Retightening of Internal Hexagonal and Conical Dental Abutment Connections: A FEA Analysis

S. SRIVASTAVA*, V. KUMAR, P. YADAV, B. SINGH, S. K. SINGH, S. K. SARANGI[1]

Mechanical Engineering Department , Rajkiya Engineering College Azamgarh, Uttar Pradesh , India
[1]Associate Professor, Mechanical Engineering Department National Institute of Technology, Patna, India, 800005

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ABSTRACT

Understanding the impact of tightening and re-tightening on the abutment screw loosening of a dental implant This study used finite element methods to determine how various materials and abutment connections react to the retightening effect of the abutment screw when saliva or blood enters the space between the abutment and the dental implant. Internal hex and conical connection preload values are found to increase while the fluid at the interface of the abutment and dental implant decreases. Retightening: compared to the tightening of the abutment screw, the conical abutment connection preload value decreases by 3%. The tightening and retightening processes proved to have depended on the type of implant-abutment connection. Removal torque for abutment screws is observed at 0.27, 0.28, 0.29, 0.30, 0.31, and 0.32, and it is found that decreasing the abutment screw pitch can also be an effective method to increase resistance to screw loosening. The internal hex is proven to be the best abutment design for increasing the preload value and is recommended for clinical applications.

INTRODUCTION

A dental implant repair is a popular option for replacing missing teeth and restoring masticatory function. This restorative method has become more popular: root-type endosseous implants. Innovative ideas and concepts have refined dental implant design. Long-term post-placement research shows loosening, bending, failure, and implant fracture. After loading dental implants with occlusal force, prosthetic components and implant fractures are seen (1–3). The most frequent type of screw loosening occurs in single implant-supported molars and is more frequent (4–7). Excessive occlusal pressures, inadequate preload, poor screw design, and variations in hex diameter and abutment equivalents can dislodge dental implants (8–10). It's a common problem with an implant-supported fixed prosthesis that requires periodic screw retightening (11). Over a period of 5 years, about 5% of the abutment screws on implant-supported fixed dental prostheses became loose (12). Abutment Micro-motion, stress distribution, and microbe implantation in micro-gaps are all affected by screw connections. Aside from screw loosening, dental implant instability and peri-implant bone resorption also occur (13–14). Various implant systems have different screw-loosening rates. Preload is necessary for maintaining abutment screw tightness. the contact force between the abutment and the implant (15–16). Geometry may affect screw loosening. Figure 1 shows three implant-abutment screw connections. Internal hex and octagonal dental implant abutments had similar mobility and stress

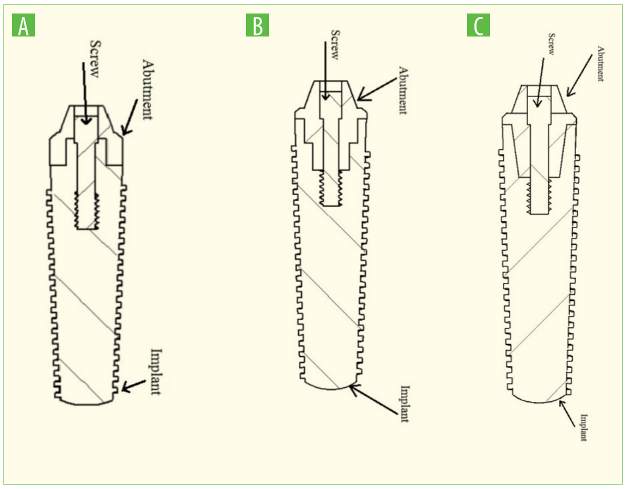

FIG. 1 A External Hex B Internal Hex
C Conical type of dental implant and abutment connection

distribution (17). Under finite element analysis's non-linear dynamic analysis, the external hex type of dental implants showed signs of rotation, but the internal taper type showed no signs of rotation (18–19). To unscrew the abutment Internal hex dental abutment de-torquing values are insignificant. Under cyclic loading, exterior connections needed retightening (20). Internal-hex implant design has less de-torque but higher microleakage, increasing screw loosening (21–22). Conical connections have less row removal torque than octagon connections (23). Comparing removal torque before and after cyclic loading for conical and internal hex connections To make a similar chewing load, fatigue loading is applied; conical abutment connections are more stable than other abutments (24).

Combining preload and the abutment connection helps reduce abutment screw loosening. Abutment screws should be stretched to their yield strength for optimum preload (15, 25). The implant screw should be torqued correctly for the best preload (19). Tightening and loosening abutment screws may impair osseointegration of dental implants, the designers' principal goal (27). Many designers use screws and other tools to keep the abutment screw in place. Silicone plugs are used as a way to stop the device from turning (28). mechanical proctor to measure how tight the target torque value needs to be (29). The use of a double screw when tightening the abutment with the fixture reduces the risk of the screw coming loose (30). A cemented abutment screw retains occlusal loads better than a screw connection after 12 months of testing (31). Single-implant procedures are more likely to fail than multi-implant treatments. The abutment screw, whether adhesive or cement, is not timed to coincide with the operation. During surgery, abutment screws are repeatedly closed and opened. Blood or saliva contaminate the implant's inner hole and abutment screw, smoothing the surface and reducing friction. Friction helps retain the screw after surgical implantation.

The friction coefficient is the ratio of frictional forces to normal forces. Frictional forces between the implant and abutment screw threads and the screw head and abutment conflict with insertion torque (33). At a given torque, the friction coefficient changes the preload (34). Guda et al. If the abutment screw backs off, preload is lost. Increasing preload minimizes loosening (33–34). Preloading the implant and abutment creates a secure connection against external loading. for screw torque calculations. Budynas and Nisbett (37) suggested different formulas, i.e., for applying torque at the wrench region (Twr) in Equation (1), torque in the conical region of the screw (Tcon) in Equation (2), and torque in the thread region of the screw (Tsc) in Equation (3). The required torque for abutment screw removal is Tre in Equation (4). From Equation 3, it is evident that thread region torque (Tsc) is the function of mean pitch diameter, pitch of thread, and thread angle. As a result, changes in these design parameters affect abutment screw loosening:

$$T_{wr} = T_{con} + T_{sc} \tag{1}$$

$$T_{con} = \frac{\mu}{3sin\beta} X \frac{D^3-d^3}{D^2-d^2} \mathrm{X\ P} \tag{2}$$

$$T_{sc} = \frac{d_m}{2} X \frac{p+(\mu\pi d_m sec\alpha)}{(\pi d_m)-(\mu p sec\alpha)} X\ P \tag{3}$$

$$T_{sc} = f(d_m, p, \alpha)$$

$$T_{re} = \frac{d_m}{2} X \frac{(\mu\pi d_m sec\alpha)-p}{(\pi d_m)-(\mu p sec\alpha)} X\ P \tag{4}$$

All the three regions and the parameters are shown in Figure 3.

Preload is inversely proportional to friction and is influenced by tightening torque and the thread characteristics of the abutment screw (38). Long-term implant-abutment fatigue loading affects the reverse torque value under centric lateral load, and high tightening torque is one explanation for torque loss after loading (39–40). Retightening is often ideal for stable connections (41). The screw's functioning mechanism must be understood to prevent loosening. So, friction, preload, and abutment connection design can converge to minimize screw loosening. The dental implant and abutment are clamped together, causing preload in the abutment screw, which elongates it and stores elastic energy equal to the clamping force. A dental occlusal load acts as a joint-separating force. The dental implant, abutment, and abutment screw assembly will release if the clamping force is less than the joint separating force. After tightening the abutment screw, the contacting metal becomes flat. This reduces contact distance and flattens the surface. This results in an approximate 10-per cent loss in pre-load value after tightening, which is called the "settling effect" or "embedded relaxation." (42-43). Now, because fluid has gotten into the space between the abutment, abutment screw, and dental implant after the surgery, the preload may go up or down (44–45). So, after a dental implant is put in a person's jaw with fluid in the connection, which may lower the coefficient of friction, its effect on preload and removal torque needs to be looked at.

In this study, preload and removal torque are required to be investigated for internal-hex and conical connection dental implant systems. Tightening the abutment screw gets relaxed after a certain period of time, so retightening could be an option for increasing the removal; this should be investigated. In

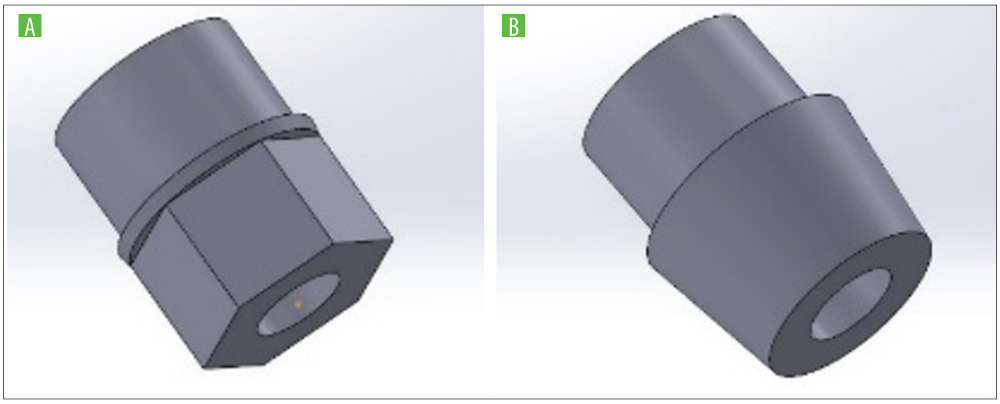

FIG. 2
A Internal hex abutment
B Conical or Morse taper abutment

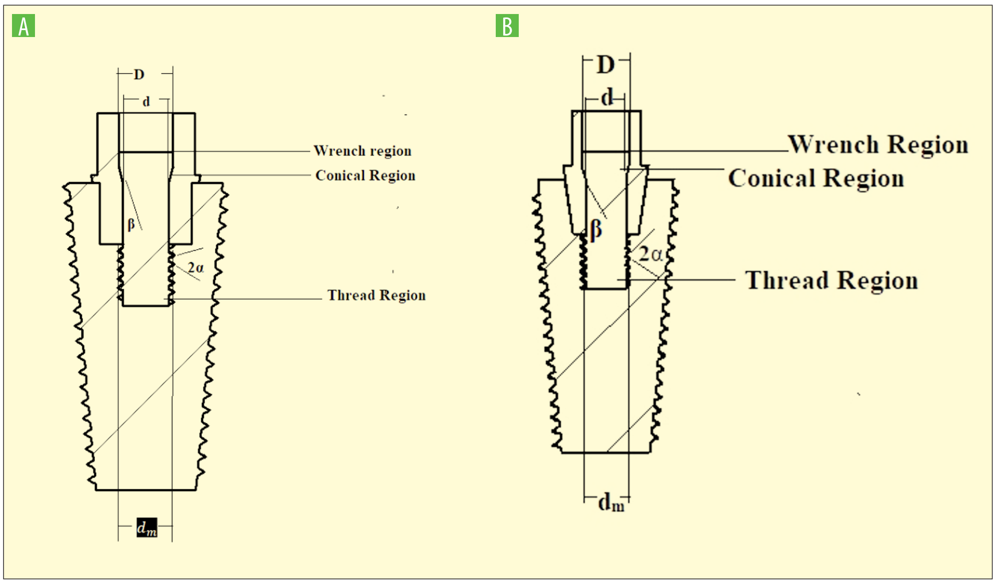

FIG. 3
A Internal Hex
B Conical assembly with screw parameter

this row, many times some blood or saliva also enters the interface of the dental implant and abutment connection, which can increase or decrease the removal torque or preload value. FEA is used to conduct the investigation, as manufacturing the dental implant and testing the removal torque are time-consuming and costly processes. For this article, the null hypothesis is that using any lubricant or contamination will increase the preload value of the abutment screw.

MATERIAL AND METHOD

Solid Works models the dental implant's internal hex and conical connections (Figure 2). Figure 3 shows an abutment screw, abutment, and dental implant. Figure 3 shows the characteristics of abutment screws, including pitch (p = 0.3 mm), thread angle (2 = 30 o), screw diameter (d = 1.5 mm), outer diameter (D = 1.75 mm), screw diameter (dm = 1.6 mm), and taper angle (= 140). All dental implant parts are made of titanium alloy (Ti-4Al-6V) and are isotropic and homogenous (Young modulus (E) = 1.1 x 1011 Pa, poisons ratio (R) = 0.3, and density (D) = 4.42 x 10-6 Kg/m3 (46–47).

The hex dominant method with element size 0.25 mm is used for meshing and a total of 35650 nodes and 18459 nodes are generated during the assembly of the conical abutment, abutment screw, and dental implant. Internal hex abutment screws and dental implant assembly generate a total of 32834 and 16821 nodes, respectively. The simulation is converging on a 0.25 mm mesh size.

The removal torque value (Tre) is calculated from Equation 4, and the observed removal torque (Tore) is obtained from the FEM analysis for all four stages. Using preload, coefficient of friction, removal torque, and pitch of the abutment screw, internal hex, and conical connections of dental implants are compared. For this, an internal hex and conical abutment are modeled in SolidWorks software (Figure 2), and a dental implant assembly for both abutments is done as shown in Figure 3.

Ansys software is used for finite element analysis, a boundary condition assuming complete osteointegration of a dental implant in the human bone, and five various friction coefficient values of 0.1, 0.12, 0.16, and 0.20 are used. The same coefficient of friction is used for the abutment and implant, the

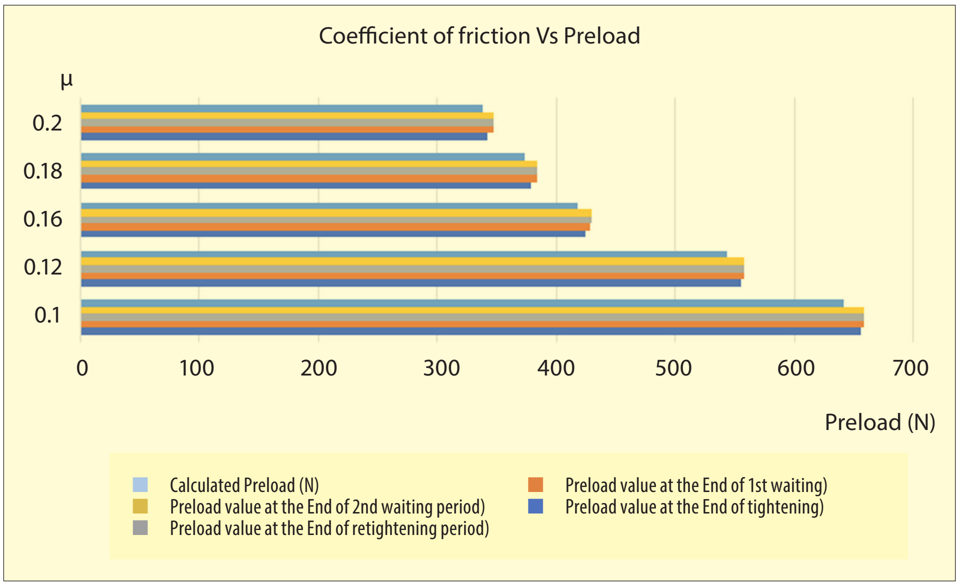

FIG. 4 Observed and Calculated Preload in abutment screw Vs different coefficient of friction for Internal hex dental implant.

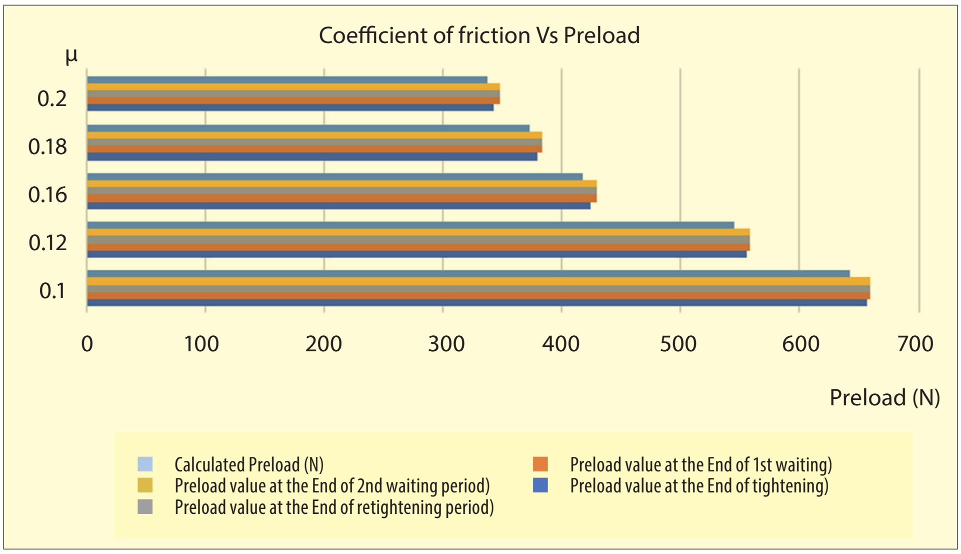

FIG. 5 Observed and Calculated Preload in abutment screw Vs different coefficient of friction for conical connection.

abutment screw and implant, and the dental implant and abutment screw. Using five friction coefficients, five models were generated in ANSYS software to analyze the effect of abutment screw tightening, relaxing, re-tightening, and again relaxing on abutment screw loosening.

The abutment screw is tightened to a torque value of 30 N-cm. Using Equation (1-3), the preload value is calculated (calculated preload) (48). In a 10-second reparative process with four stages, the 1st stage is abutment screw tightening (for 1 sec); the 2nd stage is relaxing (for 4 sec); the 3rd stage is abutment screw re-tightening (for 1 sec); and the 4th stage is again relaxing (for 4 sec).

RESULTS AND DISCUSSION

From Figure 4 and Figure 5, it is evident that as the coefficient of friction increases preload value of both the abutment screws decreases. The observed preload value is observed with higher value compared to the predicted value of preload (Equation 1) as shown in Figure 4 and Figure 5. This signifies that both the coefficient of friction is inversely proportional to the preload value as shown in Equations (1) to (3). If any fluid is in the interface of the abutment and dental implant, it should increase the preload. However, the value of the conical abutment connection while it is re-tightened after 4 seconds of relaxing period it loses the preload value.

This decrease in preload value from 680N to 660 N for 0.1 coefficient of friction, 580N to 560 N for 0.12 coefficient of friction, and almost 3% of decrease in preload value in 0.16,0.18 and 0.2 value of coefficient of friction. This signifies that interface of the dental implant-abutment connection is one of the parameters which affects the preload value of the abutment screw. This also signifies that re-tightening is not one of the effective methods for all dental implants.

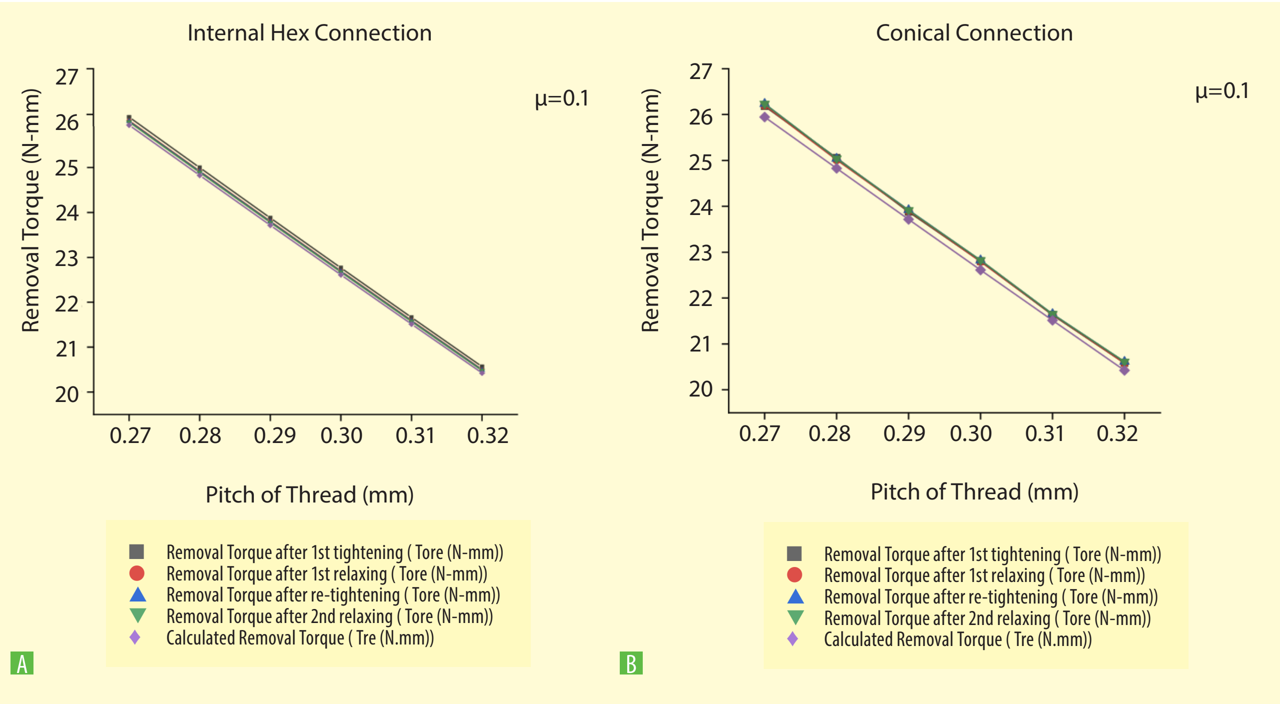

FIG. 6 Pitch of screw Vs Removal torque(N-mm) in A Internal Hex and B Conical Connection for coefficient of friction 0.1.

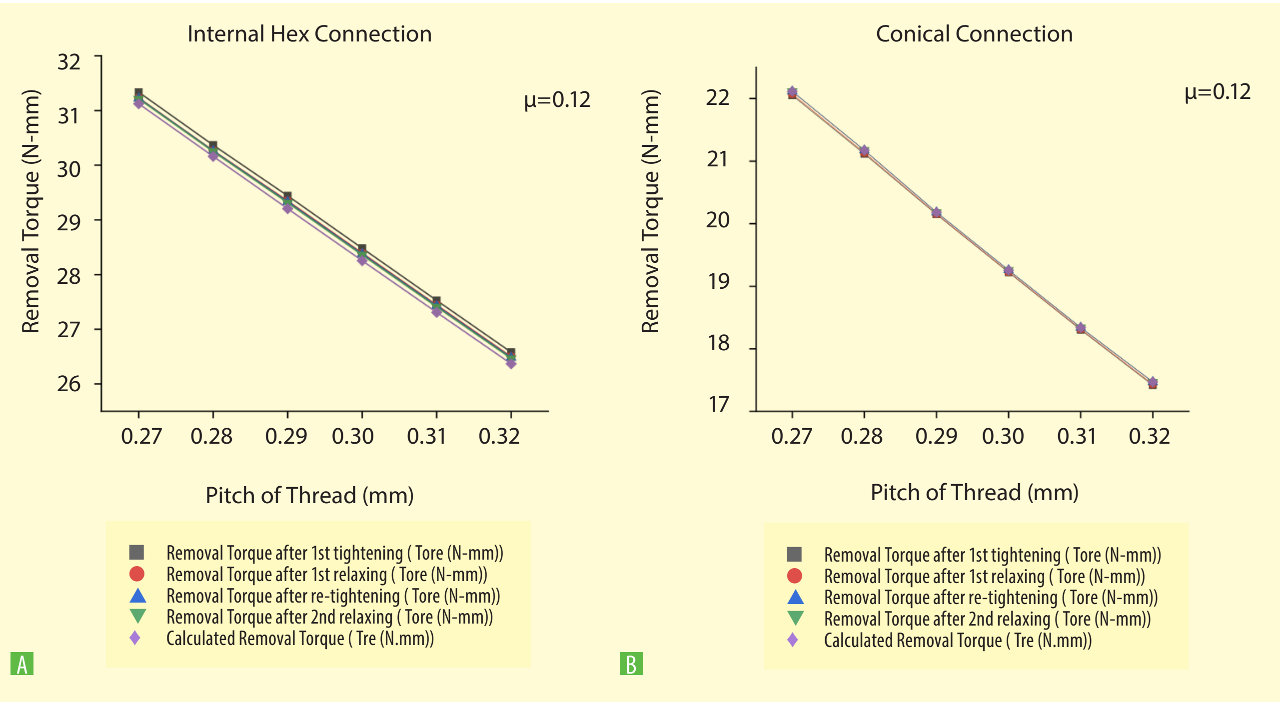

FIG. 7 Pitch of screw Vs Removal torque(N-mm) in A Internal Hex and B Conical Connection for coefficient of friction 0.12.

From Figure 6 to Figure 10, a consistent decrease of Removal torque is shown in all four stages and coefficient of friction.

This proves that the pitch of the abutment screw should be on higher side for increasing resisting the abutment screw from loosening. Thus, this research promotes the use of lubricant for increasing the resistance of abutment screws from loosening and supports the hypothesis.

CONCLUSION

This study compares the internal hex abutment connection and the conical abutment connection for screw loosening if any kind of fluid enters the assembly of a dental implant. Using the Ansys software simulation technique, it is determined that if blood or any other type of fluid enters the dental implant, in

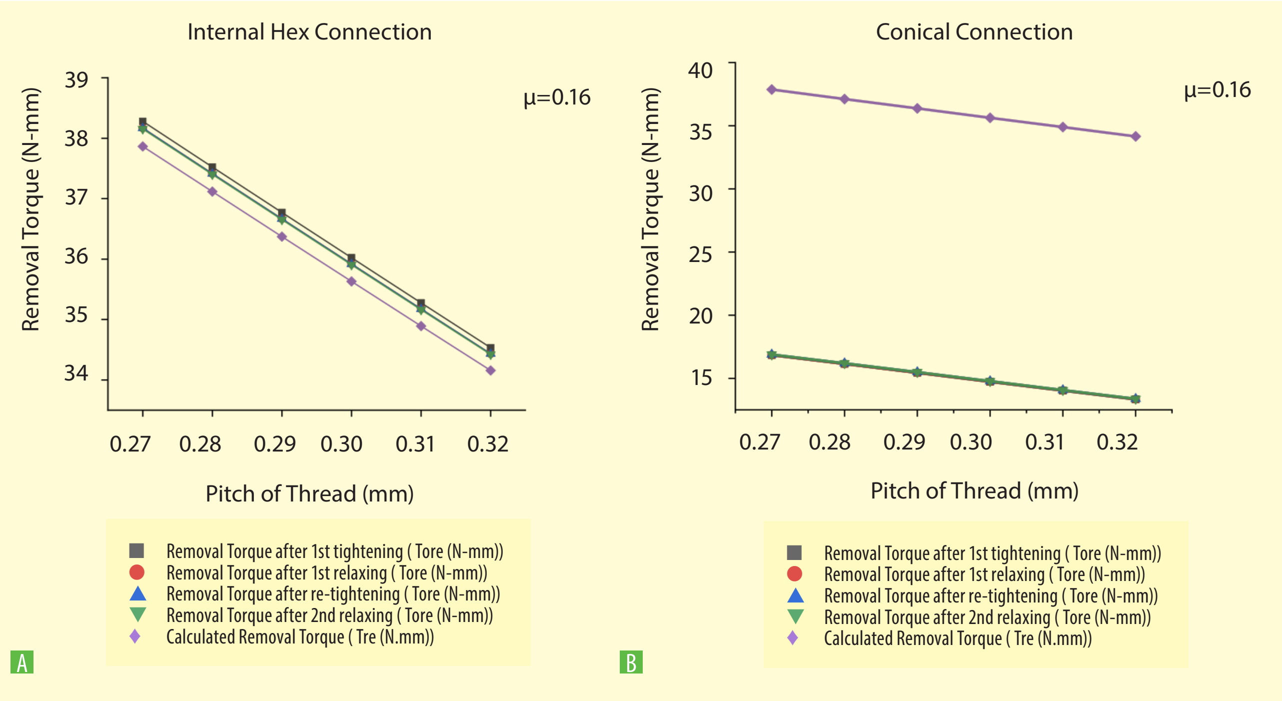

FIG. 8 Pitch of screw Vs Removal torque(N-mm) in A Internal Hex and B Conical Connection for coefficient of friction 0.16.

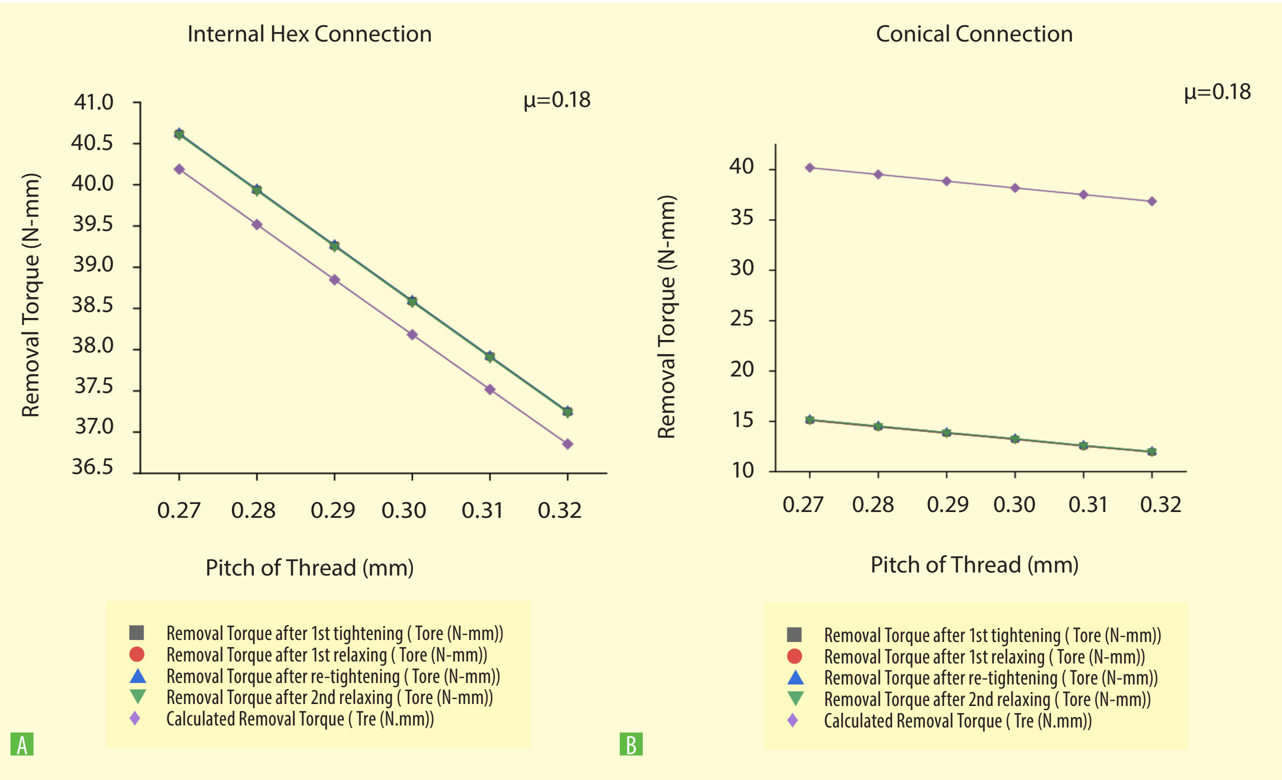

FIG. 9 Pitch of screw Vs Removal torque(N-mm) in A Internal Hex and B Conical Connection for coefficient of friction 0.18.

comparison to a conical connection, an internal hex abutment is more resistant to screw loosening. The conical connection after stage 2 (re-tightening) is evident with decreased removal torque of the dental implant when compared to stage 1 (tightening). Thus, the re-tightening effect depends on the type of dental implant connection. In the end, if the pitch of the dental implant abutment screw is increased, the removal torque is decreased, so a designer should use a low value of screw pitch to increase the resistance to abutment screw loosening. a future scope of physical checking of the removal torque of the abutment screw

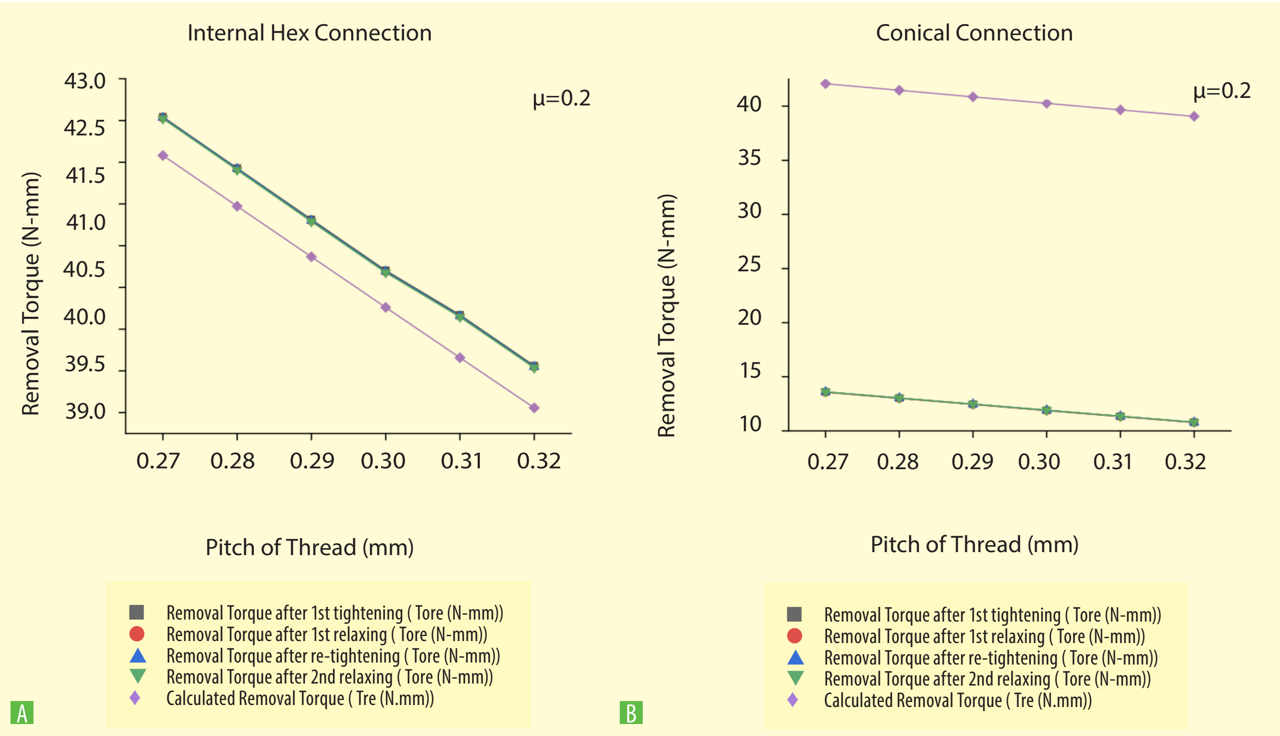

FIG. 10 Pitch of screw Vs Removal torque(N-mm) in A Internal Hex and B Conical Connection for the coefficient of friction 0.2.

by using some fluid and obtaining the minimum limit of pitch value of the abutment screw for obtaining the maximum removal torque.

Conflict of Interest

The authors declare that they have no conflict of interest to report regarding the present study

Data Availability Statement

Data analyzed in this study are obtained from simulation, which can be collected on demand from the corresponding author.

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