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Original Article

IMPLANT ABUTMENT CONNECTION: BIOMECHANICAL PERSPECTIVES

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Abstract:

Dental implant therapy is a fast growing and brightest prospect in the rehabilitation of completely and partially edentulous arches. Study of implants has become indispensable and so is the biomechanics related to dental implant therapy. Implant abutment connection is a crucial synapse between the implant and the abutment. It is an important determinant of the strength and stability of an implant supported restoration, and play a major role in the success of the implant. The review describes the biomechanics of this crucial connection.

Keywords : Implant-abutment interface, Biomechanics, Abutment screw design.

Introduction:

The emergence of dental implant therapy continues to increase enabling the rehabilitation of partially and completely edentulous arches with greater success and predictability. The wide spread adaptation of dental implants have made the clinician to use implant materials and protocols that further expand their use. This has contributed in part to the evolution of "restoration-driven" implant dentistry .In this context, the sound knowledge regarding the implant abutment and the various design principles is an important factor for the dental implant success.

Dental implant abutments :

A dental implant abutment is formally defined as "that portion of a dental implant that serves to support and/or retain a prosthesis".[1] It functions to physically connect the clinical crown (i.e., prosthesis) to the implant. There are at least three ways this occurs among different implant systems. One is a modular design in which the endosseous implant and the transmucosal abutments are separate components. Alternatively, the endosseous implant and transmucosal aspect of the system may be one component and, in such cases, the crown margin is part of this integrated implant system. The two key features that are critical to use and understanding of the modular versus integrated design systems are that the integrated design system lacks an implant/abutment interface approximating the implant/bone interface, and that the crown margin for integrated implant designs is established by implant placement and cannot be modified with preparation of the implant itself. A modular system, while presenting an implant/abutment interface at the implant/bone interface, permits the crown margin location to be modified in relation to implant position. A third design has emerged that is unitary in which the endosseous, transmucosal, and restorative aspects of the implant system are a single component.[2]

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Abutment Screw Design

The effectiveness of the technology on screw joint stability has yet to be fully documented with independent research and in clinical trials.

Screw Head Design

A screw is tightened by applying torque. The applied torque develops a force within the screw called the preload. It is defined as the tension generated in an abutment screw upon tightening and is a direct determinant of clamping force. As a screw is tightened, it elongates, producing tension. Elastic recovery of the screw pulls the 2 parts together, creating a clamping force.[3]

To achieve secure assemblies, screws should be tensioned to produce a clamping force greater than the external force tending to separate the joint. In the design of a rigid screw joint, the most important consideration from a functional standpoint is the initial clamping force developed by tightening the screw. Forces attempting to disengage the parts are called joint separating forces. The force keeping the parts together can be called the established clamping force

In an effort to minimize clinical complications, the features of the screw have been enhanced to maximize preload and minimize the loss of input torque to friction. The head of the screw is wider than the thread diameter and for an abutment most often is flat (Fig 1). Tapered head design reduces the clamping effect and reduces the tensile force in the threads of the screw. The tapered screw head distorts and aligns nonpassive components and gives a nonpassive casting the appearance of proper fit, but the superstructure is not deformed permanently and leads to stress in the system. Even a 10 N/cm torque force applied to an inclined plane of a screw can distort a superstructure and result in significant stress at the crestal bone region. In addition, most of the force within the tapered screw is distributed to the head rather than to the fixation screw component. A flat-head screw distributes forces more evenly within the threads and the head of the screw and is less likely to distort a nonpassive casting. As a result, the dentist can identify and correct the nonpassive casting. As such the abutment head also should be flat on top to increase the clamping force in the screw head and the tensile force in the threads

Thread Design and Number

The thread design and number of threads are also primary factors influencing the risk of screw loosening. The most common abutment screw design used by implant manufacturers is a fixture that is a V-shaped 30 degree angle .The fixture design allows the preload torque applied to the screw to stretch the male component down the 30 degree angle of the female component of the screw to help fixate the metal components. However, this screw design places most all of the torque in the first few threads. As a result, most manufacturers only have a few threads on their abutment screw designs. The most common design is a flat head, long-stem length with six threads to achieve optimal elongation (fig 2)

Metal Composition

The construction material is suggested as a primary factor to increase the performance of the screw. The composition of the metal may influence the amount of preload before fracture and therefore directly affect the amount of preload that can be used safely. Screw design and yield strength vary greatly between manufacturers (12.4 N for a gold screw to 83.8 N to a titanium screw fixation).These variations also may be due to outer screw diameter, depth of screw threads, accuracy of components, taper, and poor tooling and may cause great variations in screw-loosening complications.

The elongation of metal is related to the modulus of elasticity which depends on the type of material, its width, its design, and the amount of stress applied per area. Thus a gold screw exhibits greater elongation but a lower yield strengh than a screw made of titanium alloy. The material of which the screw is made (e.g., titanium alloy or gold) has a specific modulus of elasticity. The plastic deformation or permanent distortion of the screw is the end point of the elasticity modulus. Titanium alloy has four times the bending fracture resistance of Grade 1 titanium. Therefore abutment screws made of grade 1 titanium will deform and fracture more easily than the alloy. As such, a higher torque magnitude can be used on the titanium alloy abutment screw and female component (implant body). Although the strengths of different titanium grades are dramatically different, the modulus-elasticity is similar.

Surface Condition

The surface condition of the screw is a controversial issue in screw mechanics. However, those who advocate use of friction-reducing coatings claim that the gain in preload is an effective way to enhance fixation. Tests on lubricated and unlubricated screws indicate that there may not be any statistical difference.

Screw Diameter

The diameter of the screw may affect the amount of preload applied to the system before deformation. The greater the diameter, the higher the preload that may be applied and the greater the clamping force on the screw joint. As a general rule, abutment screws loosen less often and can take a higher preload compared with coping screws. In addition, coping screws do not engage an antirotational hexagon, and therefore antitorque devices cannot be used [4]

Implant abutment joint:

Parlk et al stated that dental implants are potentially subject to failure in the screw connection areas of an implant system, which can occur due to screw loosening or fracture.[5]

Binon et al reported that the instability between the components of an implant system may cause not only frequent screw loosening and chronic fracture of the screws but can also cause the accumulation of plaque, an unfavourable soft tissue response, and the failure of osseointegration, etc.[6,7]

Carr et al.[8] and Byren et al.[9] reported that the fitting of the implant-abutment interface is important for obtaining joint stability of the implant system. Moreover, under such conditions, the preload also reaches the maximum value. McGlumphy et al. [10] reported that the ideal preload is 75 % of the maximum torque causing screw fracture.

The various reasons for screw loosening have been suggested as insufficient interlocking, extension of screws due to excessive stress, incompatible prostheses, and poor machining of components, etc.[11]

In order to prevent screw loosening, macroscopic structures such as the length of the screw, the thread and groove shape, the number of screw threads, etc. can be altered; additionally, microscopic factors such as the roughness of the screw surface, the interposition of lubricant, etc. should also be designed properly [12]. In an effort to reduce frictional resistance even more, dry lubricant coatings have been applied to abutment screws. Most notable are TorqTite (Nobel Biocare) and Gold-Tite (Implant Innovations). TorqTite is a proprietary Teflon coating applied to titanium alloy screws, with a reported reduction of the frictional coefficient by 60% .(fig 3) The reported data indicate an effective increase in attainable preload for titanium alloy screws at a significantly lower cost than its gold-alloy counterpart. [13]

Feature	CenterPulse (Screw-Vent)	Astra Tech (Astra)	Straumann (ITI)	Nobel Biocare (Replace Select)	Alatec Technologies (Camlog)	Friadent (Frialit2)	3i (Osseotite Certain)
Length of internal connection	1.2mm	2.4 mm	2mm	3.8mm	5.4mm	3.4mm	4mm
Type of retention	6-point internal hex (with friction fit)	12-point conical seal	8-point Morse taper	3-point internal tripod	3-point internal tripod	6-point internal hex	6or 12 -point internal hex
Verification X-ray of seating	X-ray	X-ray	X-ray	X-ray	X-ray	X-ray	X-ray or audible click
Abutment positioning	60°	30°	45°	120°	120°	60°	30°or 60°

Table 1 Table Comparison of Internal Connection System[23]

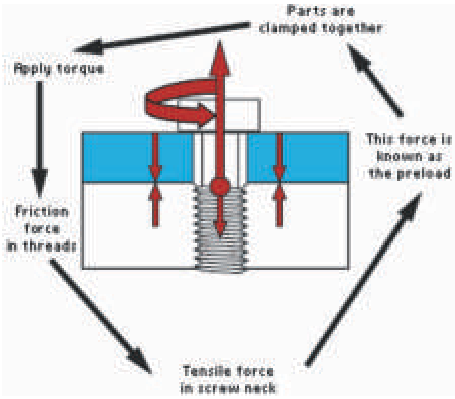

Figure 1 : Implant abutment screw.

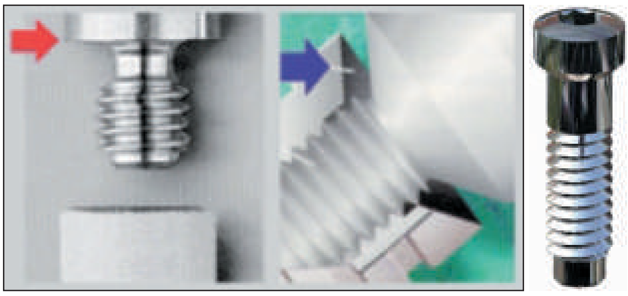

Figure 2 : Titanium, Gold-palladium, Titanium-coated Teflon (TorqTite), Gold-plated gold- palladium (Gold-Tite)

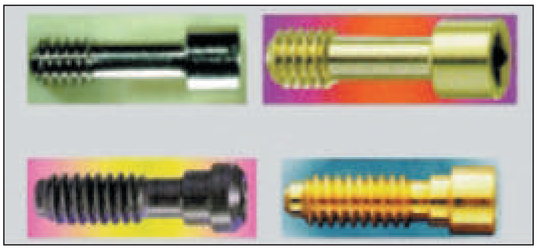

Figure 3 : various antirotational features incorporated into abutment

Figure 4 : Morse Taper Connection.

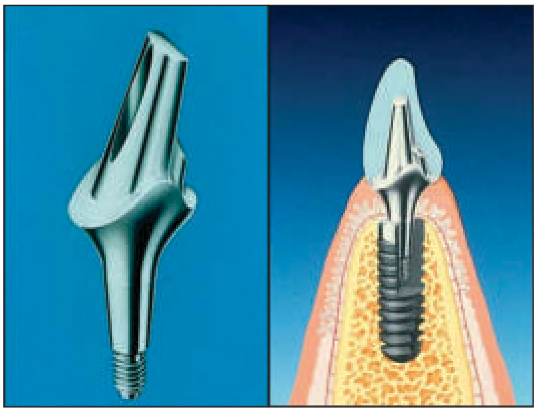

Figure 5 Implant/abutment interface

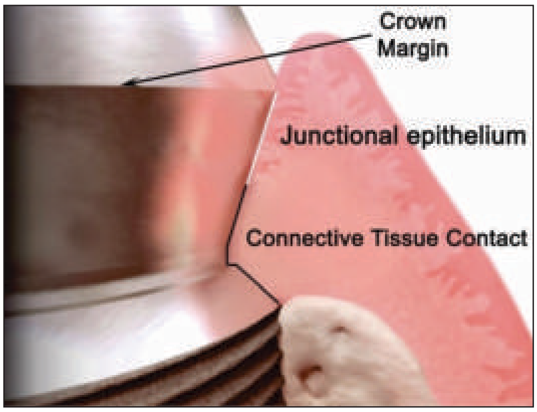

Figure 6 : Platform switching in dental implants

Abutment implant interface:

The implant / abutment interface connection, is generally described as an internal or external connection. The distinctive factor that separates the two groups is the presence or absence of a geometric feature that extends above the coronal surface of the implant. The connection can be further characterized as a slip fit joint, where a slight space exists between the mating parts and the connection is passive or, as a friction fit joint, where no space exists between the mating components and the parts are literally forced together. The joined surfaces may also incorporate a rotational resistance and indexing feature and / or lateral stabilizing geometry. This geometry is further described as octagonal, hexagonal, cone screw, cone hex, cylinder hex, spline, cam, cam tube and pin / slot.[13] (Fig 4)

The deficiency with earlier connections was originally noted by Branemark, who recommended that the external hex connection should be a minimum of 1.2 mm in height to provide both lateral and rotational stability, particularly in single tooth applications. The original 0.7 mm design and its countless clones, however, remained unchanged until recently when wider and taller hexagonals were introduced. Hexagonal screw joint complications, consisting primarily of screw loosening, were reported in the literature that ranging from 6 % to 48%.[14]

To overcome some of the inherent design limitations of the external hexagonal connection a variety of alternative connections has been developed. The most notable are the cone screw, the cone hex, the internal octagonal, the internal hexagonal, the cylinder hex, the Morse taper, spline, internal spline and resilient connection; of these, the internal octagonal connection (Omniloc@) and the resilient connection (IMZ) are no longer available.

The goals of new designs are to improve connection stability throughout function and placement, and simplify the armamentarium necessary for the clinician to complete the restoration. There are at least 20 different implant/abutment interface variations on dental implants that are cleared for marketing by the FDA.[15]

The implant/abutment interface determines joint strength, stability, and lateral and rotational stability. One of the first internally hexed implants was designed with a 1.7 mm-deep hex below a 0.5-mm wide, 45° bevel[16, 17]. Its features were intended to distribute intraoral forces deeper within the implant to protect the retention screw from excess loading,[17,18] Internally connected implants also provide superior strength for the implant/abutment connection.[18,19,20]

Since the introduction of the internal connection concept, further design enhancements have been made in an attempt to enhance the implant/abutment connection(Table 1).[21,22,23]Included in such efforts is the “Morse” taper,(Fig 5) wherein a tapered abutment post is inserted into the nonthreaded shaft of a dental implant with the same taper.[23,24] Other internal connection designs have followed, frequently with variations in their use of joint designs (eg, bevel, butt), or the numbers of 'hexes' present for the restorative phase.[21,22,23]

Implants designed with Morse taper interface engage their abutments by using a five degree angulated friction fit internal wall into which an abutment with a rounded male extension is placed. The abutments achieve an antirotational properties due to the cold-weld phenomenon that occurs after placing and torquing the abutment.[13]

Cold or contact welding is a solid state welding process in which joining takes place without fusion at the interface of the two parts to be welded. Cold welding is defined as an increase in loosening torque with respect to tightening torque and it has been suggested that this might occur and result in lack of retrievability, which is inherent in the 3-component system of the external hex design. Sutter et al.1 demonstrated that the loosening torque was 124% of the tightening torque at a clinically relevant level of 25 Ncm, which was presented in a favourable light, with reduced risk for loosening.[24]When it is made accurately enough seal can be a hermetic one, eliminating microbial leakage.[13]

When using these implant/abutment connections, clinicians had to be mindful of their application in the intraoral environment, an often challenging region due to the involved bone topography, soft tissue contours, rotational forces, and the requisite prosthetic components particularly for aesthetic, single-implant restorations.[25]

The cone screw tapered connection originated with the ITI group in Switzerland (ITI Straumann). Although the connection is called a “Morse” taper, the mating angle between component parts is 8 degrees. A true Morse taper exist at 2^0 and 4^0 and has unique self-locking characteristic without threads. Interference fit components are free of displacement upon function. More significantly, such interfaces are also geometrically locked against potential displacement that results from functionally imposed bending movements. The combined interference from rotational displacement, the high surface area, and the geometric constraint to displacement from lateral loads creates an implant/abutment interface that is largely free of micromotion and resistant to clinical prosthetic complication or failure.[2]

A new internal connection implant design (Osseotite Certain, 3i Implant Innovations, Inc., and Palm Beach Gardens, FL) incorporates an audible and tactile "click" when the components are properly seated. This unique feature eases placement for the clinician and may reduce the need for radiographs following placement of the restorative components[24]

The implant's internal connection allows 4 mm of internal engagement, with contact along a significant length that provides lateral stability from off-axis forces.[17,19,20] The deep, 4mm multilevel engagement zone of this internal connection achieves a precise, secure connection with low torque. No more than 20 Ncm is required to maintain screw retention without loosening. The design of the internal connection allows the height of the screw to be only 1.95 mm from the top of the screw to the seating surface, allowing flexibility in abutment preparation without damaging the head of the screw.

This internal connection design incorporates a 6-point hex and a 12-point, double-hex internal design. The 6-point internal hex provides a stable base for the use of straight abutments. The 12-point, double-hex of the internal connection allows 30-degree increments of rotational flexibility for placement of machined preangled abutments to correct the off-axis emergence of the implant[25]

Implant-Abutment Junction (IAJ) (Fig 6)

The association of neutrophils with the implant-abutment interface of two-piece implants suggests that this physical attribute of implant design contributes to the recruitment of these cells when located at alveolar bone. Significant and comparable inflammatory cell infiltrates were associated with the presence of a microgap at the bone crest regardless of the timing of abutment connection (immediately or delayed) but were not observed in the absence of a microgap. It is unknown whether different implant-abutment connections, such as an internal cone, would yield a different distribution or intensity of inflammatory cell recruitment as compared with the flat, butt- joint interface [26]

Post restorative reductions in crestal bone height around endosseous dental implants have long been acknowledged to be a normal consequence of implant therapy involving two-stage hexed implants.[27]

Several published studies have shown that crestal bone loss occurs following implant placement and its connection to the abutment [28.] Research by Hermann, et al demonstrated that crestal bone loss typically occurs approximately 2 mm apical to the implant-abutment junction (IAJ).This position appears to be constant, regardless of where the IAJ is situated relative to the original level of the bony crest.[29] Investigations by various researchers offered explanations on why the presence of the IAJ appears to trigger resorption in the adjacent bone.

Ericsson, et al found histological evidence of inflammatory cell infiltrate associated

With a 1-mm– to 1.5-mm–tall zone adjacent to the IAJ. Berglundh and Lindhe concluded that approximately 3 mm of peri-implant mucosa is required to create a mucosal barrier around a dental implant.[30] These investigations have focused on implant systems in which the diameter of the implant-seating surface matches that of the abutment.

Conclusion :

The requirements for an optimal implant abutment connection can be summarized as follows: precise rotational orientation for Single tooth restorations, maximum mechanical stability instead of optimal fatigue resistance minimized microgap, overload protection. High surface compression in the critical perimeter area of the connection results in a minimal microgap between the implant and the abutment, which in turn reduce the occurrence of bacterial contamination. The misfit between abutment and implant interface has many clinical implications as: abutment overload; screw loosening or fracture or even of the implant itself; incorrect transmission of force to implant and marginal bone and microbial proliferation. These factors can lead to a persistent inflammation around peri-implant tissue. The gap between implant and abutment is an ideal place for bacterial proliferation and fluid microleakage what can lead to peri-implantitis .It is important to say that the force applied in the tightening torque is only valid if the machining and adjustment degree between abutment and implant were proper because high levels of tightening torque would not produce the desired result on components that do not have proper mortise. Decisions regarding dental implant abutments are essential aspects of clinical dental implant excellence.

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