IMPLANT SCREW MECHANICS AND THE SETTLING EFFECT: AN OVERVIEW

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One of the most serious and prevalent problems associated with the restorative aspect of dental implants is loosening and fracturing of screws. Implant screws should be retightened 10 minutes after the initial torque application as a routine clinical procedure to help compensate for the settling effect. Mechanical torque gauges should be used instead of hand drivers to ensure consistent tightening of implant components to torque values recommended by implant manufacturers.

KEY WORDS

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INTRODUCTION

One of the most dramatic services the dental profession has to offer is the replacement of missing teeth with implants. Implants are not new to dentistry. Seashell fragments were used to replace 3 missing mandibular incisors as early as 600 AD, and human transplants were used in many diverse early cultures. In recent years, oral implantology has undergone a well-deserved rebirth or rediscovery, and implants are now considered the treatment of choice in an increasing number of carefully selected cases. Today, implant prosthodontics has reached the point at which it can be successfully performed by both general dentists and specialists.

One of the most serious and prevalent problems associated with the restorative aspect of dental implants is loosening and fracturing of the screws that attach the prosthesis to the implant. Screw loosening may be an early warning of inadequate biomechanical design and/or occlusal overloading. In order to attempt to solve the problem of loose screws, the clinician must first understand the mechanics involved with the screw joint.

SCREW MECHANICS

McGlumphy et al[1] defined the screw joint as 2 parts tightened together by a screw, such as an abutment and implant being held together by a screw. A screw is tightened by applying torque. The applied torque develops a force within the screw called the preload. As a screw is tightened, it elongates, producing tension. Elastic recovery of the screw pulls the 2 parts together, creating a clamping force.[2] The preload in the screw, from elongation and elastic recovery, is equal in magnitude to the clamping force.[1]

Opposing the clamping force is a joint-separating force, which attempts to separate the screw joint. Screw loosening occurs when the joint-separating forces acting on the screw joint are greater than the clamping forces holding the screw unit together.[1] Excessive forces cause slippage between threads of the screw and threads of the bore, resulting in a loss of preload.[3]

It is not necessary to eliminate separating forces, only to minimize them.[1] Minimizing separating forces and maximizing clamping forces will act to prevent screw loosening.

When the clinician applies a torque to a screw to tighten its components together, the tightening torque creates a preload in the screw. The preload is determined by the applied torque and other factors, such as the screw alloy, screw head design, and abutment surface. The established preload is proportional to the applied torque. The torque value can be controlled by the clinician and can be reproduced from implant prosthesis to implant prosthesis. Too little torque may allow separation of the joint and result in screw fatigue, loosening, and failure. Too large a torque may strip the screw threads.[1]

Increasing the torque will increase the preload. Increasing the preload maximizes the stability of the screw joint by increasing the clamping threshold that separating forces must overcome to cause screw loosening. The amount of torque than can be applied is limited by the ultimate strength of the screw. McGlumphy et al[1] have stated that the optimal torque value is 75% of the torque needed to cause screw failure.

Another variable in the amount of torque that can be applied is how the torque is produced by the clinician. Torque can be applied manually or with a mechanical device. Until the introduction of mechanical torquing devices to the profession, implant components were tightened manually. The novice or inexperienced clinician often undertightened the screws in an implant system. Dellinges and Tebrock[4] found that the average torque applied with a screwdriver is only 10 N-cm.

In a pilot study, Jaarda et al[5] found that test subjects with little implant experience were not generally able to provide the recommended torque to implant prosthesis–retaining slotted gold screws. The investigators also reported that experienced test subjects tended to generate more than the recommended torque, and none of the test subjects were able to generate consistent torque values (Figure 1).

FIGURE 1. Tohnichi torque gauge used for research in Jaarda et al,[5,7] Bakaeen et al,[9] Siamos et al,[10] and Winkler et al (unpublished data, 2003), (Tohnichi America Corporation, Northbrook, Ill).

JOINT-SEPARATING FORCES

Clinically, the screw unit within an implant prosthesis is constantly subject to external joint-separating forces. Such intraoral separating forces may include off-axis occlusal contacts, lateral excursive contacts, interproximal contacts between natural teeth and implant restorations, protrusive contacts, parafunctional forces, and nonpassive frameworks that attach to the implants. Once external forces exceed the screw joint preload, the joint becomes unstable. The external load rapidly erodes the preload, resulting in vibration and micromovement that lead to screw loosening. Once loosening occurs, the screw joint ceases to perform the function for which it was intended and can be considered as failed.[3]

The clinician must recognize the possible forces that will be acting on the screw joint, so that screw loosening and other possible complications can be minimized or avoided.

Clinicians are urged to use some type of mechanical torque-applying instrument to ensure consistent tightening of implant components to the specified torque values recommended by implant manufacturers.

SETTLING EFFECT

A significant mechanism that results in screw loosening of implant-supported restorations is the settling effect. The settling effect (embedment relaxation), which plays a critical role in screw stability, is the result of no surface being completely smooth. No matter how carefully machined an implant surface is, it is slightly rough when viewed microscopically. Because of this microroughness, no two surfaces are completely in contact with one another.

Settling occurs as the rough spots flatten under load, since they are the only contacting surfaces when the initial tightening torque is applied. When the screw interface is subjected to external loads, micromovement occurs between the surfaces. Wear of the contact areas brings the 2 surfaces closer together. It has been reported that 2% to 10% of the initial preload is lost as a result of settling.[6] As a result, the torque necessary to remove a screw is less than the torque initially used to place the screw.[7]

The extent of settling depends on the initial surface roughness, surface hardness, and magnitude of the loading forces. Rough surfaces and large external loads increase the settling. When the total settling effect is greater than the elastic elongation of the screw, the screw works loose because there are no longer any contact forces to hold it in place.[8]

Thread friction is higher for the first tightening and loosening of a screw, and then decreases after repeated tightening and loosening cycles.[8] A number of authors have suggested tightening of implant screw joints after the initial screw insertion and periodically thereafter.[2,9,10]

Bakaeen et al[9] have reported that when prosthetic gold screws were tightened to 10 N-cm according to the manufacturer's instructions, the untightening torque of the different groups tested was about 2 to 3 N less than the tightening torque. These observations correspond to the findings of Sakaguchi and Borgersen,[6] who reported a 2% to 10% reduction in preload within the first few seconds or minutes after tightening as a result of the settling effect.

Siamos et al,[10] as a result of an in vitro investigation, also suggested that retightening abutment screws 10 minutes after initial torque applications should be routinely performed. The investigators also reported that increasing the torque values for abutment screws above 30 N-cm can be beneficial for abutment-implant stability and to decrease screw loosening.

To reduce the settling effect, implant screws should be retightened 10 minutes after the initial torque application.[2,9,10] This technique should be used as a routine clinical procedure.

In vitro studies

In vitro studies examining the dynamics of screw loosening using servohydraulic testing machines have limitations due to the difficulty of reproducing the complex nature of the chewing cycle. Clinical variables, such as intermittent high impact loads, varying angles of load application, and varying positions of load application in relation to the implant axis, may have significant damaging effects on the implant-abutment interface leading to screw loosening and failure.[11(p68)]

Ideally, load application and duration applied during testing should simulate these normal functional parameters. Cyclic fatigue studies frequently report maximum load applications of 100 to 200 N, which are at the low range of reported data for maximum bite forces (200–3500 N).[11(p68)] It is assumed that an individual has 3 episodes of chewing per day, each 15 minutes in duration, at a chewing rate of 60 cycles per minute. This produces an equivalent of 2700 chewing cycles per day or 10^6 cycles per year.[12,13] Accurately simulating these normal functional parameters is both time consuming and technically challenging.

DISCUSSION

Generally, simple tightening or replacement of loose retaining or abutment screws is all that is necessary, which is an inconvenience for both the clinician and the patient. Often extensive repair is involved, especially if abutment screws cannot be retrieved. This may necessitate abandonment of the involved implant and/or require modification or remake of the affected prosthesis.

Bakaeen et al[9] found that screw loosening can be reduced by narrowing the occlusal table of molar single-tooth implants when using 1 implant for support.

Ongoing research at Temple University School of Dentistry (S. Winkler et al, unpublished data, 2003) suggests that the percentage of difference between the applied torque and the counter torque increases significantly at lower initial torque values. The research also indicates that high initial torque values recommended by some manufacturers for their implant screws are beyond the limitations of the screws provided and may result in stripping, breakage, and other problems.

CONCLUSIONS

To reduce the settling effect, implant screws should be retightened 10 minutes after the initial torque application as a routine clinical procedure. Mechanical torque instruments should be used instead of hand drivers to ensure consistent tightening of implant components to the specified torque values recommended by implant manufacturers.

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