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EVALUATION OF SCREW LOOSENING OF PROSTHETIC ABUTMENTS IN IMPLANTS WITH INTERNAL HEXAGON AND MORSE TAPER CONNECTIONS AFTER FATIGUE TESTING

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ABSTRACT

Aim: To verify the counter-torque required for screw removal from prosthetic abutments on internal hexagon and Morse taper implants after mechanical cycling. Ten internal hexagon implants (IH- Titamax II plus" 3,75 x 13 mm - Neodent) and ten Morse taper implants (MT-Titamax Cone Morse" 3,75 x 13 mm- Neodent) were used, where the implants IH received the abutment of 4,5 x 6 x 1 mm and the MT implants received the solid abutment of 4,5 x 6 x 0,8 mm. The samples received a 20 Ncm torque, recommended by the manufacturer, with a digital torquemeter, and after a period of 10 minutes, all samples were torqued with 20 Ncm again. Groups were subjected to mechanical loading, with 100 Ncm load, 90° to the long axis, per 212,600 cycles at 25 Hz. Subsequently, removal torque was measured with the same digital torquemeter. After the mechanical cycling there was no difference on the removal torque measured on the internal hexagon and Morse taper abutment-implants (Mann-Whitney test *p=0,257*). The present study suggests that the Internal Hexagon and Morse taper connections presented similar removal torque values after mechanical cycling, and there was no superiority of a system in relation to the other.

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INTRODUCTION

Some of the indicators of clinical success of implant treatments are biological and mechanical stability and possibility of sanitation (Nentwig, 2004). The most common mechanical complications are loosening or fracture of the fixation screw, retention problems of the overdentures, fracture of the implants, metal structures, overlay materials and/or fracture of the antagonist prostheses (Adell *et al*., 1990; Goodacre *et al*., 1999; Schwarz, 2000; Arshad *et al*., 2017; Goodacre *et al*., 2018; Huang & Wang, 2019; Shinohara *et al*., 2019). Norton (1997) pointed out that the function of a prosthesis on implant is closely related to the transmission of load both at the implant-bone interface and between the components within the implant-pillar complex of the prosthesis. The design of the interface between the components of this complex can have a profound influence on the long-term function of the implant-supported prosthesis (Huang & Wang, 2019). Indeed, the screw, for example, plays an important role. Its loosening can result in the displacement of the prosthesis and cause the loss of prosthetic function (Jemt *et al*., 1991). Clinical studies have reported that between 6% and 31% of screws were loose at the first visit to the dentist after denture installation (Scheller *et al*., 1998; Priest, 1999; Schwartz-Arad *et al*., 1999; Goodacre *et al*., 2018). In this regard, the implant-abutment connection is known to influence the mechanical integrity of the implant-abutment complex and governs the strength of the fit and stability. Three are the basic implant-abutment connection models: the external connection, the internal connection, and the cone-Morse. The Morse taper was introduced with the claim that it would provide a self-locking interface with greater mechanical stability (Binon, 2000). There are numerous systems on the market, with internal connections that vary in both taper and overall design (Binon, 2000).

According to Okesson (2000), the masticatory efforts present in the oral cavity are significant, since in a 24-hour period the average mastication and swallowing is around 590 times. Thus, it is of utmost importance to simulate the masticatory stress in in vitro research, through fatigue tests, so that clinical situations can be mimicked in the laboratory, thus contributing to a better understanding of the dynamics of the oral cavity. Thus, it would be interesting to verify the effect of the type of implant-abutment connection (internal hexagon x Morse taper) on screw loosening when subjected to fatigue. The aim of this research was to verify the counter-torque required for screw removal from prosthetic abutments on internal hexagon and Morse taper implants after mechanical cycling.

METHODOLOGY

This study followed a totally randomized design, in a single-factor scheme, which compared abutments/implants with Morse cone and internal hexagon platforms (Titamax Cone Morse and Titamax II plus, both with 3.75 x 13 mm, Neodent - São Paulo - SP - Brazil). The response variable was countertorque, obtained by means of a digital torque meter, in N.cm. Ten implants divided into two groups were used in this study: HI GROUP (internal hexagon) with 6 implants and CM GROUP (cone Morse) with 4 implants. PVC tubes with 17 mm diameter X 23 mm height (Krona Tubos e Conexões/ Joinville - Santa Catarina - Brazil) were used. Self-curing acrylic resin (Jet - São Paulo - SP - Brazil) was poured into each tube, waiting for curing time. After this, a perforation was made in the center of each specimen with a trephine drill of 4 mm in diameter and 17 mm deep. Acrylic resin was placed inside each perforation. Then the implants were inserted into the cavities, leaving them 1 mm above the resin base, waiting for final setting. After embedding the specimens, the prosthetic abutments were installed, and the HI implants received the Universal II Plus 4.5 x 6 x 1 mm trunnion (Neodent). The CM implants received the 4.5 x 6 x 0.8 mm CM Universal Trunnion (Neodent) (Figure 1a). The abutments were tightened with a 1.17 mm digital wrench (Conexão Sistemas de Prótese - Arujá - SP - Brazil) coupled to a digital torque meter (LT Lutron TQ 8800, IMPAC - São Paulo - SP - Brazil), and the torque measurement unit used was N.cm. The torque applied to the screws was 20 N.cm as recommended by the manufacturer (Figures 1b, 1c and 1d). Ten minutes after the initial torque a retightening with the same torque was performed in order to minimize the effect of softening (sedimentation) suffered by the screw coils and to help maintain an optimal preload (protocol suggested by Dixon *et al*., 1995).

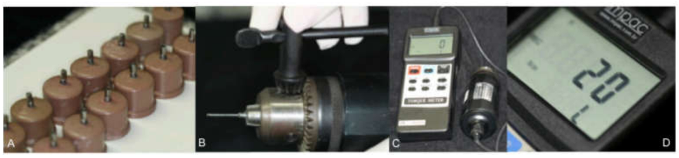

Figure 1. Embedded specimens with the trunnions in position (A); 1.17 key coupled to the digital torquemeter (B); digital torquemeter (C) and illustration of 20N.cm torque (D)

Then, a wax-up was performed on the abutments as a crown, in the form of a cylinder that tries to reproduce a premolar without cusps, following the methodology used by Binon (1996), and then cast in a cobalt-chromium alloy, which were finished and polished (Samuel Prosthesis Laboratory - Sorocaba - SP - Brazil). Cementation was performed with temporary cement (Hydro C / Dentsply - Petrópolis - RJ / Brazil), using digital pressure until complete setting of the material, for 1 minute, as indicated by the manufacturer. All excess cement around the crowns was removed with the aid of an explorer probe (Figures 2a and 2b). The groups were subjected to fatigue testing. To perform this test, the specimens were positioned and mounted in a specific device on the mechanical cycling machine (MTS Material Testing System, Minneapolis - Minessota, USA - model 810, TestStar II software) to enable the incidence of perpendicular force on the sample. The load ratio was 0.1, i.e., at the greatest distance from the tip of the machine to the body there was a pressure of 10 N and at the greatest effort the load was 100 N. Cyclic compression tests were performed on the abutment superstructure with a load perpendicular to 90° in relation to the long axis of insertion of the components to the implants, with a loading of 212,600 cycles, with a load of 100 N at a frequency of 25 Hz (Nery, 2006). According to Okesson (2000), this methodology simulates one year of component function, because in a 24-hour period the average chewing and swallowing is around 590 times (Figure 2c).

Figure 2. Temporary cement used (A); cemented crown (B) and illustration of mechanical cycling (C)

After mechanical cycling, the cemented prostheses were removed with the aid of curved Kelly forceps, performing bascule movements, so that the counter-torque of the screws could be measured.44e44r
The counter-torque on the abutments was measured with the same digital torque wrench used previously. The counter-torque values were subjected to descriptive analysis and the nonparametric Mann-Whitney test, since the data did not exhibit normal distribution and homogeneity of variance. The significance level adopted was 5% and statistical calculations were performed in SPSS 20 software (SPSS Inc., Chicago, IL, USA).

RESULTS

The mean values of the counter-torque, in N.cm, observed for the Morse taper and internal hexagon platform abutments/implants after fatigue testing are shown in Table 1. Standard deviations, median, minimum, and maximum values are also presented. The Mann-Whitney test showed that there was no difference in the counter-torque measured in the internal hexagon and morse taper platform abutments/implants ($p = 0.257$), as shown in Figure 3.

Table 1. Descriptive analysis of the counter torque values, in N, verified for the morse taper and internal hexagon platforms

DESCRIPTIVE ANALYSIS	PLATFORM	
	MORSE TAPER	INTERNAL HEXAGON
Sample Size (n)	4	6
Mean (standard deviation)	7 (5)	8 (2)
Median	5	8
Min/Max	3/14	6/10

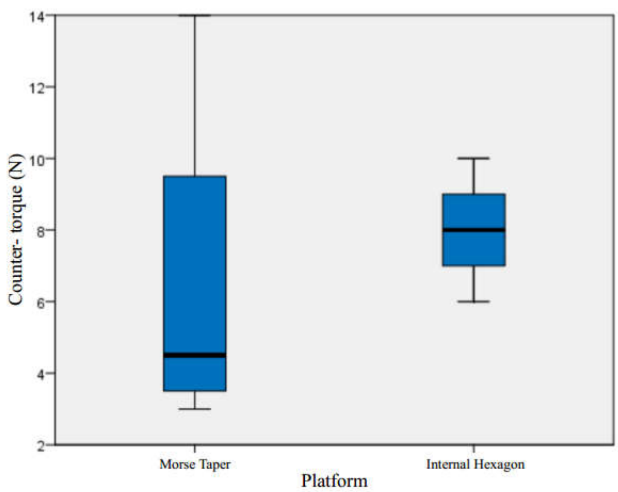

Figure 3. Box plot of the counter torque of morse taper and internal hexagon platform abutments/implants after fatigue testing

DISCUSSION

The most common complication reported in single crowns is loosening of the fixation screw (Goodacre *et al*., 2018). The present study showed that between the internal hexagon and Morse taper connections, there was no significant difference regarding the loss of torque of the abutment screws after mechanical cycling, and both connections suffered equivalent loosening. The mechanical cycling axis used in the study may have had an influence on this result. Furthermore, the results may have been influenced by the loss of part of the specimens during the experiment, which may have decreased the power of the sample to detect differences. However, in some studies that analyzed the mechanical behavior and torque loss of screws from internal hexagonal (HI) connection abutments, it was shown that the results found for the HI group were better or equal to those provided by the Morse taper. These findings may have occurred due to the inherent characteristics of the HI type of abutment/implant connection, which suggests greater protection of the abutment fixation screws. (Nakamura *et al*., 2006; Theoharidou *et al*., 2008; Santafé, 2010; Truninger *et al*., 2012; Seddigh & Mostafavi, 2019). One of the studies, which evaluated external hexagon, internal hexagon, and Morse taper connections, showed that the most stable mechanical behavior among those measured, after mechanical cycling, was that of the internal hexagon group (Santafé, 2010). Thus, within a correct diagnosis and planning, the performance of the internal hexagon type connection can be comparable to that of the Morse taper type, confirming the findings of this study.

However, several studies have shown the superiority of the Morse taper connection over the others, with respect to a lower torque loss of the abutment fixation screw and a higher flexural strength (Norton, 1997; Merz *et al*., 2000; Khraisat *et al*., 2002; Ricomini Filho *et al*., 2010; Fernandes *et al*., 2011; Ceruso *et al*., 2017; Sammour *et al*., 2019; Huang & Wang, 2019). The Morse taper connection, even demonstrated in some studies, an increase in the screw removal torque from the prosthetic abutment, after mechanical cycling tests (Fortes *et al*., 2008; Coppedê *et al*., 2009; Fernandes *et al*., 2011). This was most likely because in the Morse taper connection the abutment is held to the implant by the screw and friction welding, with mechanical locking (frictional locking) of the internal surface of the implant with the abutment surface. This mechanical locking allows the abutment to have an extremely low preload loss, decreasing the possibility of micro-movement during loading (Merz *et al*., 2000). In addition, the Morse taper connections proved to be better, with greater long-term clinical stability and presenting less tension on the fixation screw (Norton, 1997; Merz *et al*., 2000; Khraisat *et al*., 2002; Ricomini Filho *et al*., 2010; Ceruso, 2017; Sammour SR, 2019; Huang, 2019), results that are contrary to those found by Santafé (2010) and Seddigh (2019), where the worst screw removal torque values, after mechanical cycling, were presented precisely by the Morse taper group.

When analyzing the external hexagonal connection, one of the studies evaluated concluded that this is the most stable type of connection, and the other connection types were mechanically inferior (Ribeiro *et al*., 2011). Some studies, however, found no statistically significant differences in screw torque loss among the three best known types of abutment-implant connections-external hexagon, internal hexagon, and Morse taper (Dixon *et al*., 1995; Theoharidou *et al*., 2008; Tsuruta *et al*.,2018). Rangel *et al*. (2007) reported that mechanical cycling, which simulates masticatory function, increased the torque loss of the screws; such data indicate the need for clinical monitoring of single prostheses on implants and that periodic readjustments of prosthetic abutments may be necessary. The present study was performed using crowns simulating cuspidless premolars, cemented on prosthetic abutments before mechanical cycling, according to the methodology proposed by Binon (1996). Several studies reported herein did not perform the fatigue tests with cemented crowns on the respective abutments, a fact that may have caused divergence in the results (Dixon *et al*., 1995; Norton, 1997; Norton, 1999; Norton, 2000a; Norton, 2000b). The fact that both groups evaluated in this study, both CM and HI, showed no differences regarding the loss of screw torque after mechanical cycling may have occurred due to the presence of frictional micro-soldering (adhesive wear or micro-asperity welding), of the abutment surface with the internal surface of the implants, as reported by Merz *et al*. (2000). The literature provides many studies analyzing the fatigue resistance of dental implants and prosthetic components (Khraisat *et al*., 2002; Çehreli *et al*., 2004; Nakamura *et al*., 2006; Piermatti *et al*., 2006; Rangel *et al*, 2007; Fortes *et al*., 2008; Pastor *et al*., 2008; Coppedê *et al*., 2009; Tsuge, Hagiwara, 2009; Ricomini Filho *et al*., 2010; Santafé, 2010; Fernandes *et al*., 2011; Truninger *et al*., 2012), some presenting very different results from each other. However, a factor that must be taken into consideration is the fact that there is no standardization among the studies reviewed in this research, regarding the applied force (N), loading (number of cycles), the type of load (load application angle) and the applied load frequency (Hz). All these factors may have had a direct influence on the results obtained in each research studied. Regarding this fact, the present study followed the methodology adopted by Nery (2006), using 25 Hz frequency and 212,600 cycles. Another important point that can have direct influence on screw loosening is the type of screw of the prosthetic pillar (Pastor *et al*., 2008; Stüker *et al*., 2008; Tsuge, Hagiwara, 2009; Coppedê *et al*., 2011), both in relation to its manufacturing material and its design. Some studies have shown a superiority in the destorque values of abutment screws manufactured in titanium (Pastor *et al*., 2008; Tsuge, Hagiwara, 2009). In contrast, the work of Stüker *et al*. (2008) concluded that gold screws were superior in preload stability. The screws used in this study were made of titanium.

Regarding the design of the abutment screw, the study by Coppedê *et al*. (2011) showed that morse taper screws were superior in terms of preload maintenance when compared to conventional screws. Also in this regard, Piermatti *et al*. (2006) found that screw design seemed to play an important role in preload maintenance, claiming that screws with thick and short shank are less likely to suffer torque loss, being indicated for patients who present parafunction. Manual grinding of the screw seating base significantly increased the values of the force required to untorque the screws (Daroz *et al*., 2008). Thus, one way to increase the force values for torque release would be to grind the screw seating base; however, this procedure was not conducted in this research and its effect would need to be checked under fatigue conditions. Dixon *et al*. (1995) suggested a protocol to minimize the reduction in preload that occurs in the first few minutes after initial bolt tightening, a phenomenon called softening or sedimentation. This protocol consists in retightening the screw with the same torque value, ten minutes after the initial torque. This same protocol was adopted in this study. However, another work conducted by Alnasser *et al*. (2020) demonstrates that torquing and untorqueing the fixation screw for 3 times, significantly increases the screw removal torque value. Clinically, loosening of the fixation screws of the abutment-implant connections seems to be mainly linked to biomechanical problems related to failures in planning, diagnosis, and treatment indication (Binon, 2000; Khraisat *et al*., 2002; Çehreli *et al*, 2004; Nentwig, 2004; Weigl, 2004; Nakamura *et al*., 2006; Piermatti *et al*., 2006; Rangel *et al*., 2007; Fortes *et al*., 2008; Pastor *et al*., 2008; Coppedê *et al*., 2009; Tsuge, Hagiwara, 2009; Ricomini Filho *et al*., 2010; Fernandes *et al*., 2011; Truninger *et al*., 2012; Goodacre *et al*., 2018). Regarding the type of connection, the present study showed that there was no influence of the types of connections evaluated on the loosening of the screws, after simulation of mechanical fatigue. In view of the results obtained in this study, it is believed that clinically, the option for any of the studied connections produces similar clinical results regarding the loosening of the fixation screws.

CONCLUSION

From the analysis of the results obtained, it was possible to conclude that there were no differences regarding the counter-torque necessary for the removal of fixing screws from internal hexagon and Morse taper prosthetic abutments after mechanical cycling.

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