of one with an external abutment connection configuration (right).

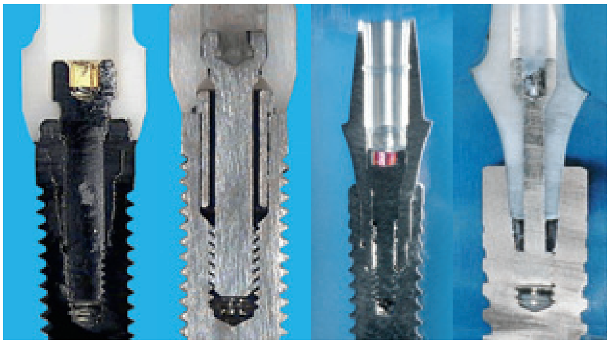

Fig 3 **(a)** Cross section of a with a Certain ZiReal zirconia abutment 3i Osseotite NT Certain implant. **(b)** Cross section of a Replace Select implant and of a zirconia abutment. **(c)** Cross section of a Straumann Bone-Level (ST) implant and of a titanium abutment. (a), (b) and (c) are examples of implant systems with an internal abutment configuration which are without self-locking since they present a flat-to-flat interface between the floor of the abutment and the implant platform that is perpendicular to the implant axis. **(d)** Cross section of an Ankylos Balance implant and of a zirconia abutment. This is an example of true self-locking configuration characterized by a conical connection.

((a) and (b) reproduced with permission from Nguyen et al., 2009. (c) and (d) reproduced with permission from Seetoh et al., 2011.)

- A decreased incidence of screw loosening and fracture.

When analyzing the implant-abutment connection geometry, the questions that will be addressed are the following:

- What are the differences among different connections and what are the mechanical consequences on screw loosening and fracture?
- Is there a difference in the performance of zirconia abutments compared to metal abutments?

When speaking about internal connection implant systems, there is a tendency to talk as if all configurations behave in the same manner. The reality is that internal configurations are very diverse not only in appearance and ease of engagement, but also in the load transfer mechanism (Fig 3a to 3d). First of all, they can be differentiated in two groups based upon whether they present a self-locking engagement or not.[30] In mechanics, the term "self-locking" indicates that any movement or rotation of two components is prevented by static friction between their surfaces. The static friction (ie, no relative movement) depends on the area and geometry of the mating surfaces and is caused by the pressure applied to both components against each other, typically by a connecting screw.

In order to transfer the occlusal forces to the underlying implant and, subsequently, to the surrounding bone, it is important for the friction not to be overcome by external forces. This is why proper preload, that is tension, has to be applied to the connecting screw clamping the structures together, es-

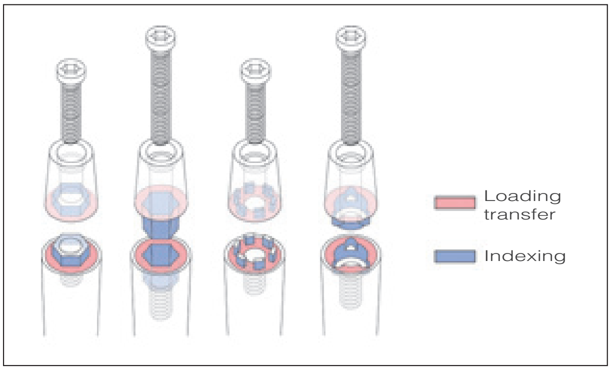

Fig 4a Force transmission versus indexing in flat-to-flat abutment connectors. In flat-to-flat configurations, the surfaces intended for force transmission are perpendicular to the clamping forces of the screw.

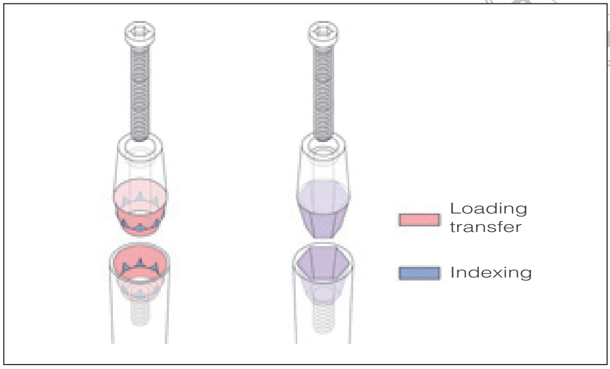

Fig 4b Force transmission versus indexing in biconal connectors. In this configuration, the surfaces intended for force transmission are oblique to the clamping forces of the screw. (Both images reprinted with permission from Wiskott HWA, Fixed Prosthodontics, Quintessence Publishing, 2011).

pecially in those configurations without self-locking. If a screw has to prevent joint opening or separation, that screw has to have sufficient preload to exceed the separating forces generated by occlusal contacts acting on the assembly.[31] If, instead, the occlusal loads exceed the preload, plastic deformation of the screw can take place, which can eventually lead to screw loosening and catastrophic fracture. In other words, the higher the preload, the more difficult it is to separate the components when subjected to occlusal loads. As a consequence, the forces are better distributed within the implant-prosthetic unit and to the surrounding bone. To apply the correct preload, it is necessary to tighten the screw with calibrated torque devices at the recommended torque.

The implant systems without self-locking generally present a flat-to-flat interface between the floor of the abutment and the implant platform that is perpendicular to the implant axis (Fig 4a). These systems also have an internal keying element, or index, that allows the transfer of the exact rotational position of the abutment between oral cavity and master cast or vice versa, Wiskott et al 32 demonstrated that the index features of the implant's head do not participate in the mechanical strength of the implant-abutment connection. This configuration, however, exhibits a clearance fit necessary to allow full adaptation of the components, and, thus, if static friction is lost, micromovements between implant and abutment will ensue. *In vitro* research has demonstrated that all internal connections without self-locking exhibit some relative movement.[30,32,33]

On the other hand, implant systems with self-locking are characterized by a conical connection (Fig 4b). The conical surfaces of the joint form a positive frictional fit as the gap disappears due to the conical geometry and the contact pressure generated by tightening the connecting screw or by functional loading. In these systems, the self-locking effect prevents the connected components from detaching readily even if the screw is loose or not present. It also prevents micromovements between components.[30] Of course, the degree of separation force needed depends, among other factors, on the cone angle, the preload and the contact area of the connecting cone. Generally speaking, the self-locking effect increases as the cone angle decreases. The so called Morse taper configurations where the friction is so high that it becomes extremely difficult to separate the components have a cone angle of less than 5 degrees in a true self-locking configuration, no screw is needed (eg, in the Bicon System).

Given this background, it is meaningful to investigate whether a particular implant-abutment configuration is more effective than others in terms of stability under load and, secondly, whether it displays a clinically relevant difference as far as soft and hard tissue behavior that can be linked to aspects related to the configuration itself. Since the results of the *in vitro* studies are often contradictory due to the lack of evidence for the diverse methods of loading implant abutments/restorations, an analysis of the clinical performance over time of different implant systems is considered more relevant.

Different literature reviews[34-40] have analyzed in depth the *in vivo* incidence of complications in both external and internal connection implant systems. Especially the more recent reviews reported only on clinical studies, RCTs, prospective and retrospective cohort studies on single implant restorations that fulfilled the following inclusion criteria:

- A mean follow-up of at least 3 years for metal abutments/reconstructions and 1 year for zirconia abutments/reconstructions.
- The patients had to be examined clinically at the follow-up intervals.
- Detailed information about the connection type and the type of abutments being used had to reported
- Abutment and prosthetic complications had to be reported.

Clinical studies on single implant restorations (SIRs) are considered of particular interest since a single restoration is subjected to transverse forces that, in splinted units, would unlikely produce any detectable effect. Therefore, in these instances, the role of screw material, screw preload and abutment material can be better investigated.

Alumina-based abutments/reconstructions were excluded from the most recent review since they are no longer available on the market.

Metal abutments and metal-based reconstructions

The most common mechanical complications reported with metal SIRs is abutment screw loosening. Abutment fracture and fracture of the fixture have been reported as well, but as a rare event. A systematic review demonstrated an implant fracture rate of 0.4% at 5 years and 1.8% at 10 years.[34] Table 1 summarizes the data collected from the papers reviewed by Gracis et al.[40]

All reviews pointed out that screw loosening occurred both in external- and internal-connection fixture, but the incidence was statistically significantly higher in the former. The explanation for this is found in the lack of standardized protocols for the tightening of the screws at predetermined torque levels in many of the older studies[41,42,44] and in the fact that the screws used then were made of titanium (Fig 5). This material did not allow reaching high preloads and, thus, in more recent times, it was replaced by alloys with surface treatments that allowed a sensible increase in stability of the abutment-fixture joint.

In a 15-year follow up study on 47 external hex implants,[44] the incidence of screw loosening was relatively high: 20 of the crowns required retightening. In the materials and methods section, the author explained that the titanium screws had been only hand tightened and that, once they had been replaced by gold screws and torqued correctly, the problem did not present itself again.

Screws can loosen even in wide diameter implants if they are only hand torqued, even though the incidence was about one-third of that in regular platform implants (5.8% versus 14.5% incidence in a 3 to 7 year longitudinal study).[43] When these loose screws were tightened with a torque driver, the authors did not observe any further loosening of the screws.

Zirconia abutments and zirconia-based reconstructions

Esthetics is the major driving force behind the increase in the use of zirconia abutments. Unfortunately, very few studies have been published on ceramic abutments, although the first ceramic abutments were introduced in 1993. For the reviews[38-40] to find suitable papers to analyze, it was necessary to lower the follow-up interval to 1 year only. Even then, very few had the proper design and the total number of units surviving at the end of the study was extremely small: 54 for the external connection implants (36 in Glauser et al[45]; 18 in Zembic et al[46]) and 108 for the internal connection ones (30 in Canullo[47]; 40 in Nothdurft & Pospiech[48]; 38 in Hosseini et al[49]) (Table 2).

Fig 5 Abutment screw materials have changed over time to allow the clinician to reach a higher preload for the same applied torque.

Two additional new studies have appeared in the literature, one prospective (Kim et al[50]) and one retrospective (Ekfeldt et al[51]). However, they had to be excluded from the review due to lack of data on the patient population clinically examined.

Therefore, the evidence extracted from the accepted studies, that is that the incidence of mechanical complications with zirconia abutments ranges from very low to absent, irrespective of the platform, has to be interpreted with caution. The reader has to bear in mind that zirconia, like all ceramics, is prone to aging and accumulative damage, which

Table 1 Clinical studies on complications of single-implant metal abutments and metal-based reconstructions

Authors and year of publication	Study design	Setting	Mean follow-up (years)	Implant system (manufacturer)	No. of abut-ments
INTERNAL CONNECTIONS					
Wennstrom et al[62]	Prospective	University	5	Astra (Astra Tech)	41
Bragger et al[63]	Prospective	University	10	ITI (Straumann)	69
Cooper et al[64]	Prospective	University	3	Astra (Astra Tech)	54
Gotfredsen[65]	Prospective	University	10	Astra (Astra Tech)	20
				Total	184
EXTERNAL CONNECTIONS					
Henry et al[41]	Prospective	Private practice	5	Brånemark (Nobel Biocare)	107
Andersson et al[66]	Prospective	Private practice	5	Brånemark (Nobel Biocare)	65
Scheller et al[67]	Prospective	University private practice; multi center	5	Brånemark (Nobel Biocare)	99
Wannfors & Smedberg[42]	Prospective	Hospital	3	Brånemark (Nobel Biocare)	80
Cho et al[43]	Prospective	University	3.2	Brånemark (Nobel Biocare)	213
Vigolo et al[68]	Prospective	University	4	Osseotite (Biomet 3i)	40
Jemt[44]	Retrospective	University	up to 15	Brånemark (Nobel Biocare)	47
Schropp & Isidor[69]	RCT	University	5	Osseotite (Biomet 3i)	42
Zembic et al[46]	RCT	University	3	Brånemark (Nobel Biocare)	40
Jemt[70]	Retrospective	University	10	Brånemark (Nobel Biocare)	18
				Total	751

n.r.: not reported.

No. of abutments at end of time interval	Abutment material	Location in arch	No. of screw loosenings	No. of screw fractures	No. of abutment fractures
32	Titanium	Maxilla and mandible	3	0	0
64	Titanium	n.r.	1	0	0
43	Titanium	Anterior maxilla	0	0	0
19	Titanium	Anterior and premolar maxilla	2	0	0
158			**6**	**0**	**0**
86	Titanium	Anterior maxilla	28	1	0
58	Titanium	Maxilla and mandible	0	0	0
97	Titanium	Maxilla and mandible	0	0	0
76	34 Titanium, 44 Gold	Maxilla and mandible	14	0	0
213	Gold	Posterior mandible/maxilla	24	0	n.r.
40	20 Titanium, 20 Gold	16 max. premolar, 16 max. molar, 8 mand. molar	0	0	0
32	Titanium	Maxilla and mandible	20	0	0
34	Titanium or Gold	Maxilla and mandible	0	0	0
28	Titanium	Maxilla and mandible	0	0	0
13	Titanium	Anterior and premolar regions	2	0	0
677			**88**	**1**	**0**

Table 2 Clinical studies on complications of zirconia abutments and zirconia-based reconstructions

Authors and year of publication	Study design	Setting	Follow-up (months)	Implant system (manufacturer)	No. of abut-ments	No. of abut-ments at end of time interval
EXTERNAL CONNECTION						
Glauser et al[45]	Prospective	Private practice	49.2 (mean)	Brånemark (Nobel Biocare)	54	36
Zembic et al[46]	Prospective RCT	University	36 (mean)	Brånemark (Nobel Biocare)	20	18
					74	54
INTERNAL CONNECTION						
Canullo[47]	Prospective	Private practice	40 (mean)	TSA (Impladent)	30	30
Nothdurft & Pospiech[48]	Prospective	University	12	XiVE S plus (Friatec)	40	40
Hosseini et al[49]	RCT	University	12	Astra (Astra Tech)	38	38
					108	108
				TOTAL	182	162

may induce a decrease in the physical properties.[46,52]

There is some concern regarding the use of full zirconia abutments in internal connection implants due to the fact that the thickness of the portion engaging the internal chamber is extremely limited. Because of this, some companies offer zirconia abutments with a secondary coupling abutment or a metallic insert which some *in vitro* studies showed that they withstand higher bending moments than one-piece internally or externally connected abutments.[38,53] However, in one of only two clinical studies that recorded abutment fracture[51] the two abutments that failed had a metal insert, and in another study where nearly all 40 full

Abutment material	Reconstruction material	Cemented	Screw retained	Location in arch	Screw loosening	Screw fractures	Abutment fractures
Zirconia	All ceramic (leucite glass ceramic)	36	0	25 incisors, 14 canines, 15 premolars	2 (at 8 months and at 27 months)	n.r.	0
Zirconia	17 all ceramic 1 metal-ceramic	16	2	2 canines, 11 premolars and 5 molars	0	0	0
		52	2				
Zirconia with titanium insert	All ceramic	30	0	12 incisors, 4 canines, 10 premolars, 4 molars	0	0	0
Zirconia	All ceramic (zirconia supported)	40	0	Posterior	0	n.r.	0
Zirconia	Zirconia	38	0	Premolars	0	0	0
		108	0				
		160	2				

zirconia abutments had to be reshaped with diamond grinding tools,[48] no fracture was recorded after 12 months.

A publication with the results of a scanning electron microscopy analysis of 5 clinically fractured one-piece zirconia abutments suggests that fractures may occur because of friction stresses generated by the fixation screw or to overpreparation and thinning of the lateral walls.[54] In their study, Glauser et al[45] mentioned that a minimum thickness of 0.5 mm should be maintained; otherwise, the abutment may fracture.

Table 3 summarizes the answers to the two questions posed regarding the influence of the implant-abutment connection geometry on screw stability.

Table 3 Questions regarding the influence of the implant-abutment connection on screw stability with the respective answers

Question	Answer
Is there a difference in abutment screw loosening and fracture between internal and external connections?	No, on the basis of scientific evidence, if the proper screw is utilized and if it is tightened at the appropriate torque. Otherwise, a difference can be observed penalizing external connection implant systems.
Is there a difference in reliability between metal and zirconia implant abutments/reconstructions?	No, on the basis of scientific evidence, but the number of zirconia abutments analyzed is very limited and the follow-up time reported is short.

Abutment insertion protocol

Aside from all the factors that concern biological aspects and implant design features, the operator may also have a role in affecting the healing process and the establishment of the hard and soft tissue apparatus around the implant (Figs 7a–7k). How soon after implant uncovering or placement the healing abutment is removed, the emergence profile developed for the intramucosal components, the utilization of impression copings, and the number of times that an abutment or a fixture-level restoration is removed and replaced may not only spread bacterial contamination on the peri-implant tissues[55,56] but also disrupt the mucosal attachment. Repeated injury to this attachment around implants may, in turn, affect the position of marginal bone.

When analyzing the abutment insertion protocol, therefore, the questions that will be addressed are the following:

- Does repeated abutment connection/disconnection influence negatively bone and soft tissue stability?
- Does abutment or reconstruction micromovement have any influence on bone and soft tissue stability?

Very few papers were found in the literature regarding this topic.

Abrahamsson et al,[57] in an experimental study in 5 beagle dogs, placed two external hex implants (Brånemark System, Nobel Biocare) at bone level. After 3 months of healing, a healing abutment was applied and a plaque control program was commenced and ran for 6 months. In each animal, the test implant had the healing abutment removed and reconnected after cleaning in alcohol once a month for 5 times. The control healing abutment, instead, was never removed. At the end of the study, the animals were sacrificed and a histometric analysis carried out. The results demonstrated that repeated abutment disconnection and reconnection resulted in an

Fig 7a Prosthetic protocols may require several abutment or restoration connections and disconnections. This 42-year old female patient had lost tooth no. 21 because of a fracture. The tooth was extracted and an implant positioned immediately with a provisional. After 5 months in situ, the procedures for the fabrication of the definitive restoration were commenced.

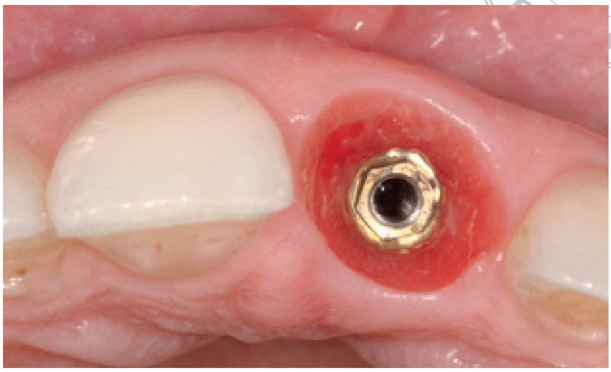

Fig 7b The mucosal tunnel after tissue maturation around the provisional crown. The implant system utilized has an external hex abutment connection configuration.

Fig 7c The tissues were shaped by adding small increments of composite resin to the acrylic resin provisional in its intramucosal portion.

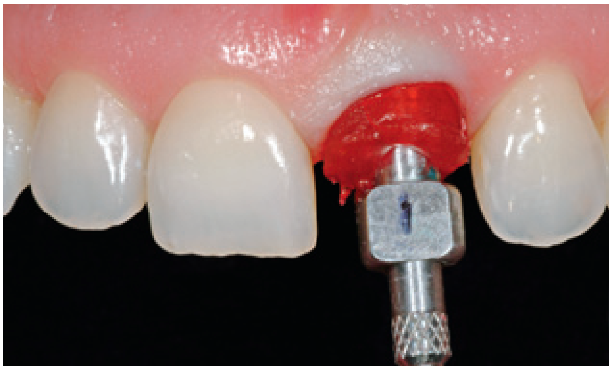

Fig 7d The impression coping was customized with acrylic resin to reproduce the same emergence profile of the provisional crown.

Fig 7e Try-in of the zirconia screw-retained framework.

Fig 7f Bisque bake try-in of the definitive crown.

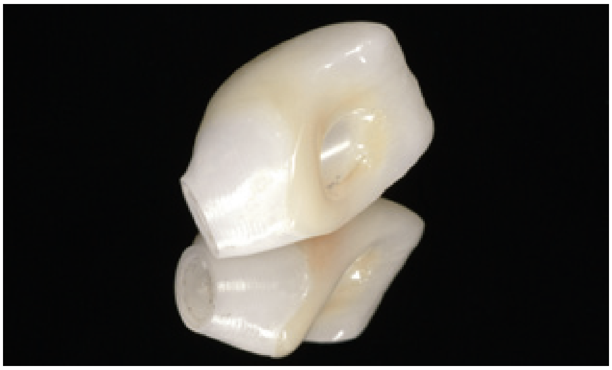

Fig 7g The completed zirconia-supported implant restoration veneered with a compatible ceramics.

Fig 7h The definitive restoration in situ. The access hole on the palatal surface was sealed with composite.

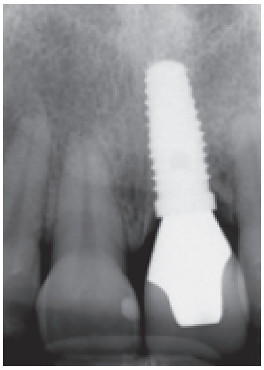

Fig 7i Periapical radiograph at delivery of the restoration.

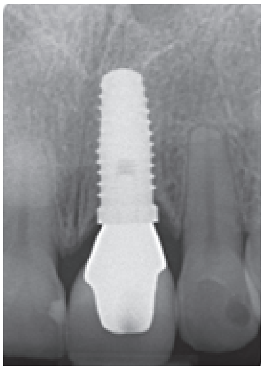

Fig 7k 4-year post-op radiographic control. No change in M-D bone level is noticed.

Fig 7j The same implant after 4 years in function.

apical shift of the barrier epithelium and connective tissue attachment, as well as loss of marginal bone.

A few years later, the same group published another study[58] in which it was shown that a single shift from a healing abutment to the definitive abutment apparently did not cause any deleterious effects on the soft and hard tissue integration to the implant. In this case, 6 internal connection implants (Astra, Astratech) were placed in each of 6 beagle dogs. After 3 months of healing, the implants were surgically uncovered and four healing and 2 permanent abutments were connected. After 2 weeks, the 4 healing abutments were replaced by 4 permanent abutments. The animals were then followed for 6 months under a plaque control protocol. Then, they were sacrificed and histologic and radiographic data were collected.

Analyzing these two papers, a number of observations can be made that may make the reader transpose with caution their results to the clinical situation:

- No bleeding was observed during any of the repeated abutment disconnection and reconnection.
- At the end of the experimental period, the peri-implant soft tissues of both the test and control implant sites were clinically free of inflammation.
- The thickness of the peri-implant mucosa of the test sites was smaller than the corresponding dimension of the control sites: 2.50 mm vs 3.3 mm.
- Most of the marginal bone loss detected (~1 mm) occurred before the implants were exposed to the oral environment.

In another animal study,[59] 60 two-piece implants were inserted in 5 dogs 1 mm above bone level and were divided in 6 groups that differed in gap size between abutment and fixture (<10 μm in groups A and D, ~50 μm in groups B and D, and ~100 μm in groups C and F) and in each gap category, one group (A, B and C) had the abutment laser welded to prevent any movement, while the other did not (D, E and F). The abutments in the non-welded groups were unscrewed and retightened at 4, 8 and 10 weeks after first-stage surgery. At 12 weeks from first-stage surgery, all animals were sacrificed and a decalcified histologic analysis carried out. The results showed that, in these unloaded implants, significantly increased amounts of crestal bone loss occurred for all non-welded 2-piece implant configurations, which were independent of the size of the microgap. However, soft tissue levels were not recorded.

A prospective clinical study was performed in order to evaluate bone resorption in humans after multiple abutment disconnections and to validate the hypothesis that the non-removal of the abutment placed at the time of the surgery would improve bone healing around implants.[60] Twenty-four patients with partial posterior mandibular edentulism were consecutively treated with two immediately restored 3.5 diameter tapered implants. A total of 48 implants were placed in healed sites and immediately splinted with a temporary restoration, which was placed in such a way as to avoid occlusal contact. Six months after surgery, 12 patients underwent the standard prosthetic protocol and twelve patients underwent the "one abutment at one time" protocol to deliver metal-ceramic restorations. The patients were then followed for three years and radiographs taken at regular intervals with a customized positioning jig. The results of the study seem to confirm that, if the implant-abutment unit is not altered or modified over time, the favorable healing of the hard tissue obtained in the first months after surgery can be safeguarded for as long as 3 years after implant placement. The non-removal of abutments resulted in a statistically significant reduction of the horizontal bone remodeling (0.25 mm for the test group vs 0.12 mm for the control group), but not in the vertical bone healing dimension. As a matter of fact, at the 36-month follow-up, bone was found coronally to the implant platform in both groups. However, no clinical difference could be observed and, in the discussion, the authors point out that:

- The study focused only on the effects of the abutment disconnection on hard tissues; patient biotype and the width of the mucosa were not examined.
- It is not possible to compare the results of mean marginal bone loss of butt-joint connection implants with machined collar and those for tapered implants with a rough collar due to the different nature of the surgical protocols.
- Only mesial and distal bone levels were assessed due to the intrinsic limitation of periapical radiographs; the future use of CBCT technology will certainly assist in the effort to determine hard tissue behavior in buccal and lingual areas.

Another clinical study[61] analyzed bone loss around implants placed in fresh extraction sockets of maxillary premolars 3 years after surgery. The patients received either a provisional (Group 1: 10 implants) or a definitive (Group 2: 15 implants) platform-switched titanium abutment and were immediately loaded with a provisional crown. Only the abutments in the first group were connected and reconnected several times. The others were connected only once. The 'one abutment at one time' group at 3 years' follow up exhibited a statistically significant smaller amount of marginal bone loss (0.2 mm) as evidenced on standardized intraoral radiographs. However, once again, no clinically visible differences could be observed. The limitations of this study are:

- A bucco-oral jumping distance that exceeded 1 mm was detected in 23 out of 25 (14 for test and 9 for control group) patients, and was filled with nanostructured hydroxyapatite.
- Radiographs were taken with a parelleling technique, not with customized positioning jigs.
- The sample size is limited and only maxillary premolars were included.

Since the evidence provided by these clinical studies is non conclusive, a close screening of the papers included in the literature review mentioned before that reported the highest percentage of screw loosening and fracture[41-44] was carried out. Even though bone and soft tissue remodeling was not the focus of their research, observations on these aspects were sought.

Henry et al,[41] in a prospective study following 86 implants for 5 years, with an overall incidence of 28 loose screws and one fractured screw, noted that all implants were surrounded by stable, healthy tissue, with a yearly rate of marginal bone loss of less than 0.2 mm, which "reflected adequate hygiene maintenance and prosthetic design."

Wannfors and Smedberg,[42] in a 3-year follow up analysis of 76 Brånemark implants, despite an abutment screw loos-

Table 4 Questions regarding the abutment insertion protocol with the answers based upon the literature review

Question	Answer
Does repeated abutment connection/disconnection have an influence on bone and soft tissue stability?	Yes, on the basis of scientific evidence, but this evidence is based mainly on animal studies and its impact is difficult to observe clinically.
Does abutment or reconstruction micromovement have any influence on bone and soft tissue stability?	No, on the basis of scientific evidence, but more specific long-term clinical studies are needed.

ening incidence of 28% in the first year, did not notice any increased bone loss in these implants. They did, instead, register significantly greater marginal bone loss around the 8 implants that displayed a gap between cemented crowns and underlying abutments (mean of 1.80 mm vs 0.42 mm in the rest of the implants).

Cho et al,[43] in a 3- to 7-year longitudinal clinical study of external hex implants, did not mention anything on the state of the tissues surrounding the 24 abutments with loose screws out of a total pool of 213 followed for up to 60 months.

Jemt,[44] in a retrospective study of 47 single-implant crowns followed for 15 years, reported no significant difference in mean marginal bone loss for implants with no mechanical/fistula problems (n = 14) and for those with fistulas and loose screws (n = 31) (0.69 mm (SD: 0.61) and 0.68 mm (SD: 0.64) during the first 5 years in function, respectively). He concluded that bone loss was not affected by mechanical or mucosal problems or persistent fistulas during the entire follow-up period.

Based upon the review carried out, the answers to the questions posed regarding the influence of the abutment insertion protocol on bone and soft tissue stability are highlighted in Table 4.

Discussion on prosthetic and biomechanical factors influencing soft and hard tissue remodeling

Hannes Wachtel

Because of lack of time, we should concentrate our discussion on the topics for which there isn't strong scientific and/or clinical evidence and that may be controversial due to different approaches within this group. So, the question to discuss is whether there is a difference in reliability between metal and zirconia implant abutments or reconstructions.

Stefano Gracis

The reliability, that is the stability of the screw retention and the fracture resistance, of metal and zirconia seems to be the same. However, for zirconia abutments there are too few studies, with too short-term follow ups, and too small numbers. There is only one study that analyzes zirconia with a metal insert for internal connection implants. According to this study, it seems that it works, but it is not a good study.

Nitzan Bichacho
There are some internal connection implant systems for which full zirconia abutments should never be used because sometimes they break and it is difficult to predict when. When it happens, it is very difficult to remove the fragments. There isn't any evidence to use a zirconia abutment when it is possible to use a metal one. My personal recommendation is to avoid them in internal connections.

Tidu Mankoo
Are we talking about anterior implants or posterior implants? I have had a long experience with zirconia abutments in different internal connection implant systems and I have not seen a single fracture. When there is a report about zirconia abutment fracture, there are many factors that could have caused this outcome, and the system used is one of them.

Stefano Gracis
In the literature there isn't any evidence to support the use of zirconia abutments in the posterior area of the mouth.

Kony Meyenberg
It is very important to stress that the zirconia abutment reliability is system dependent. There are a lot of differences among the systems. Many laboratory studies have pointed out that zirconia abutments for internal connections cannot be considered reliable nor safe.

Aris Tripodakis
It is my experience that, in the long run, zirconia abutments do break. Examining the fractured zirconia abutments through ECM and Raman Micro Spectroscopy, we found a monoclynic phase and fracture on the compression side of the abutments which means that the fatigue of the material is a very important reason why they break and, thus, it is not only the tensile stress around the screw head that can be detrimental.

Hannes Wachtel
Should we then recommend zirconia abutments with metal inserts as the ideal solution?

Ueli Grunder
No, we should not. It depends on the implant system. Using these abutments with metal inserts increases the level of complication in the fabrication of the restoration because of all the different materials being layered and because it increases costs. So, whenever we can, we should use full zirconia abutments.

Hannes Wachtel
So, we may conclude with what was just being said by Ueli, that the possibility to use full zirconia abutments is system dependent.

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