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College of Dentistry

Implant abutment connection technologies

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By

Ehab mohammed kazem

Supervised by

Dr.Ali Abdulrazzaq

B.D.S., M.Sc, Ph.D. Prosthodontics

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وَقُل رَّبِّ زِدْنِي عِلْمًا

Declaration

This is to certify that the organization and preparation of this project have been made by (Ehab Mohammed Kazem) under my supervision in the university of Baghdad, college of Dentistry in partial fulfillment of the requirements for B.D.S degree.

Dedication

To my parents, who never stop giving of themselves in countless ways, To my second family in college, To my supervisor for his guidance, encouragement, help support, To my best friend karar hassan for his love and support, I made this project.

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Introduction

Introduction

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 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.

Aim of the review

To study the technology in the Implant abutment connection and choose the optimal techniques for the interrelationship between (implant and abutment) as well as the comparison between the materials used and the best connections method and get the best result to prevent the leakage of micro-organisms.

Chapter one

Review of literature

1.1 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”. 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 end osseous 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 **(Lyndon F. Cooper,2008,etl...).**

1.1.2 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 **(Takuma Tsugei And Yoshiyuki Hagiwara, 2009)**.

1.1.3 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 **(Takuma Tsugei And Yoshiyuki Hagiwara, 2009)**. As a screw is tightened, it elongates, producing tension. Elastic recovery of the screw pulls the 2 parts3 together, creating a clamping force. 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 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)**.

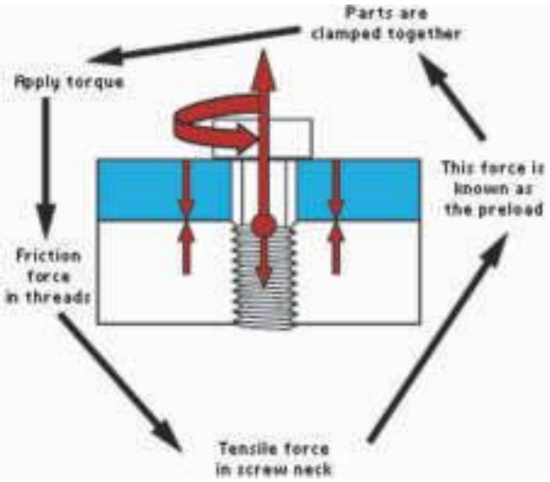

Figure 1: Implant abutment screw.

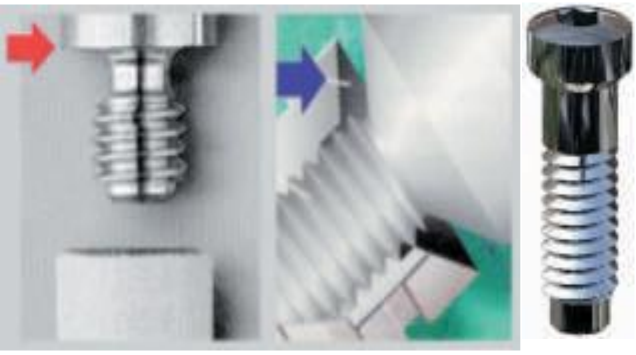

Figure 2: Titanium, Gold-palladium, Titanium-coated Teflon (TorqTite), Gold-plated gold- palladium (Gold-Tite)

1.1.4 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 **(Song Park, Sang Yong Won, 2008).**

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 strength 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.

1.1.5 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 **(Binon PP, 2000).**

1.1.6 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 **(Carl E Misch, 2005)**.

1.1.7 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 **(Song Park, Sang Yong Won,Tae Sung Bae etal, 2008)**. 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 **(Binon PP, Sutter F, Brunski J, Gulbransen H, Weiner R. 1994, Binon PP. 1996)**. Carr et al **(Carr AB, Brunski JB, Hurley E, 1996)**. and Byren et al **(Byren D, Houston F, Cleary R, 1998).** 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 **(.E. A. McGlumphy, D. A. Mendel, and J. A. Holloway,1998)**. 10reported 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. **(Binon, PP. QDT. 2000).**

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 (Metals and Materials International 2005). 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)** There ported data indicate an effective increase in attainable preload for titanium alloy screws at a significantly lower cost than its gold-alloy counterpart **(Binon PP, 2000).**

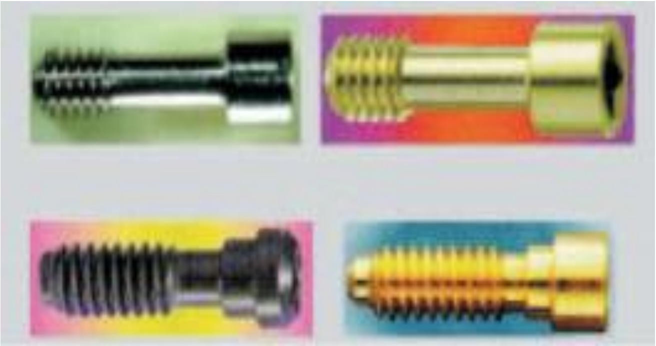

Figure 3: various antirotational features incorporated into abutment.

Table 1.1 Table Comparison of Internal Connection System

Feature	**CenterPulse (Screw-Vent)**	**Astra Tech (Astra)**	**(ITI) Straumann**	**(Replace Select) Nobel Biocare**	**Technologies (Camlog) Alatec**	**(Frialit2) Friadent**	**Certain) 3i (Osseotite**
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°**

1.1.8 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. **(Binon PP,2000)**. **(Fig 4).**

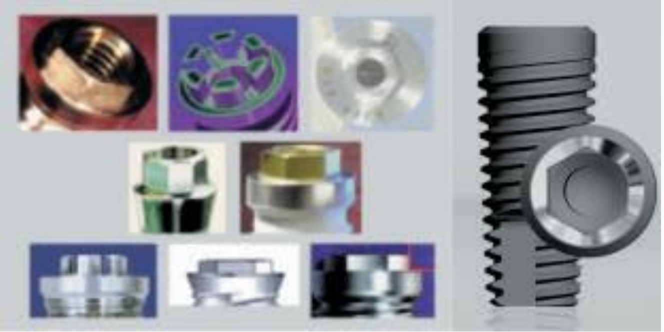

Figure 4: Morse Taper Connection.

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**%** **(Butz F, Heydecke G, Okutan M, Strub JR, 2005)**.

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 **(Israel M. Finger,2003)**.

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 **(Niznick GA,1983, Niznick GA,1991)**. Its features were intended to distribute intraoral forces deeper within the implant to protect the retention screw from excess loading**, (Niznick GA,1991, Binon PP1,996)** Internally connected implants also provide superior strength for the implant/abutment connection**(Binon PP1,1996, Norton M,2000, Mollersten L, Lockowandt P, Linden L-A,1998**). 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). **(Sutter F, Weber HP, Sorenson J,2002,etl…).**

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**. (Perriard J, Wisckott WA, Mellal A, Scherrer SS, Botsis J, Besler UC,2002,NORTON, M. R, 1999).**

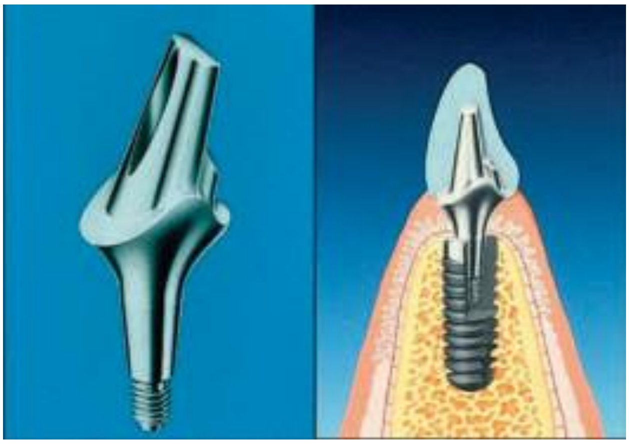

Figure 5 Implant/abutment interface.

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 **(Sutter F, Weber HP, Sorenson J, Belser U,1993, Arvidson K, Bystedt H, Ericsson I,1990, Perriard J, Wisckott WA, Mellal A, Scherrer SS, Botsis J, Besler UC,2002).**

. 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 **(Binon PP,2000)**. 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 **(NORTON, M. R, 1999)**. When it is made accurately enough seal can be a hermetic one, eliminating microbial leakage **(Binon PP, 2000)**.

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 **(Quirynen M, van Steenberghe D,1993)**.

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 0 0 exist at 2 and 4 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 **(Lyndon F. Cooper, Ingeborg J. De Kok, Ms Lee Culp, 2008)**.

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 **(NORTON, M. R, 1999)**.

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 **(Niznick GA, 1991, Norton M, 2000, Mollersten L, Lockowandt P, Linden L-A,1998)**.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 **(Finger IM, Castellon P, Block M, Elian N;2003)**.

1.1.9 Implant-Abutment Junction (IAJ)(Fig6)

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 **(N. Broggini L.M,2003)**.

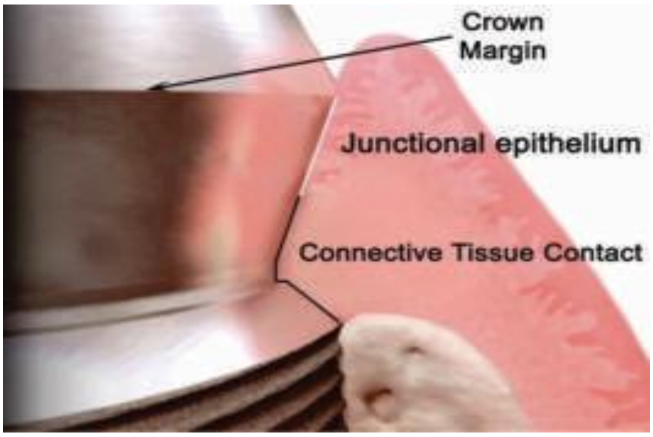

Figure 6: Platform switching in dental implants.

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 **(Morris HF, Ochi S,1992).** everal published studies have shown that crestal bone loss occurs following implant placement and its connection to the abutment **(Hermann F, Lerner H, Palti A, 2007)** 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 **(Hermann JS, Schoolfield JD, Nummikoski PV, Buser D, Schenk RK, Cochran DL, 2001**).

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 **(Berglundh T, Lindhe J, 1996)**. These investigations have focused on implant systems in which the diameter of the implant-seating surface matches that of the abutment.

FIGURES 7A through 7G. The On-1 (Nobel Biocare) allows platform switching while maintaining a continuous abutment attachment. This sequence shows how the system — which is now available to U.S. clinicians — is used. The implant with its conical connection is placed at bone level (A). The base is attached at the time of surgery; this represents the abutment that will remain fixed to the implant (B). The healing abutment is attached and the tissues are allowed to integrate (C, D). Once integrated, the sectional healing abutment is removed, with the base remaining in situ. A wellformed sulcus results, with the base sited subgingivally (E). Next, subsequent components can be placed, and the soft tissue integration remains intact, with the base holding the tissues (F, G). *COURTESY PETER SCHUPBACH, PhD*

1.2 Micro-movements at the implant-abutment interface: measurements, causes and consequenses

purpose: Most of two-component or multi-component implant systems use an implant-abutment connection with a clearance it. The clinical impact is assumed as high according to the following factors:

1) Implant systems consisting of two or several components are much more widespread than single component systems because they offer a number of well-known clinical and technical advantages.

2) Unconnected crowns in the posterior region are more susceptible to technical failure of the implant-abutment interface.

3) Crestally or subcrestally placed implant-abutment interfaces are frequently subjected to crestal bone resorption following abutment connection. This *in-vitro* study examined the dynamic behaviour of different designs of implantabutment connections.

Materials and methods: Abutments were loaded at an angle of 30° with a force of up to 200 N. The distance of the point of force application from the implant platform was 8 mm; the gradation of the force was 0.3 N/ms. The interface of the implant-abutment connection was examined and measured radiographically using a professional high speed digital camera (1,000 images per second).

Result: The results showed that, under simulated clinical conditions, complex mechanisms are responsible for the presence or absence of a micro-motion. All implantabutment connections with a clearance it exhibit a micro-motion (implant systems: SIC®; Replace Select®; Camlog®; XIVE®; Straumann synOkta®; Bego-Semados®; Straumann massive conical abutment®). Precision conical connections (implant systems: Ankylos®; Astra Tech) show no micromotion.

Table 1.2 implant systems

Implant	**Index**	**Micro-spalt at 200 N**
Astra Tech	**dodecagonal**	**0.0 µm**
Ankylos®	**non indexed**	**0.0 µm**
Straumann massive abutment®	**non indexed**	**0,1–4 µm**
Bego-Semados®	**hexagonal**	**0,1–4 µm**
Replace Select®	**3-positions**	**12–16 µm**
XIVE®	**hexagonal**	**16–20 µm**
Straumann synOkta®	**oktagonal**	**20–24 µm**
SIC®	**hexagonal**	**28–32 µm**
Camlog®	**3-positions**	**32–36 µm**

The potential clinical relevance of these results can at this point only be derived from theoretical considerations. Presumably, the pumping effect caused by the micro-motion plays an important role for crestal bone resorption. It is assumed that the bone is contaminated with liquid contained in the implant **(Zipprich H, Weigl P, Lauer H-C, 2007).**

1.3 Biological Responses to the Transitional Area of Dental Implants

The stability of peri-implant tissue is essential for the long-term success of dental implants. Although various types of implant connections are used, little is known about the effects of the physical mechanisms of dental implants on the stability of peri-implant tissue. This review summarizes the relevant literature to establish guidelines regarding the effects of connection type between abutments and implants in soft and hard tissues. Soft tissue seals can affect soft tissue around implants. In external connections, micromobility between the abutment and the hex component of the implant, resulting from machining tolerance, can destroy the soft tissue seal, potentially leading to microbial invasion. Internal friction connection implants induce strain on the surrounding bone via implant wall expansion that translates into masticatory force. This strain is advantageous because it increases the amount and quality of peri-implant bone. The comparison of internal and external connections, the two most commonly used connection types, reveals that internal friction has a positive influence on both soft and hard tissues.

1.3.1Typical Dental Implant Connection Types.

1.1 External Hex Connection: Butt-Jointed Interface In external hex-type connections, the abutment is connected to the implant by an abutment screw. This connection is also called a butt joint interface because the flat surfaces on the top of the implant and the bottom of the abutment are in direct contact with each other. This external connection is stabilized entirely by fastening of the abutment screw. When torque is applied to the abutment screw connecting the implant and the abutment, the abutment screw is elongated, generating a preload. Screw dynamics play an important role in this interaction because the mechanism linking this connection is fundamentally dependent on the preload of the screw **[*Bozkaya, D.; Muftu, S,* 2003].** The preload acts as a clamping force on the implant–abutment complex, and provides stability to the connection **[*Jeong, C.G.; Kim,* , 2017,etl…].q**

The Brånemark implant (NobelBiocare, Zurich, Switzerland), the first commercially available screw-shaped implant, is a representative external connection-type implant. When masticatory force is applied to this type of implant, the vertical component of the masticatory force is supported by the top platform of the implant. The lateral component of the masticatory force is placed on the hex structure of the top of the implant and the abutment screw, and the rotational component of this force is resisted by the hex structure.

Previous biomechanical analyses indicate that the manufacturer's recommended torque of 30–35Ncm is not sufficient to prevent screw loosening **[*Jeong, C.G.; Kim, S.K.; Lee, J.H.; Kim, J.W.; Yeo, I.S.L,*2017, Michalakis,K.X.;Calvani,P.L,2014]**.Repeated tightening of the abutment screw is considered essential because of the preload loss in screw mechanics, which is the cause of screw loosening **[*Jeong, C.G.; Kim, S.K.; Lee, J.H.; Kim, J.W.; Yeo, I.S.L,*2017].** It is also helpful to use other methods in addition to screw tightening to maintain the stability of the implant–abutment connection. One option that makes this possible is the use of the frictional force generated between the interfaces.

1.2 Internal Friction Connection: Frictional Interface

In internal friction connections, stability is maintained by close contact between the inner surface of the implant and the outer surface of the abutment, in addition to the preload applied to the abutment screw. The tight contact between the abutment and implant creates frictional force, and this plays a major role in supporting the stability of the connection. Therefore, this type of connection is also called a friction-screw-retained connection.

The degree of tapering at the interface between the implant and the abutment is an important factorto consider when determining the abutment mobility of the internal conical connection. A wider tapering angle will result in a more unstable connection in this type of internal connection, although the possibility of implant fracture decreases **[*Bozkaya, D.; Muftu, S,* 2003, *Lee, J.H.; Huh, Y.H.; Park, C.J.; Cho, L.R,* 2016]**. In addition, the role of frictional forces in maintaining the stability of the connection is decreased, while the burden on the abutment screws is increased (Figure 1).

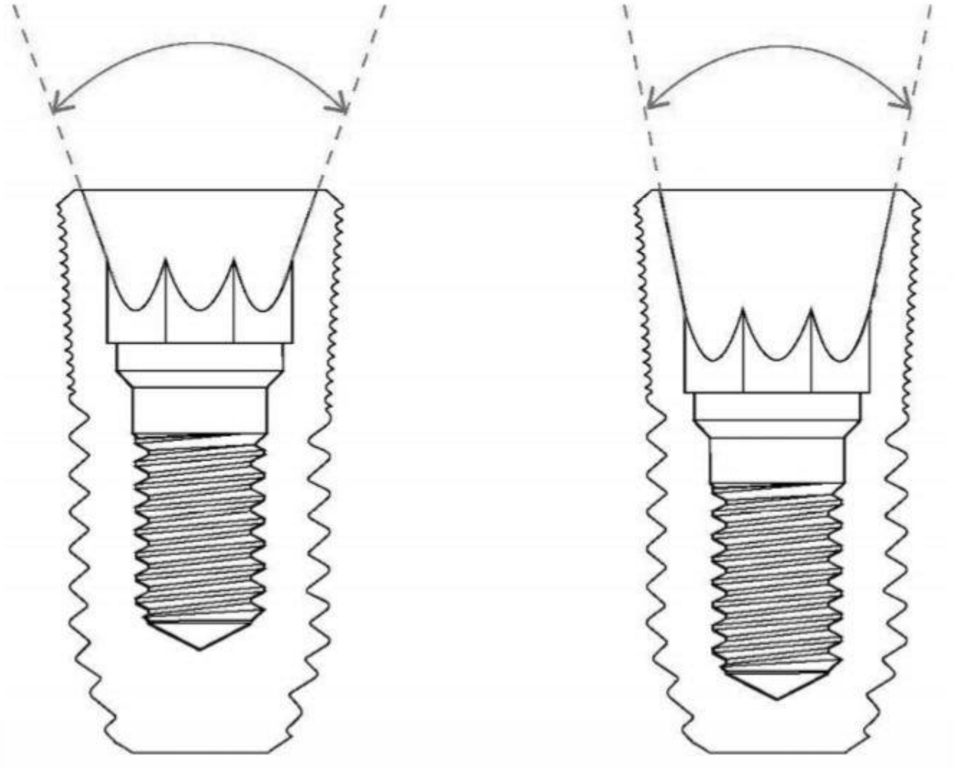

Figure 8. The degree of conical connection. A wider tapering angle (left) results in a more unstable connection for abutment mobility in internal connection-type implants.

A systematic review reported that internal friction connection provides less microleakage at the implant–abutment interface than external hex connection type in both static and dynamic loading tests **[*Mishra, S.K.; Chowdhary, R.; Kumari, S*, 2017].** The presence of gap could lead to accumulation of bacteria and the phenomenon might affect the success rate of implants.

When an abutment is connected to an internal conical connection-type implant, the abutment is first brought into contact with the upper part of the implant inner wall **[*Lee, J.H.; Huh, Y.H.; Park, C.J.; Cho, L.R*, 2016, *ilmaz, B.; Gilbert, A.B*,2015]**. As the implant at the top is slightly flared, it comes into greater contact with the abutment as the implant is combined. The abutment screw becomes slightly loosened when the abutment is completely combined with the implant by opening the implant wall. Because of the preload loss from such an abutment sinking and settling effect, repeated screw tightening is essential **[*Michalakis,K.X*, 2014, *Saleh Saber, F.; Abolfazli, N.; Jannatii* , 2017].**

1.3.2 Soft Tissue Responses to Different Implant System Materials and Structures

2.1. The Soft Tissue Seal Theory

Humans are exposed to a variety of external environments involving external forces, ultraviolet rays, and microorganisms. Human skin is the first line of defense that protects the human body against these external stresses. When human skin is pierced, the resulting hole must be closed by the immune system and healing mechanisms. Teeth are one of the few organs in the human body that are located across the skin. The root of the tooth is surrounded by alveolar bone, while the part that penetrates through the soft tissue is in contact with epithelial tissue and/or the connective tissue of the mucosa **[Bartold, P.M.;Walsh, L.J.; Narayanan,2000].**

Holes in the mucosa created by teeth are sealed by a special structure composed of epithelium and connective tissue **[Bartold, P.M.; Walsh, L.J;Narayanan,2000].**An internal basal lamina and the hemi-desmosomes of epithelial tissue are attached to teeth, and a combination of dento-gingival fiber and cementum links teeth to the surrounding connective tissue.

The holes connecting the inside and outside of the human body that contain teeth are secured by soft tissue attachments **[Bartold, P.M.;Walsh, L.J.; Narayanan,2000].**

Like natural teeth, dental implants are an artificial organ located in a hole on the surface of the body, and the hole is sealed via a mechanism similar to the one that seals the holes around natural teeth using soft tissues. However, these sealing mechanisms are not identical to each other. Dental implants are in contact with the alveolar bone or soft tissue (epithelial and connective tissue) of the transition area (Figure 2) **[*Berglundh, T.; Lindhe, J.; Ericsson, I.; Marinello*, 1991].** Fibers in the connective tissue attached to the abutment mainly run parallel to the surface and are circular in shape, whereas dento-gingival fibers, such as Sharpey's fibers, are attached vertically to the cementum in natural teeth (Figure 1) **[*Berglundh, T.; Lindhe, J.; Ericsson, I.; Marinello*, 1991].**

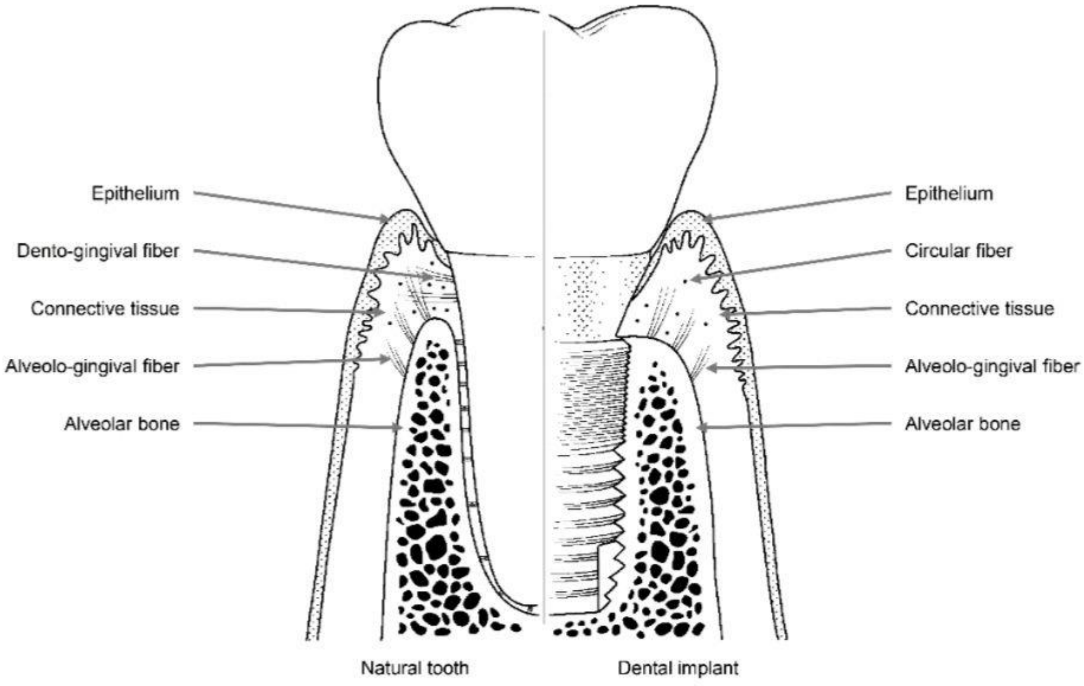

Figure 9. Soft and hard tissues with collagen fibers surrounding a natural tooth (**left**) and a dental implant (right).

2.2. Attachment of Soft Tissue

The stability and immobility of soft tissue attachments in contact with the implant abutment are important factors that affect the long-term prognosis of the implant **[*Atsuta, I.; Ayukawa, Y.; Kondo, R,*2016,*Abdallah, M.N.; Badran, Z.; Ciobanu, O.; Hamdan, N.; Tamimi, F,* 2017]**. If the soft tissues around the implant are deformed owing to the movement of the lip, cheek, tongue, or jaw, the weak soft tissue seal surrounding the implant may be destroyed. This allows microbes to penetrate through the damaged mucosal seal, increasing the likelihood of disease around the implant **[*Atsuta, I.; Ayukawa, Y.; Kondo, R,* 2016, *Abdallah, M.N.; Badran, Z.;* 2017].** Therefore, a stable soft tissue seal is essential to prevent microbial invasion and peri-implant disease **[*Abdallah, M.N.; Badran, Z,*2017, *Hermann, J.S.; Schoolfield, J.D,*2001]**. The soft tissues around natural teeth are separated into the lining mucosa and masticatory mucosa, of which the masticatory mucosa is composed of the free and attached gingiva (Figure 3). The attached gingiva is in permanent and intimate contact with the surface of the enamel, the cementum, and the alveolar bone, thereby immobilizing the soft tissue **[Atsuta, I.; Ayukawa, Y, 2000]**. It is, therefore, possible to retain the firmness and health of the mucosal seal by preventing it from detaching.

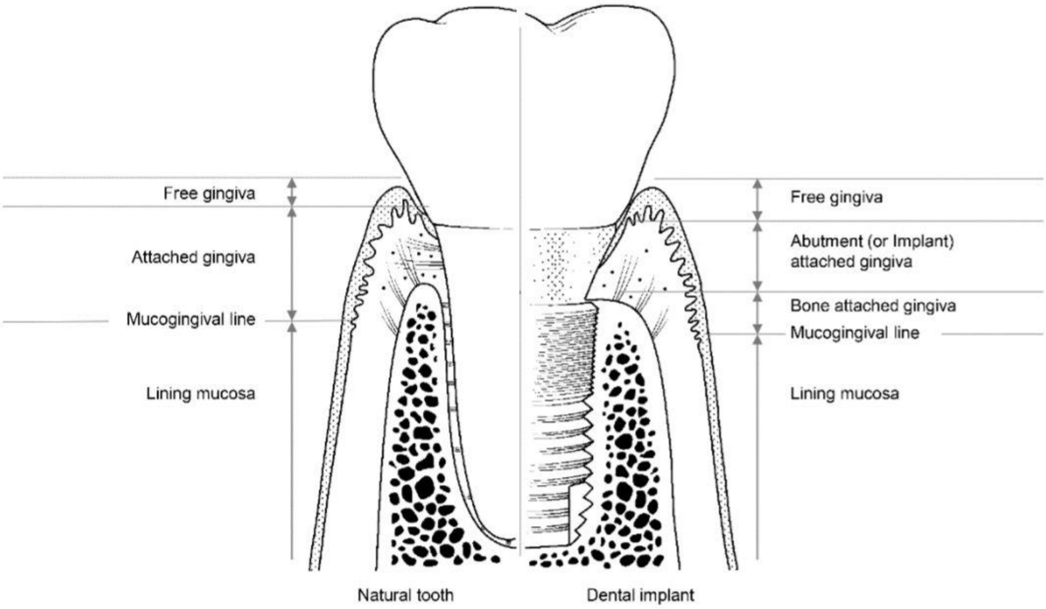

Figure 10. The structure of soft tissue around a natural tooth (**left**) and a dental implant (**right**).

2.3. Disruption of the Soft Tissue Seal

The soft tissue seal is mainly destroyed via two mechanisms; instability of the peri-implant mucosa or the implant-abutment assembly. If there is no bone-attached gingiva around the implant, the soft tissue can become mobile, and the mucosal seal will inevitably rupture. When the mucosal seal is destroyed, bacteria can penetrate the internal environment through the transmucosal rupture site, potentially leading to peri-implant disease **[*Monje, A.; Insua, A.; Wang, H.L.* 2019]**. Therefore, because of the weakness of the soft tissue attachment, it is important to ensure there is sufficient bone-attached gingiva around the implant. Thus, a plan for implant surgery should be established to maintain the bone-attached gingiva following implant placement.

In external-type implants, there is slight machining tolerance around the hex component, resulting in micromobility in the abutment.This external hex connection is, therefore, a mobile structure. Thus, most occlusal forces are concentrated on the abutment screw. This micromobility is likely to cause disruption of the soft tissue seal, bacterial infiltration, and peri-implant disease **[*Liu, Y.; Wang, J,* 2017]** (Figure 4). Implant systems with an external hex connection were originally developed for the mandibularnrestoration of a completely edentulous patient wearing a maxillary complete denture. The occlusal force in such patients is weak, and this mobile connection is able to bear this weak masticatory force with few screw loosening events or breakdown of the soft tissue seal.

In internal connection-type implants, the abutment–implant connection is firm owing to a process similar to cold-welding. Unlike external connections, in which the occlusal force is concentrated mainly on the abutment screw, the occlusal force is transmitted to the implant inner wall through the abutment–implant connection in internal connection-type implants. Therefore, less screw loosening occurs in this type of implant. In addition, the abutment–implant contact area is wider internal connection-type implants, and this prevents stress from concentrating at specific sites such as the *Materials* abutment screw, and contributes to the stability of the soft tissue seal.

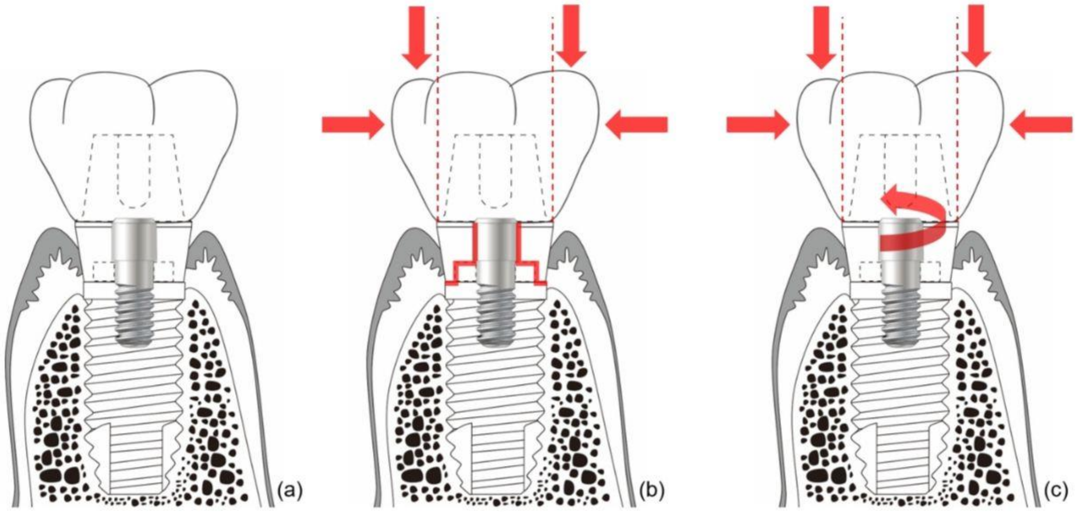

Figure 11. Schematic illustration of the ‘soft tissue seal’ theory. Micromobility of the abutment in external connection-type implants disrupts the surrounding soft tissue seal, which plays an important role in preventing external irritants from penetrating into the body. (**a**) External connection-type implant. (**b**) Parts experiencing the greatest stress (red lines) from eccentric forces (red arrows). (**c**) Abutment screw-loosening (red rotated arrow) by eccentric forces ((red arrows).

2.4. Submerged and Nonsubmerged Implants

Depending on whether the top of the implant is at the alveolar bone or gingival level, implants can be divided into submerged-type and nonsubmerged-type. For submerged implants, the soft tissue seal is formed at the abutment area, rather than at the neck part for the nonsubmerged type. Histologically, there are no significant differences in the degree and pattern of soft tissue attachment to implants between submerged and nonsubmerged types **[*Abrahamsson, I.; Berglundh, T.; Wennstrom, J.; Lindhe, J,* 1996]**. When nonsubmerged implants are placed at the proper vertical position of the alveolar bone, the mobility of the abutment does not interfere with the soft tissue seal, or cause marginal bone resorption, because the interface between the abutment and the implant is positioned outside the soft tissue **[*Hermann, J.S,* 2000, Hermann, J.S.; Schoolfield, J.D, 2001].**

2.5. Materials for Abutment

Achieving soft tissue seals may also depend on the type of material used for the abutment. Abrahamsson et al. (1998) investigated the stability of soft tissue seals attached via gold alloy, dental porcelain, titanium, and aluminum oxide. In this study, marginal bone resorption occurred when seals were attached to surfaces composed of gold alloy and dental porcelain, because no soft tissue seal formed. However, when titanium and aluminum oxide were used, a soft tissue seal was achieved, and marginal bone was not absorbed **[*Abrahamsson, I.; Berglundh, T*, 1998].** Welander et al. (2008) also reported that epithelial adhesions receded around abutments attached via gold alloy **[*Welander,M*, 2008]**. Therefore, when using a UCLA abutment, the transmucosal area of the abutment is made of gold or dental porcelain, and a soft tissue seal may not be properly achieved, resulting in marginal bone resorption.

2.6. Detachment of Abutments

the abutment becomes disconnected from a submerged-type implant, the soft tissue seal is broken, and microorganisms in the oral cavity can then penetrate into the tissues surrounding the implant **[*Rodriguez, X.; Vela, X*, 2013]**. This may result in the loss of marginal bone. Abrahamsson et al. reported that the absorption of marginal bone is doubled when the abutment is detached five times **[*Abrahamsson, I.; Berglundh, T*, 1997]**. For these reasons, some clinicians have proposed the ‘one abutment-one time (OAOT)’ concept to prevent marginal bone loss **[*Canullo, L.; Bignozzi, I*, 2010, *Degidi, M.; Nardi, D.; Piattelli, A*, 2011].** Clinicians should be aware that during a prosthetic restoration procedure, or during the postrestoration maintenance period, it may be advantageous to minimize the process of removing the abutment.

2.7. Surface Modification of Abutments

Various technologies have been explored for improving the soft tissue seal at the transmucosal part of the abutment, including surface treatments, such as coating, machining, blasting, plasma spraying, etching, and laser processing **[*Ghensi, P.; Bettio, E*, 2019]**. Yang et al. reported that, when ultraviolet light is applied to surfaces, gingival fibroblasts proliferate more readily on surfaces made of zirconia **[*Yang,Y.;Zhou,J*, 2015**]. Several studies showed that, when an abutment is laser-treated, the connective tissue is directly attached to the surface of the abutment by perpendicular fibers **[*Iglhaut, G.; Becker, K*, 2013, *Nevins, M.; Kim, D.M.; Jun, S.H*, 2010]**. In addition, as the surface roughness of the transmucosal part of the abutment increases, the soft tissue seal improves. This may be because a rougher surface has a larger surface area to which the soft tissue can attach **[*Guida, L.; Oliva, A.; Basile, M.A.; Giordano, M.; Nastri, L*,2013].**

1.3.3. Hard Tissue Responses to Implant System Materials and Structures

3.1. The Bone Stimulation Theory

The soft and hard tissues surrounding the implant play complementary roles. Alveolar bone is a hard tissue that withstands the masticatory force applied to the implant, and serves to transmit it to the jawbone. The soft tissue, gingiva, and mucosa protect the alveolar bone from external irritants such as bacteria. The condition of the soft tissue is maintained by the underlying alveolar bone, and the alveolar bone is protected by the overlying soft tissue. In general, after the restoration of an implant, between 1 and 1.5 mm of the marginal bone around the implant is absorbed during the first year owing to the application of occlusal force, and 0.2 mm is absorbed per year thereafter **[*Albrektsson, T.; Zarb, G*, 1986].** On the basis of the results of studies showing that marginal bone is steadily absorbed every year, it was thought that long-length implants should be beneficial for long-term predictability **[*Albrektsson, T.; Zarb, G*, 1986**]. This was observed in long-term studies of the Brånemark system using an external connection-type implant, which is limited and inapplicable to some internal friction connections **[*deMedeiros,R.A*,2016, *Palmer, R.M.; Palmer*,2000,*Puchades-Roman, L.; Palmer, R.M.;* 2000].** By contrast, several studies on a certain implant connection system reported that peri-implant marginal bone is increased by occlusal loading **[*Palmer, R.M.; Palmer,2000, Puchades-Roman, L.; Palmer, R.M, 2000*].** Because the use of long implants is likely to cause damage to important anatomical structures such as nerves, it may be more advantageous to insert short implants if warranted for long-term prognosis without marginal bone resorption.

The thread of the implant transforms the shear stress generated at the interface between the implant and the bone into compressive stress so that the appropriate stimulus can be transmitted to the bone (Figure 5). This stimulation is one of the factors that allows the bone to remain stable over the long term.

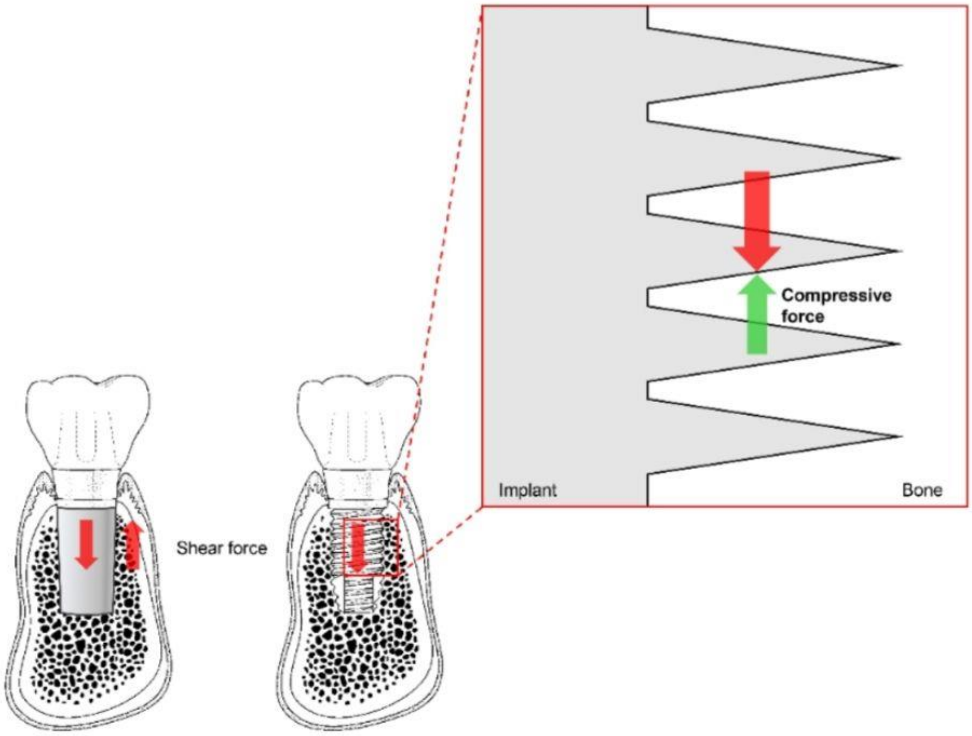

Figure 12. The thread function of non-threaded (**left**) and threaded (**right**) dental implants. Shear force(red arrows) is transformed into compressive force (green arrow) by the threads. Note the reduction of shear force due to the partial switch to compressive force in the magnified diagram (vertically and horizontally; not marked).

3.2. Mechanism of Bone Stimulation

The connection of the Astra implant system has an internal conical shape with a slope of 11 degrees.The occlusal force applied to the abutment is transmitted to the implant through this conical connection. The masticatory force delivered to the implant thus becomes the source of the stain to stimulate the alveolar bone **[*de Vasconcellos, L.G.; Kojima, A.N.; Nishioka, R.S,* 2015]**. Thus, when the abutment receives occlusal force and sinks downward, the conical opening of the implant is opened wider, and the bone around the implant is consequentially stimulated (Figure 6). This stimulation activates osteoblasts in the alveolar bone, thereby increasing the amount and quality of alveolar bone. This increase in alveolar bone can lead to a positive change in the results of clinical procedures. This reduces the need for invasive bone grafting or the placement of excessively long implants during implant surgery. This represents a positive result for both the patient and the surgeon.

3.3. Prevention of Hard Tissue Loss

The marginal bone loss that occurs in the mobile connection of external connection-type implants does not lead directly to the failure of the implant. However, it can cause considerable complications in the tissue surrounding the implant. In general, these external connection implants are known to lose marginal bone up to the second or third thread level of the implant **[*Tarnow, D.P.; Cho, S.C.; Wallace, S.S,* 2000]**. This bone loss can alter the properties of the overlying soft tissue, resulting in a reduction in the attached gingiva. This weakens the soft tissue seal and increases the likelihood of bacterial invasion and peri-implantitis. A detailed periodical examination of the condition of tissues around the implant is thus essential for long-term success when external connection-type implants are used.

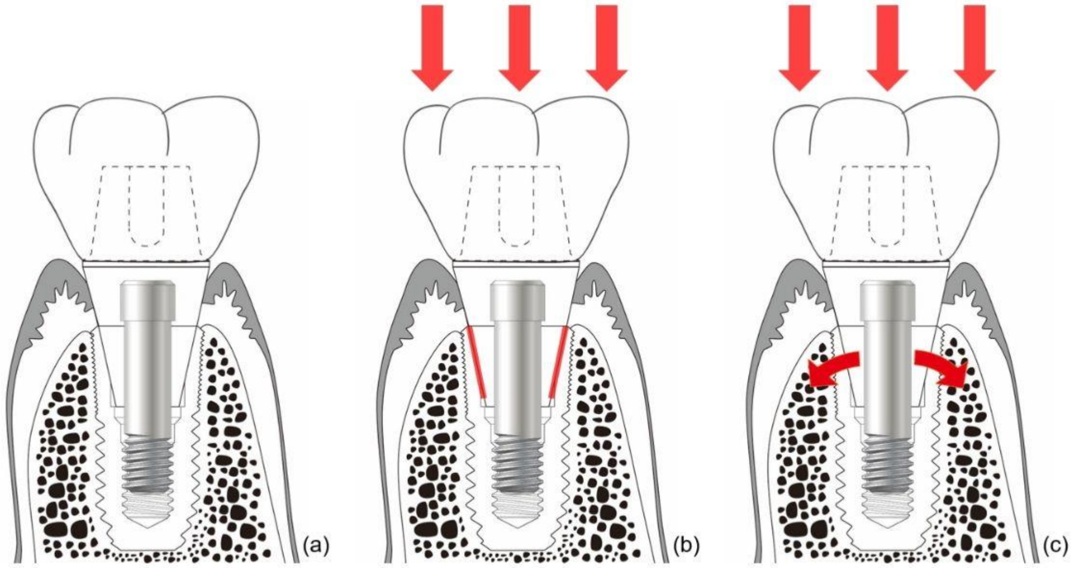

Figure 13. Schematic drawing of bone stimulation. When occlusal force is applied to an internal connection-type implant, the implant around the connection expands and stimulates the surrounding bone to induce bone proliferation. (**a**) Internal friction connection-type implant. (**b**) The occlusal force is transmitted to the implant through the conical connection parts (red lines). (**c**) The coronal expansion of the implant (curved red arrows) becomes the source of the strain that stimulates the alveolar bone.

Chapter two

Conclusion

2.1 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. Dental implants should be capable of performing dental functions for a prolonged period of time. For this to be possible, the health of the surrounding soft and hard tissues is essential. Alveolar bone must be able to withstand masticatory force, and the overlying soft tissue should be able to protect the alveolar bone from external irritants. The soft tissue seal is weaker around implants than around natural teeth. Thus, to avoid damage, the peri-implant soft tissue seal should not be mobile. Free and abutment-attached gingiva cannot prevent the destruction of the soft tissue seal that results from the movements of the lips and cheeks. Additionally, it is impossible to prevent all micromobility of the abutment in external connection-type implants. Hence, it is necessary to secure sufficient bone-attached gingiva, or use an implant system with extensive and deep connections, such as internal connection-type implants. The resulting immobility contributes to the maintenance of a healthy soft tissue seal, and prevents bacterial invasion into the peri-implant tissue.

In addition, internal connection-type implants can transform occlusal load into strain that stimulates the surrounding bone through the abutment–implant connection. This strain enhances the amount and quality of peri-implant bone. Taking these findings into account, clinicians may find it advantageous to select internal conical connection-type implants rather than external connection-type implants, to allow dental implants to function properly as artificial organs with long-term predictability.

References

A

-Arvidson K, Bystedt H, Ericsson I. Histometric and ultrastructural studies of tissues surrounding Astra dental implants in dogs. Int J Oral Maxillofac Implants. 1990;5;2:127-134.

- Albrektsson, T.; Chrcanovic, B.; Ostman, P.O.; Sennerby, L. Initial and long-term crestal bone responses to modern dental implants. Periodontology 2000 2017, 73, 41–50.

- Atsuta, I.; Ayukawa, Y.; Furuhashi, A.; Yamaza, T.; Tsukiyama, Y.; Koyano, K. Promotive effect of insulin-like growth factor-1 for epithelial sealing to titanium implants. J. Biomed. Mater. Res. A 2013, 101, 2896–2904.

-Atsuta, I.; Ayukawa, Y.; Kondo, R.; Oshiro, W.; Matsuura, Y.; Furuhashi, A.; Tsukiyama, Y.; Koyano, K. Soft tissue sealing around dental implants based on histological interpretation. J. Prosthodont. Res. 2016, 60, 3–11.

-Atsuta, I.; Yamaza, T.; Yoshinari, M.; Goto, T.; Kido, M.A.; Kagiya, T.; Mino, S.; Shimono, M.; Tanaka, T. Ultrastructural localization of laminin-5 (gamma2 chain) in the rat peri-implant oral mucosa around a titanium-dental implant by immuno-electron microscopy. Biomaterials 2005, 26, 6280–6287.

-Abdallah, M.N.; Badran, Z.; Ciobanu, O.; Hamdan, N.; Tamimi, F. Strategies for Optimizing the Soft Tissue Seal around Osseointegrated Implants. Adv. Healthc. Mater. 2017, 6, 1700549.

-Abrahamsson, I.; Berglundh, T.; Wennstrom, J.; Lindhe, J. The peri-implant hard and soft tissues at different implant systems. A comparative study in the dog. Clin. Oral Implant. Res. 1996, 7, 212–219.

-Abrahamsson, I.; Berglundh, T.; Lindhe, J. Soft tissue response to plaque formation at different implant systems. A comparative study in the dog. Clin. Oral Implant. Res. 1998, 9, 73–79.

-Abrahamsson, I.; Berglundh, T.; Lindhe, J. The mucosal barrier following abutment dis/reconnection. An experimental study in dogs. J. Clin. Periodontol. 1997, 24, 568–572.

-Albouy, J.P.; Abrahamsson, I.; Berglundh, T. Spontaneous progression of experimental peri-implantitis at implants with different surface characteristics: An experimental study in dogs. J.Clin. Periodontol. 2012, 39, 182–187.

-Albrektsson, T.; Zarb, G.; Worthington, P.; Eriksson, A.R. The long-term efficacy of currently used dental implants: A review and proposed criteria of success. Int. J. Oral Maxillofac. Implant. 1986, 1, 11–25.

B

-Binon PP, Sutter F, Brunski J, Gulbransen H, Weiner R. The role of screws in implant systems. Int J Oral Maxillofac Implants 1994;9:48-62

-Binon PP. The effect of implant/abutment hexagonal misfit on screw joint stability. Int J Prosthodont 1996;9:149-152.

-Byren D, Houston F, Cleary R. Claffey N. The fit of cast and premachined implant abutments. J Prosthet Dent 1998;80:184- 192.

-Binon, PP. The External Hexagonal Interface and Screw-Joint Stability: A primer on Threaded Fasteners in Implant Dentistry. QDT. 2000;23:91-105.

-Binon PP. Implants and components: Entering the new millennium. Int J Oral Maxillofac Implants 2000;15:1;76-94.

-Butz F, Heydecke G, Okutan M, Strub JR ;Survival rate, fracture strength and failure mode of ceramic implant abutments after chewing simulation. J Oral Rehabil.2005 ;32;11:838-43.

-Binon PP. The evolution and evaluation of two interference-fit implant interfaces. Postgraduate Dent 1996;3(1):3-13.

-Berglundh T, Lindhe J. Dimension of the periimplant mucosa. Biologic width revisited. J Clin Periodontol 1996;23;10:971-973.

-Bozkaya, D.; Muftu, S. Mechanics of the tapered interference fit in dental implants. J. Biomech. 2003, 36, 1649–1658.

-Bartold, P.M.; Walsh, L.J.; Narayanan, A.S. Molecular and cell biology of the gingiva. Periodontology 2000 2000, 24, 28–55.

-Berglundh, T.; Lindhe, J.; Ericsson, I.; Marinello, C.P.; Liljenberg, B.; Thomsen, P. The soft tissue barrier at implants and teeth. Clin. Oral Implant. Res. 1991, 2, 81–90.

-Buser, D.; Mericske-Stern, R.; Dula, K.; Lang, N.P. Clinical experience with one-stage, non-submerged dental implants. Adv. Dent. Res. 1999, 13, 153–161.

C

-Carl E Misch; Dental implant prosthetics, Elsevier Mosby Publication 2005.

-Carr AB, Brunski JB, Hurley E. Effect of fabrication, finishing, and polishing procedures on preload in prostheses using conventional gold and plastic cylinders. Int J Oral Maxillofac Implants 1996;11:589-598.

-Chan-Ik Park, Han-Cheol Choe, Chae-Heon Chung ;Effect of surface coating on the screw loosening of dental abutment screws Metals and Materials International 2005; 11, 6,449-456.

-Gould, T.R.; Westbury, L.; Brunette, D.M. Ultrastructural study of the attachment of human gingiva to titanium in vivo. J. Prosthet. Dent. 1984, 52, 418–420.

-Canullo, L.; Bignozzi, I.; Cocchetto, R.; Cristalli, M.P.; Iannello, G. Immediate positioning of a definitive abutment versus repeated abutment replacements in post-extractive implants: 3-year follow-up of a randomised multicentre clinical trial. Eur. J. Oral Implantol. 2010, 3, 285–296.

D

-De Bruyn, H.; Christiaens, V.; Doornewaard, R.; Jacobsson, M.; Cosyn, J.; Jacquet, W.; Vervaeke, S. Implant surface roughness and patient factors on long-term peri-implant bone loss. Periodontology 2000 2017, 73, 218–227.

-De Kok, I.J.; Duqum, I.S.; Katz, L.H.; Cooper, L.F. Management of Implant/Prosthodontic Complications. Dent. Clin. North Am. 2019, 63, 217–231.

deMedeiros,R.A.;Pellizzer,E.P.;VechiatoFilho,A.J.;DosSantos,D.M.;daSilva,E.V.;Goiato,M.C.Evaluation of marginal bone loss of dental implants with internal or external connections and its association with other variables: A systematic review. J. Prosthet. Dent. 2016, 116, 501–506.

-Donley, T.G.; Gillette, W.B. Titanium endosseous implant-soft tissue interface: A literature review. J. Periodontol. 1991, 62, 153–160.

-Degidi, M.; Nardi, D.; Piattelli, A. One abutment at one time: Non-removal of an immediate abutment and its effect on bone healing around subcrestal tapered implants. Clin. Oral Implant. Res. 2011, 22, 1303–1307.

E

-E. A. McGlumphy, D. A. Mendel, and J. A. Holloway, Dent. Clin. North. Am. 1998;42,71.

F

-Finger IM, Castellon P, Block M, Elian N;The evoluction of external and internal implant abutment connections Pract Proced Aesthet Dent; 2003;15;8;625-632.

G

-Glossary of Prosthodontic Terms-8.

-Gould, T.R.; Westbury, L.; Brunette, D.M. Ultrastructural study of the attachment of human gingiva to titanium in vivo. J. Prosthet. Dent. 1984, 52, 418–420.

-Guida, L.; Oliva, A.; Basile, M.A.; Giordano, M.; Nastri, L.; Annunziata, M. Human gingival fibroblast functionsarestimulatedbyoxidizednano-structuredtitaniumsurfaces. J.Dent. 2013,41,900–907.

H

-Hermann F, Lerner H, Palti A. Factors influencing the preservation of the periimplant marginal bone. Implant Dent. 2007;16(2):165-75.

-Hermann JS, Schoolfield JD, Nummikoski PV, Buser D, Schenk RK, Cochran DL. Crestal bone changes around titanium implants: A methodologic study comparing linear radiographic with histometric measurements. Int J Oral Maxollofac Impl 2001;16(4):475-485.

-Hsu, Y.T.; Mason, S.A.; Wang, H.L. Biological implant complications and their management. J. Int. Acad. Periodontol. 2014, 16, 9–18.

-histometric evaluation of unloaded non-submerged and submerged implants in the canine mandible. J. Periodontol. 2000, 71, 1412–1424. -Hermann, J.S.; Schoolfield, J.D.; Schenk, R.K.; Buser, D.; Cochran, D.L. Influence of the size of the microgap on crestal bone changes around titanium implants. A histometric evaluation of unloaded non-submerged implants in the canine mandible. J. Periodontol. 2001, 72, 1372–1383.

Hansson,S.Aconicalimplantabutmentinterfaceatthelevelofthemarginalboneimprovesthedistribution of stresses in the supporting bone. An axisymmetric finite element analysis. Clin. OralImplant. Res. 2003, 14, 286–293.

I

-Israel M. Finger; The evolution of external and. internal implant/abutment connections; Pract Proced Aesthet Dent 2003;15;8:625-632.

Ikeda,H.;Yamaza,T.;Yoshinari,M.;Ohsaki,Y.;Ayukawa,Y.;Kido,M.A.;Inoue,T.;Shimono,M.;Koyano,K.; Tanaka, T. Ultrastructural and immunoelectron microscopic studies of the peri-implant epithelium-implant (Ti-6Al-4V) interface of rat maxilla. J. Periodontol. 2000, 71, 961–973.

J

-Jeong, C.G.; Kim, S.K.; Lee, J.H.; Kim, J.W.; Yeo, I.S.L. Clinically available preload prediction based on a mechanical analysis. Arch. Appl. Mech. 2017, 87, 2003–2009.

K

-Koutouzis, T.; Mesia, R.; Calderon, N.; Wong, F.; Wallet, S. The effect of dynamic loading on bacterial colonization of the dental implant fixture-abutment interface: An in vitro study. J.OralImplantol. 2014, 40, 432–437.

L

-Lyndon F. Cooper, Ingeborg J. De Kok, Ms Lee Culp;Dental Implant Abutments: Key to Improved Dental Implant Success Functional Esthetic & Restorative Dentistry Series 1, Issue 2; 2008- Dental Implants.

-Lee, J.H.; Kim, S.H.; Han, J.S.; Yeo, I.S.L.; Yoon, H.I.; Lee, J. Effects of ultrasonic scaling on the optical properties and surface characteristics of highly translucent CAD/CAM ceramic restorative materials: An in vitro study. Ceram. Int. 2019, 45, 14594–14601.

-Liu, Y.; Wang, J. Influences of microgap and micromotion of implant-abutment interface on marginal bone loss around implant neck. Arch. Oral Biol. 2017, 83, 153–160.

-Lee, J.H.; Huh, Y.H.; Park, C.J.; Cho, L.R. Effect of the Coronal Wall Thickness of Dental Implants on the Screw Joint Stability in the Internal Implant-Abutment Connection. Int. J.OralMaxillofac. Implant. 2016, 31, 1058–1065.

-Lang, N.P.; Wilson, T.G.; Corbet, E.F. Biological complications with dental implants: Their prevention, diagnosis and treatment. Clin. Oral Implant. Res. 2000, 11, 146–155.

M

-Mollersten L, Lockowandt P, Linden L-A. Comparison of strength and failure mode of seven implant systems: An in vitro test. J Prosthet Dent 1998;78:582-591.

-Morris HF, Ochi S. The influence of implant design, application, and site on clinical performance and crestal bone: A multicenter, multidisciplinary clinical study. Dental Implant Clinical Research Group (Planning Committee). Implant Dent 1992;1;1: 49-55.

Michalakis,K.X.;Calvani,P.L.;Muftu,S.;Pissiotis,A.;Hirayama,H.Theeffec tofdifferentimplant-abutment connections on screw joint stability. J. Oral Implantol. 2014, 40, 146–152.

-Mishra, S.K.; Chowdhary, R.; Kumari, S. Microleakage at the Different Implant Abutment Interface: A Systematic Review. J. Clin. Diagn. Res. 2017, 11, ZE10–ZE15.

Moon,I.S.;Berglundh,T.;Abrahamsson,I.;Linder,E.;Lindhe,J.Thebarrierbetweenthekeratinizedmucosa and the dental implant. An experimental study in the dog. J.Clin. Periodontol. 1999, 26, 658–663.

-Monje, A.; Insua, A.; Wang, H.L. Understanding Peri-Implantitis as a Plaque-Associated and Site-Specific Entity: On the Local Predisposing Factors. J. Clin. Med. 2019, 8, 279.

N

-Niznick GA. The Core-Vent™ implant system. The evolution of the osseointegration implant. Oral Health 1983;73;11:13-17.

-Niznick GA. The implant abutment connection: The key to pros- thetic success. Compend Cont Educ Dent 1991;12:932-937.

-Norton M;In-vitro evaluation of the strength of the conical implant- to-abutment joint in two commercially available implant systems. J Prosthet Dent 2000;83:567-571.

-NORTON, M. R. Assessment of cold welding properties of the internal conical interface of two commercially available implant systems. J Prosthet Dent, v.81, n.2, p.159-66, 1999.

-N. Broggini L.M. McManus J.S. Hermann R.U. Medina Persistent Acute Inflammation at the Implant-Abutment Interface ;J Dent Res;2003; 82;3; 232-237.

O

-Ongun, S.; Kurtulmus-Yilmaz, S.; Meric, G.; Ulusoy, M. A Comparative Study on the Mechanical Properties of a Polymer-Infiltrated Ceramic-Network Material Used for the Fabrication of Hybrid Abutment. Materials 2018, 11, 1681.

P

-Perriard J, Wisckott WA, Mellal A, Scherrer SS, Botsis J, Besler UC.

Fatigue resistance of ITI implant-abutment connectors - A comparison of the standard cone with a novel internally keyed design. Clin Oral Impl Res;2002;13(5):542-549.

-Pjetursson, B.E.; Heimisdottir, K. Dental implants—Are they better than natural teeth? Eur. J. Oral Sci. 2018, 126, 81–87.

-Piattelli, A.; Vrespa, G.; Petrone, G.; Iezzi, G.; Annibali, S.; Scarano, A. Role of the microgap between implant andabutment: Aretrospectivehistologicevaluationinmonkeys. J.Periodontol. 2003,74,346–352.

Q

-Quirynen M, van Steenberghe D Bacterial colonization of the internal part of two-stage implants. An in vivo study. Clin Oral Implants Res(1993). 4:158–161.

-Quirynen M, Bollen CM, Eyssen H, van Steenberghe D Microbial penetration along the implant components of the Brånemark system. An in vitro study. Clin Oral Implants Res;1994. 5:239–244.

R

-Rodriguez, X.; Vela, X.; Mendez, V.; Segala, M.; Calvo-Guirado, J.L.; Tarnow, D.P. The effect of abutment dis/reconnections on peri-implant bone resorption: A radiologic study of platform-switched and non-platform-switched implants placed in animals. Clin. OralImplant. Res. 2013, 24, 305–311.

S

-Sutter F, Weber HP, Sorenson J, Belser U. The new restorative concept of the ITI dental implant system: Design and engineer- ing. Int J Periodont Rest Dent 1993;13:409-431.

-Srinivasan, M.; Meyer, S.; Mombelli, A.; Muller, F. Dental implants in the elderly population: A systematic review and meta-analysis. Clin. Oral Implant. Res. 2017, 28, 920–930.

Starch_Jensen,T.;Aludden,H.;Hallman,M.;Dahlin,C.;Christensen,A.E.;Mordenfeld,A.Asystematicreview and meta-analysis of long-term studies (five or more years) assessing maxillary sinus floor augmentation. Int. J. Oral Maxillofac. Surg. 2018, 47, 103–116.

-Sadid-Zadeh, R.; Kutkut, A.; Kim, H. Prosthetic failure in implant dentistry. Dent. Clin. North Am. 2015, 59, 195–214.

-Saleh Saber, F.; Abolfazli, N.; Jannatii Ataei, S.; Taghizade Motlagh, M.; Gharekhani, V. The effect of repeated torque tightening on total lengths of implant abutments in differentinte rnalimplant abutment connections. J. Dent. Res. Dent. Clin. Dent. Prospect. 2017, 11, 110–116.

T

-Takuma Tsugei And Yoshiyuki Hagiwara ;Influence of lateral-oblique cyclic loading on abutment screw loosening of internal and external hexagon implants Dental Materials Journal 2009; 28;4: 373–381.

V

-Vetromilla, B.M.; Brondani, L.P.; Pereira-Cenci, T.; Bergoli, C.D. Influence of different implant-abutment connection designs on the mechanical and biological behavior of single-tooth implants in the maxillary esthetic zone: A systematic review. J. Prosthet. Dent. 2019, 121, 398–403.e3.

W

-Wang, Q.Q.; Dai, R.; Cao, C.Y.; Fang, H.; Han, M.; Li, Q.L. One-time versus repeated abutment connection for platform-switched implant: A systematic review and meta-analysis. PLoS ONE 2017, 12, e0186385.

Y

-Yang,Y.;Zhou,J.;Liu,X.;Zheng,M.;Yang,J.;Tan,J.Ultravioletlight-treatedzirconiawithdifferentroughness affects function of human gingival fibroblasts in vitro: The potential surface modification developed from implant to abutment. J. Biomed. Mater. Res. B Appl. Biomater. 2015, 103, 116–124.

-Yeo, I.S.; Kim, H.Y.; Lim, K.S.; Han, J.S. Implant surface factors and bacterial adhesion: A review of the literature. Int. J. Artif. Organs 2012, 35, 762–772.