Comparative evaluation of biomechanical properties of implant-abutment connections: A review.

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Abstract
Dental implant is a brightest and fast growing prospect for the rehabilitation of partially and complete edentulous arches. Different studies on the biomechanics of implant have been done. Implant abutment connection is a crucial role for the success of prosthetic rehabilitation for an implant-supported restoration. In this review, we describe the biomechanics of different implant-abutment connections that are the external implant connections, internal implant connections, and the Morse taper connections in the terms of their various properties.
Keyword: External and internal connections, morse taper, biomechanics.

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Introduction

History of implant abutment connection started with the discovery of osseointegrated dental implant by Branemark. Branemark's implant was composed of a 0.7 mm external hex with a butt joint.[1] Initially there was less interest in anti-rotational features of the connection. In the design the external hex was added for the surgical placement of the implant.[1]

With time new application for single tooth replacement, abutment connections were subjected to an increased level of forces. If the implant is unable to achieve the proper esthetics, or withstand the occlusal force, the treatment is considered as failed case. Thus, the implant abutment connection plays the vital role to maintain the biomechanical properties. So it encouraged research and the development of abutment connections with better function and mechanics.[2]
Implant abutment connections can be divided into external and internal types.[3] Branemark's original implant-abutment connection was an external hexagon. Internal implant-abutment connections overcome the clinical complications associated with external connections They are subdivided according to the type of joint which is passive fit or frictional fit.[2] In 1864, Stephen A. Morse invented the Morse taper connection. this was used to connect two rotating machine components in drilling machines.[4] This idea was later used by the orthopedic industry, named as "Morse tapers".

Dental implant abutments

A dental implant abutment can be defined as "that portion of a dental implant that serves to support and/or retain a prosthesis". The design can be modular (the endosseous and the transmucosal abutments are separate components) or integral (one component) type.[5]

Abutment Screw Design

A screw is tightened by applying torque, that is called preload, producing a clamping force that should be greater than the external force to separate the joints. The screw head is wider than the thread diameter. For an abutment the head is most often flat. Tapered head design reduces the clamping effect and also reduces the tensile force in the threads of the screw thereby. within the tapered screw most of the force is distributed to the head rather than to the fixation screw component. But a flat-head screw distributes forces more evenly within the threads of fixation screw component and thus the head of the screw and is less likely to distort a nonpassive casting abutment head should be flat too to achieve the same.[6]

Thread Design and Number

The thread design and number of threads are very important factors influencing the risk of screw loosening. The most common design is a flat head, long-stem length with six threads to achieve optimal elongation.[5]

Metal Composition

The composition of the metal can affect the amount of preload before fracture.

The metal elongation is depended upon the modulus of elasticity. It is related to the type of width, design, material and the amount of stress applied per area.

The bending fracture resistance of Titanium alloy has four times than the Grade 1 titanium. a gold screw exhibits greater elongation but a lower yield strength than a screw made of titanium alloy.[5]

Screw Diameter

The greater the diameter, the higher the preload that may be applied and the greater the clamping force on the screw joint.[7]

Chronological Development of Abutment Connections

The implant abutment connection, is described as an internal or external connection.[3]

The definite factor separating the two groups is the presence or absence of a geometric feature extending above the coronal surface of the implant.[1]

Initially the relationship between the abutment and implant body was mainly associated with external connections. By time the simple butt joint has evolved into slip-fit(a little space exists between the mating parts and the connection is passive) and friction-fit joints(where no space is there between the mating components and the parts are literally forced together).[5]

The joined surfaces may also have a rotational resistance and indexing feature and lateral stabilizing geometry. This geometry is again described as octagonal, hexagonal, cylinder hex, cone screw, cone hex, spline, cam, cam tube and pin / slot. [1,8]

Hexagonal screw joint complications, consisting primarily of screw loosening, ranging from 6 % to 48%.[9] To overcome some limitations of the external hexagonal connection there is development of a variety of alternative connections. The most significant are the internal octagonal, the internal hexagonal, the cylinder hex, the cone screw, the cone hex, the Morse taper, spline, internal spline and resilient connection.[1,6]

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 almost 20 different implant/abutment variations on dental implants by the FDA.[10]

Joint Strength

Internal connections showed increase in fragility initially compared to the external connections, especially for the small diameters.

Mollersten et al., back in 1997, concluded that deep joints resist more to bending forces than shallow joints(0.7mm) and also provide greater joint strength. This criteria is very important in the molar region as it is high load-bearing area.[11]

Carr et al.[12] and Byren et al.[13] reported that the fitting of the implant-abutment interface is important for obtaining joint stability of the implant system.

Chun *et al*., in 2006, found that stress distribution in internal hexagon connection is better within the implant and redistributed within bone. In external hexagon connection, the strain concentration was highest between the implant platform and the abutment.[14]

Schmitt CM et al,2014, suggest that internal connections showed greater resistance than external connections under heavy torque stresses. [15,16]

Force Distributions

With an internal connection, between the implant, abutment connection, screw, and bone, bone is the weakest link. The force distribution with an internal connection load deep within the implant wall and distributes out towards the bone, and less to the abutment.[17]

This distribution reduces the prosthesis related complications shielding the bone.

Levine et al.'s study in 1999 showed in conical internal abutment connections screw loosening is 3.5%. There was improvement from the external connection, where studies showed screw loosening ranging from 6% to 48%.[1]

Quaresma *et al*. in 2008 showed that at the alveolar bone the stress is better distributed but at the abutment itself in Morse taper implant more concentrated.[18]

Fracture resistance:

McGlumphy et al. reported that the ideal preload is 75 % of the maximum torque causing screw fracture.[19]

Implant systems with long internal tube-in-tube connections and cam–slot fixation showed better longevity and fracture strength compared with systems with shorter internal or external connection designs.

Mollersten et al. observed huge differences in the fracture strength of the tested implant systems; however, systems with deeper joints provided better fracture strengths[11]

Balfour & O'Brien (1995) observed that the internal hexagon connection was superior to the external hexagon connection design in terms of fracture strength and fatigue strength.[20]

Rotational Misfit and Screw Loosening

The rotational misfit in internal connection designs is less than external hex connection.

Many internal connections have eliminated rotational misfit by using a friction-fit design.[1] The precise fit between implant and abutment limits the micro-motion between them, thus limiting screw loosening.

Parlk et al [21] 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.

Binon et al reported that the instability between the components of an implant system may cause frequent screw loosening, chronic fracture of the screws, accumulation of plaque, an unfavourable soft tissue response, and the failure of osseointegration.[22]

Jemt et al.[23], and Becker and Becker[24] found a high rate of screw loosening up to 40% in an external hex connection. Levine et al.found less rate of abutment loosening (3.6% to 5.3%) with the Morse taper connection in case of restoring single-tooth replacements. Morse taper connections are used, the abutment loosening is a lesser problem.

Anti-rotational property:

Morse taper type implant design interface engage their abutments by using a 5^{o} friction fit internal wall into which an abutment with a rounded male extension is placed. Anti-rotational properties for the abutment is achieved due to the cold-weld phenomenon[25] that occurs after placing and torquing the abutment.[25,26]

Esthetics

There may also occasionally appear bulky with an unesthetic emergence profile in case of external connectors. it also can have metal exposed at the finish line level since an expansive abutment cuff height is required to house the external connection of the implant.[1]

Internal connections are undeniably superior to provide an esthetic restoration. They permit a sufficient bulk with a smooth buccal contour of the restoration. In addition, it may provide a better prosthetic emergence profile for the chances of trimming the abutment.

Microbial Seal

When there is accumulation of bacterial toxins in the microgaps of implant abutment joints it can cause foul odour, increased inflammation and thereby crestal bone loss.

Internal connections have been proven for better marginal seal for microbes than do external connections**.**[1]

Bicon's study in 2004 verified that their internal morse taper connection provides a hermetic seal that does not permit bacteria to leak from outside-in or from inside-out the abutment connection (Dibart et al. 2005).in 1992 Mairgünther and Netwig showed that the Ankylos abutment connection can provide a vacuum seal for 60 hours.

Within Morse taper abutment connection, a cold-welded interface is seen between the implant and the abutment, which considerably reduced the presence of any microgaps and micromovements between the fixtures.[27]

A comparative study conducted by Jaworski *et al.*[28], 2012, demonstrated that there is lower bacterial penetration within Morse taper (30% of cases) than the external connections (60%).

When compared between internal connections Morse tapers and, Tripodi *et al*. in 2012 demonstrated that 2 out of the 10 Morse taper implants were contaminated against 5 of the internal hexagon connection implants.[25]

Sutter et al. demonstrated that the loosening torque was 124% of the tightening torque at a clinically relevant level of 25 Ncm, which was presented in a favorable light, with reduced risk for loosening4When it is made accurately enough seal can be a hermetic one, eliminating microbial leakage.[29]

Bending Moment/Maximal Load Resistance

Internal conical implant-abutment connections systems show better resistance to bending forces than other internal connections, fracture occurs in the threaded part of the screw.[2,30]

Biological Width

Any microgap, bacterial infiltrated, and existence of abutment micromovement predisposes to bacterial contamination and hampers the biological width. If the biological width isdisturbed and is reduced to <3 mm, that can cause pocket formation or gingival recession leading to implant failure.[31]

Internal connections show superior performance in terms of mechanical strength, stress distribution, microgap, and bacterial penetration than external abutment connections, thus implants supported with internal abutment connections preserve biological width better than external connections.[25]

When other internal abutment connections are compared, Morse tapered connections distribute stress better at the alveolar bone level and better resistance to bacterial leakage. [28] Morse taper connections with platform switching showed reduced inflammation and bone loss.

New Modification:

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.[29]

Platform Switching

The concept of platform switching was introduced by Lazzara and Porter based on a concept of narrower abutment. This can increase the distance between the implant-abutment microgap contamination and the crestal bone and may allow adequate dimensioned biological width, thereby reduces bone resorption.[32]

Siffert and Etienne *et al*. in 2011 also showed biological and biomechanical consequences leading to decreased bone resorption. Under biomechanical consequence, they observed that the force is concentrated more toward the center of the implant which was further redistributed harmoniously into the crestal bone. Thus, there is less stress at the implant abutment junction.[33]

Internal connection with platform switching, gives them an added benefit against external connections. Zipprich *et al*. in 2007 showed that the Morse taper connections did not show microgap opening during micromovements in relation to other internal connections (without platform switching).[34]

Conclusion

The requirements for an optimal implant abutment connection can be summarized as follows: anti-rotational feature for Single tooth restorations, maximum mechanical stability instead of optimal fatigue resistance minimized microgap, overload protection. Different implant–abutment connection designs exhibited significant differences in survival time under dynamic loading and in maximum fracture strength. Clinically, Morse taper connections produce lower stress over the surrounding bone resulting to reduced marginal bone loss and therefore preserve biological width. The decision of selecting the implant abutment connection is thereby taken very precisely for long term better prognosis.

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Figures

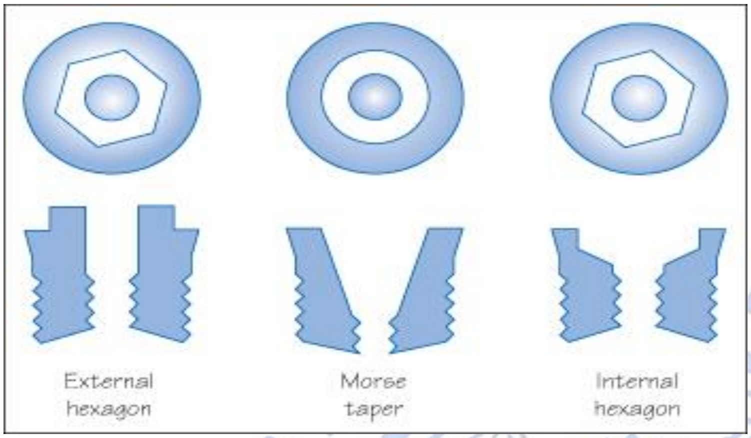

Figure 1

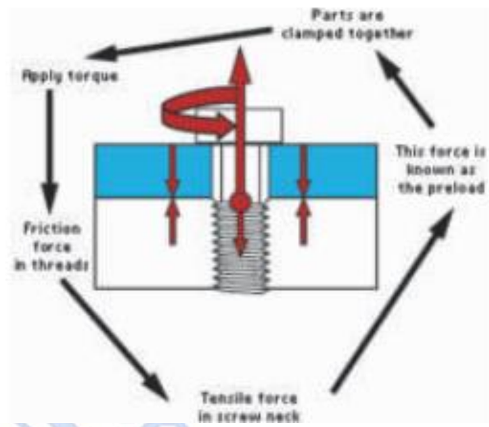

Figure 2

Figure 3

Figure 4

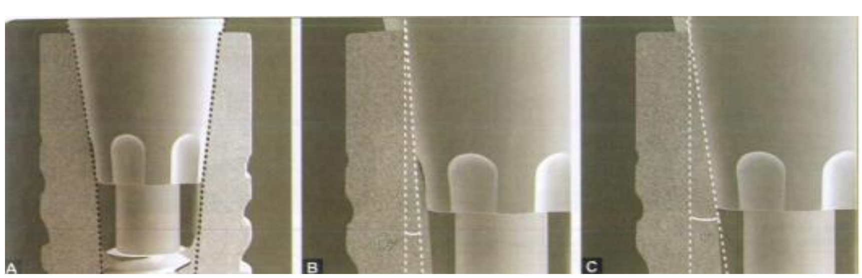

Figure 5: Various degree of morse taper connections

Figure 6: Implant-abutment interface

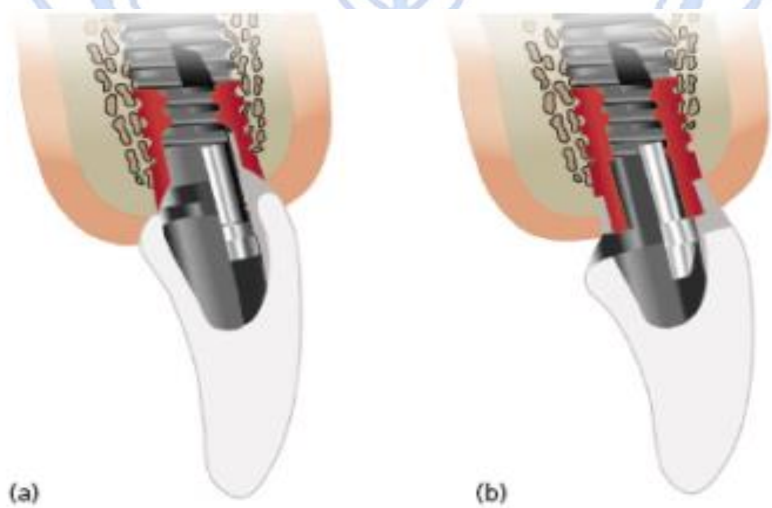

Figure 7

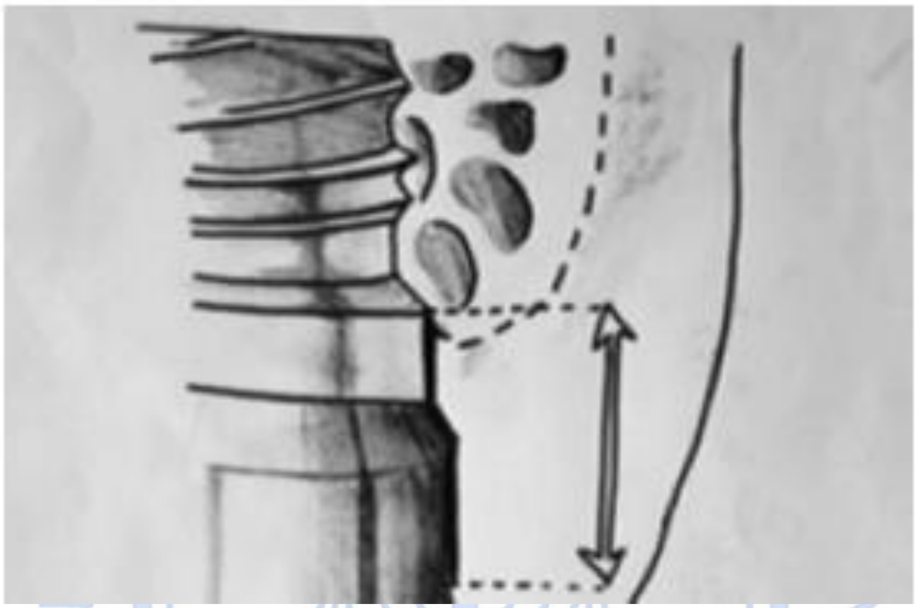

Figure 8: Peri-implant biological width