Prosthetic Screw: Design & Behaviour

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Abstract :

Dental implant which is being widely used to restore edentulous space has great mechanics involved for long term success. Apart from good osseointegration, implant functioning also depends on the design and behaviour of abutment screw which holds the abutment to the implant body. Screw loosening is the second most common cause of implant abutment failure after poor osseointegration which if properly understood can add to a successful functioning implant. So, this article highlights the implant abutment screw geometry, the material used for its fabrication and the mechanics involved in the functioning of abutment screw implant interface and the factors which affect abutment screw loosening.

Keywords: Abutment screw, Implant abutment screw, Dental implant abutment srcew.

Introduction

Restoring an edentulous space has undergone great revolution since 1980's after the introduction of concept of osseointegration by Branemark.[1] When the abutment teeth are sound and healthy, placement of single implant to restore missing tooth is both functional and esthetic.[2]After the dental implant osseointegrates in jaw bone, it is restored with an abutment and prosthetic crown. The abutment is connected to the implant body with the help of screw known as Abutment Screw. It is a critical component for the success of implant prosthesis and is available in different shapes, sizes and materials depending on the manufacturer and requires great understanding for ultimate implant success.

A pubmed search was conducted using keywords abutment screw, implant abutment screw, dental implant abutment srcew from 1980 till 2017 and relevant articles were selected for review. Screw loosening and fracture has been reported to be one of the most serious and common cause of implant failure. Inadequate biochemical design and occlusal overloading have been stated as the reason behind this.

Screw Tightening Mechanism

A screw is tightened by applying an external torque which develops a tensile force within the screw called Preload (produced due to elongation of screw under influence of external force).[2,3] Elastic recovery of screw pulls the two parts together creating a clamping force which is equal in magnitude to the preload. The goal of preload is to place the abutment/implant assembly in compression, which will result in friction between the screw and internal threads, the head of screw and the abutment, and the top of the implant and inferior surface of the abutment. If the joint separating force (force which opposes the clamping force)exceeds the clamping force, screw loosening occurs leading to abutment failure.[3]

The golden rule to prevent screw loosening is to minimize joint separating forces and maximize clamping forces. Clinician must recognize the possible joint separating forces such as off-axis loading, protrusive and lateral contacts, interproximal contacts, parafunctional forces, non passive frameworks, etc., so as to minimize them.The preload is determined by various parameters which in turn determine the implant success viz; Torque magnitude which is the amount of force applied to tighten a screw joint which in turn determines the clamping force and has a direct relation to preload.Too little torque may allow joint separation and too large a torque may strip the screw threads.[4];Screw head design which is normally wider than the outer screw thread diameter and should be flat in shape to maximize preload ;Thread design should be V shaped at 30 degree angle and the thread number should not exceed twice the width of screw diameter; Metal composition influences the amount of strain in the screw and directly affects the amount of preload ;Surface condition enhances friction in screw and minimizes risk of loosening; *Screw* diameter also has direct relation to the preload. The greater the diameter, the higher the preload that may be applied and greater the clamping force on the screw.[5]Surface treatment/ lubricants like pure gold coating, diamond like carbon (DLC), nitride coating are used to reduce friction during tightening.

Abutment screw has three basic components as shown in Fig 1.

Figure 1: Parts of abutment screw

Screw head is the upper end of screw which contains the driver fitting site, which is used to rotate the screw into position. The various driver site types available are slot (flat-head), Phillips (plus shaped), Robertson (square), hex and star out of which hex type is the most commonly used. There can be variations in screw head designs. The head of the screw is wider than the outer thread diameter and its shape can be tapered or flat.The tapered head (usually 30 to 45 degrees taper) acts as an inclined plane to align the misfit pieces as the screw is tightened into position.This design is less popular in dental implants as tapered head design reduces the preload and thus reduces the clamping effect as most of the torquing force is distributed to the screw head rather than the screw threads (eg.out of 20N cm torque force applied only 5Ncm is perceived by the screw threads and rest by the tapered head inclines).

Another screw head design which is preferred over tapered design is Flat head screw which distributes forces more evenly within the threads and the screw head and is likely to distort on non passive casting(eg.applying 20 Ncm torque distributes 10Ncmtorque to the screw head and 10 Ncm to the screw threads thereby increasing the strain in the components and decreases the risk of loosening).[6,7]Shank is the unthreaded portion of the screw below the head.It is variable in length depending on the geometry of the components that are being held together.Threadis the portion of the screw which engages the internal threads of the implant and provides the surfaces onto which force is transmitted and converted to preload.The most common thread design used by many implant manufacturers is a V shaped 30 degree angle threads .This 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 design places all strain in the first few threads.

Thread number should not be more than two times the diameter of the screw. [8] Common screw design generally has a flat head seat (for less frictional resistance and higher preload), long stem length (to achieve optimal elongation and preload) and six thread to decrease friction because first three threads carry most of the load.[9]A prosthetic screw should have four threads as it has less diameter. However additional threads increase resistance to screw loosening, Spiralock® thread shape patented by Biohorizon® implants is manufactured exclusively on this concept with 8 threads for abutment screw and 10 threads for prosthetic screw and no screw loosening was reported in 5 year prospective study by Kline et al in 2002.[10]Spiralock® thread design has self locking threads which gives a locking feature to tapped holes that prevents vibration loosening while still allowing standard external threaded parts to spin freely during assembly. It provides a wedge ramp at the root of the internal thread that only engages when the joint starts to build clamp load during tightening. At that point, the crest of the standard external threads draws tightly against the wedge ramp, eliminating all radial clearance and creating a continuous spiral line of contact between the internal and external threads as shown in Fig 2.

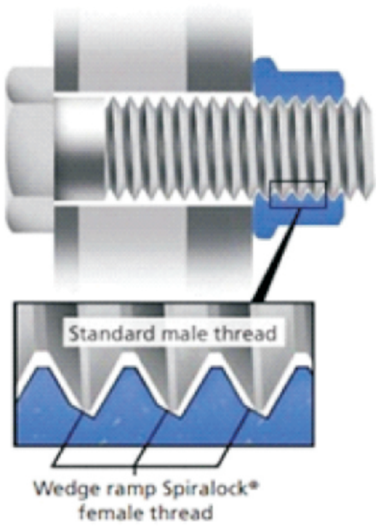

Figure 2: Spiralock® thread design.

Abutment screw materials: Motosch (1976) studied the basic screw mechanics and found that out of the total initial rotational torque only 10 % is transferred as preload, the rest is used to overcome the friction of threads sliding past one another. So research is focused on decreasing the amount of friction to allow greater preload values for the amount of torque applied. The coefficient of friction (COF) is the ratio of the frictional force to the force acting perpendicular to the two surfaces in contact. It is a major factor in influencing the preload achieved at a given torque force.[11]It depends on screw material in terms of yield strength and elastic modulus, screw screw design, surface treatments and machining tolerance. Guda et al established a lower limit on COF to achieve optimum preload and Lang et al advocated a COF of about 0.12 to prevent screw loosening.[12]

Gold and titanium are two most common screw materials. Gold act as a dry lubricant (due to low yield strength) and has a smaller COF that allows increased rotation and elongation of screw. Gold screws can achieve a preload almost twice that of Ti alloy screws (because of decreased COF) but are weaker and will fracture sooner than Ti. Gold screws are subject to irreversible plastic deformation and are thus indicated for single use only.

Cp Ti, screw after tightening, undergoes reversible elastic deformation and thus can be used many times. Ti screw though stronger has larger frictional resistance between mating surfaces with a tendency to cause galling of implant internal threads. Galling is localized welding and roughening of mating surfaces due to excessive friction. Also due to large frictional resistance, it generates least amount of preload force for a given torque when compared with other materials.

Various alloys used for screwcan be Titanium alloy (90% Ti, 6% Al, 4% Vn), Gold-Tite (80% Pd, 10% Ga, 10% Cu, Au, and Zn with a 0.76 µm pure gold coating), TorqTite(a Ti alloy with a surface treatmentthat is proprietary information). [13]Titanium alloy has four times the bending fracture resistance of grade 1 titanium and is 2.4 times stronger than grade 4 titanium. As such a higher torque magnitude can be used on the titanium alloy abutment screw and female component, less on grade 4 and least on grade1 Titanium and on gold screws.

Will et al (2001) found that Torque Tite abutment screw has the greatest average rotational angle at 20 and 32 Ncm which could be attributed to reduced coefficient of friction and the decrease in surface area contact between the mating threads. The gold tite abutment screw had significantly greater preload values at 20 and 32 Ncm torque than the other screws tested.[13]

Surface coatings/ dry lubricantsare used in an attempt to decrease the friction and increase the preload. Pure Gold, carbon carbide (DLC-Diamond like carbon) and aluminium titanium nitride are the coatings most commonly used.

Another variable is mechanism of torque application by the clinician via hand screw drivers, torque wrenches and electronic drivers, the latter being most consistent when regularly caliberated.[14]Dellinges and Tebrock found average torque applied with a screwdriver to be 10 Ncm.[15] Clinician should use mechanical torque application instrument to ensure consistent tightening of abutment screws to manufacturer specified torque values. Lang et al reported thattorque beyond the manufacturers' recommendations resulted in a more stable implant complex. [16]

Settling effect (embedment relaxation)is another factor resulting in screw loosening. Due to certain surface roughness at microscopic level, no two surfaces in screw interface can be in total intimate contact with each other. As the rough areas flatten under load, settling occurs, reportedly leading to 2- 10 % loss of preload. Screw loosening occurs when settling effect exceeds elastic elongation of screw. Screw thread friction reportedly decreases with repeated screw tightening and loosening.[17] Many authors advocate periodic screw retightening after initial screw insertion.[4] Implant screw should be retightened 10 minutes after initial torque application to counteract settling effect.Jabbari (2008) observed screw thread deterioration after 4-10 years and recommended that retaining screws be replaced every 10 years.

Apart from inherent screw factors Implant connection and restoration design also influences screw loosening. Connection geometry influences the stress distribution, micromotion and microgap at IAJ and thus effect screw loosening.

External hexagon connection produces highest magnitude of micromotion and require least detorque values as compared to internal octagonal and hexagonal connection. Morse taper connection produces minimal screw loosening due to cold welding between implant and abutment.

Narrowing of occlusal table or flattening of cuspal inclines reduces the loading forces to implant support ratio and result in less stress to the abutment screw. Load distribution over a wider area (wider or more number of implants) reduces plastic deformation at the interface of the implant and the abutment.

Discussion

Like any other joint system implant and abutment are clamped together by tightening a screw. The screw stretches and a tension called Preload is generated which determines the amount of clamping force. Screw behaves like a spring, which is stretched by the preload and this stretch is maintained by the friction forces in the thread. According to Gudda and Patterson, preload should be 60-75% of yield strength of screw material so as to prevent screw loosening. Manufacturers constantly strive to achieve optimum preload by either increasing the tightening torque or reducing the coefficient of friction, both of which are determined by screw material, design and surface coating. The recommended torque values are based on design features and metal composition of implants and screws unique to each system.[17] Screw head slotted, square, star or hexagonal driver engagement provides a guiding effect while tightening resulting in more effective force transfer and greater stability. Metallurgical properties of titanium screws allow for generation of a more consistent, albeit lower preload than with gold retaining screws. Manufacturers determine torque value according to elastic limit of the screw and biomechanics of bone implant interface. Tan B et.alrecommended torque values of below 57.5% of yield strength for gold alloy screws and 56% for titanium screws.[18] Torque exceeding the yield strength can lead to loss of integration at bone implant interface and stripping of threads[3] (McGlumphy).

Settling effect i.e. decrease in metal contacting surfaces due to their flattening after screw tightening can lead to a preload loss of upto 10% and requires retightening of screw after 10 minutes to compensate for this loss.Additional preload reduction may occur due to plastic deformation and creep of metal contacting surfaces. Increasing occlusal load to implant support ration and connection geometry may also influence screw loosening depending on amount of load concentration on screw and implant.

Conclusion

Abutment screw is the easiest, safest and most efficient method to fixate prosthetic components to an implant body but the main drawback with use of screw retained prosthesis is screw loosening. It can be prevented with proper understanding of screw design and mechanics, and adhering to manufactures recommended tightening torque values. Adequate tightening torque, reducing coefficient of friction between implant internal surface and screw internal hex morse taper connection, adequate number and width of implant with decreased cantilever and axial loading are the measures recommended in literature to reduce the incidence of screw loosening

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