Study of the abutment screw threads of Internal Hexagon and Morse Taper Connection Implants and their loosening after Fatigue Testing

ABSTRACT

Aims: To evaluate the length of the thread portion and the distance between the thread pitches of internal hexagon (IH) and morse taper (MT) connection screws and their loosening after fatigue testing.
Methodology: Ten IH and ten MT implants received abutments torqued 20 N.cm. The implant-abutment sets were subjected to fatigue by mechanical cycling. After testing the removal torque of the abutments was measured and the abutments and screws were analyzed by scanning electron microscopy.
Results: Student's t-test showed there was no significant difference between the removal torque values among the groups ($p=0.609$). The length of the screw thread portion of the IH connection was significantly longer than that of the MT connection ($p<0.001$). There was no significant difference between the groups regarding the distance between the threads of the screws. ($p=0.734$).
Conclusion: The thread portion of screws in the internal hexagon connection was larger than that of screws in the morse taper connection. However, the distance between thread pitches and the removal torque values under fatigue testing were similar for screws in both types of connections.

Keywords: Osseointegrated Implants, Osseointegration, Prostheses and Implants, Torque, Fatigue, Bone-Anchored Prosthesis.

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1. INTRODUCTION

Osseointegrated implants have fundamentally reshaped the landscape of oral rehabilitation for both fully and partially edentulous patients, representing a pivotal advancement in prosthetic treatment modalities and the pervasive adoption of implant-supported prostheses [1,2].Integral to the functional and clinical success of these implants are stringent criteria encompassing biocompatibility, osseointegration, avoidance of anatomical compromise, and the ability to effectively transfer forces to the surrounding bone within physiological thresholds [3,4]. Despite these advancements, mechanical and biological complications can compromise implant-supported prostheses, adversely affecting patient function and well-being [5–8].

One of the most prevalent complications, screw loosening, poses a significant challenge in single implant prostheses. Contributing factors include inadequate torque application during implant placement, suboptimal prosthesis fabrication, improper abutment seating, excessive loading, and design-related issues pertaining to the screws [9,10]. Studies have indicated a correlation between the design of the implant-abutment connection system and the incidence of screw loosening, with external connection systems exhibiting higher susceptibility compared to internal hexagon connections [11–15]. On the other hand, internal hexagon connections seem to demonstrate better interface sealing, force distribution, greater stability, and resistance to lateral forces[12–16]. Also compared to the external hexagon system, morse cone platforms have shown less loosening and screw fractures[11,17,18].

A critical mechanical factor to consider in mitigating screw loosening and fracture is the application of preload, defined as the stress induced in the abutment screw during torque application [19]. However, challenges arise due to frictional forces within the screw threads, potentially leading to reduced preloads [9,17,20,21].

Various parameters affect the preload, including the magnitude of the torque, the shape of the screw head, the shape and number of threads, the metal composition, the surface condition, and the screw diameter [22].

This study aimed to evaluate the impact of thread length and pitch distance on screw torque loss in internal hexagon and morse taper connections following fatigue tests. The hypothesis of this study is focused on assessing whether screws with varying thread characteristics exhibit different torque loss behaviors in these two connection types.

2. MATERIAL AND METHODS

The sample size in this study was determined based on similar studies in the literature [11,16,21]. A total of 20 implants with 3.75 mm diameter x 13 mm length (Neodent, Curitiba, PR, Brazil) were distributed into two groups with different connection: Internal Hexagon - Titamax II Plus (IH, n=10) and Morse taper -Titamax CM (CM, n=10). To obtain the specimens, self-curing acrylic resin (JET, São Paulo, SP, Brazil) was embedded in PVC tubes, 23 mm height and 17 mm in diameter. After polymerization, a 4 mm diameter by 17 mm height perforation was performed in the center of each specimen using a trephine drill (Neodent, Curitiba, PR, Brazil).The implants were then inserted into the cavities, positioned 1 mm above the resin base, and fixed with the same self-curing acrylic resin.

Abutments were affixed to the implants using specific trunnions for each connection type. A torque of 20 N.cm was applied to the abutments using a digital torque meter and a 1.17 mm hexagonal wrench(ConexãoSistemas de Prótese, Arujá, São Paulo, Brazil), with a re-torque procedure after 10 minutes to ensure preload maintenance, following the protocol proposed by Dixon et al. (1995)[23]. Superstructures were fabricated using a wax-up technique and a cobalt-chromium metal alloy (Starloy C, Dentsply, Petrópolis, RJ) according to the manufacturer's specifications, and cemented using a calcium hydroxide-based temporary cement (Hydro C, Dentsply, Petrópolis, RJ, Brazil) under digital pressure for 1 minute by a single operator.

Subsequently, the specimens were subjected to cyclic compressive loading ranging from 10 N to 100 N at a frequency of 25 Hz, as in the study described by Khraisat et al. (2002)[24], for a total of 212,600 cycles to simulate one year of masticatory function[25]. Following the

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fatigue test, the removal torque of the abutments was measured in N.cm using a digital torque meter to assess the maintenance of the pre-established torque.

Scanning electron microscopy (SEM) analysis was conducted on the abutments and screw. Descriptive statistics were performed on the removal torque values, thread portion lengths, and thread pitch distances of the screws of the internal hexagon and morse taper connection implants. Statistical analysis was carried out using t-student and Tukey's test at a 5% significance level to compare the torque loss between the two implant types.

3. RESULTS AND DISCUSSION

The data showed no significant difference between the values of removal torque presented by the internal hexagon and morse taper connections ($P = 0.609$), as shown in table 1. It was verified that the length of the screw thread portion of the internal hexagon connections was significantly greater than that presented by the morse taper connections ($P < 0.001$ - table 1), as illustrated in figures 1 and 2. Regarding the distance between screw pitches, no significant difference was observed between the screws of both types of connection evaluated ($P = 0.734$), as shown in figures 1 and 2.

Table 1. Mean (±SD) of the torque values of the length of the thread portion and the distances of the screw thread pitches of the internal hexagon and morse taper implants.

Connection type	Untorque (N.cm)	Length of thread portion (mm)	Thread pitch distances (µm)
Internal Hexagon	8.3 (1.5) a	3.36 (0.11) a	371.8 (15.0) a
Morse taper	7.4 (4.0) a	2.44 (0.07) b	374.2 (19.9) a

*Means followed by different lowercase letters indicate statistically significant difference between groups.

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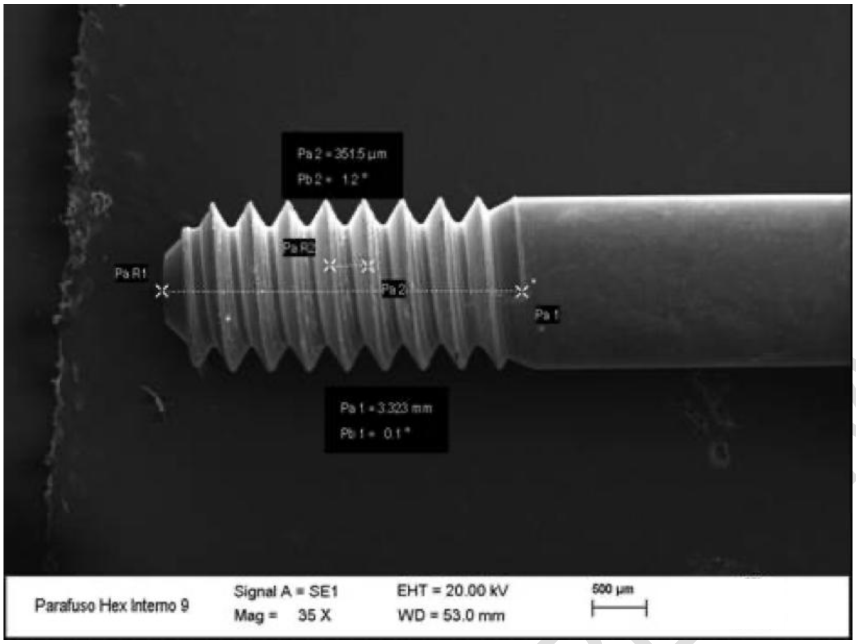

Figure 1. Scanning electron microscopy photomicrograph of an internal hexagon connection screw, revealing the length of the threaded portion and the distance between the thread pitches.

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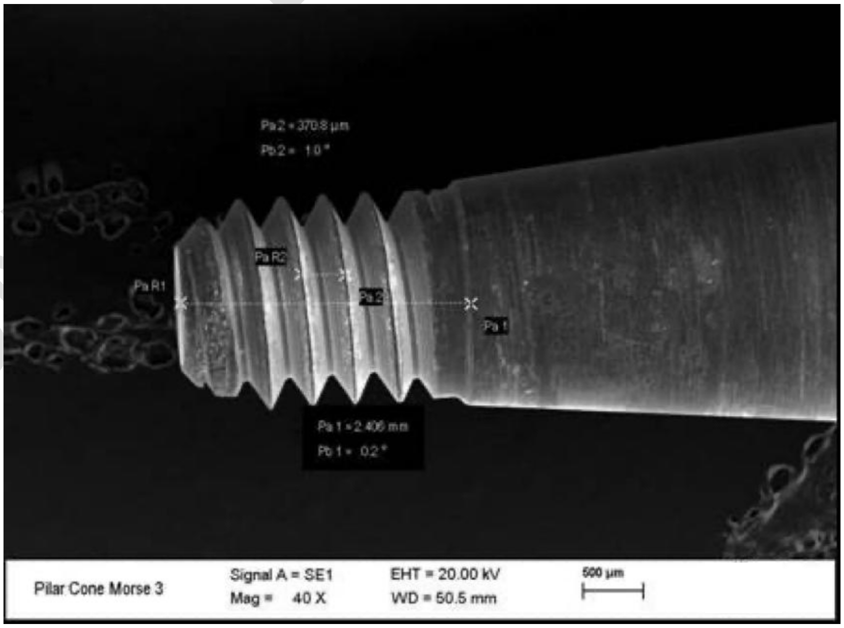

Figure 2. Scanning electron microscopy photomicrograph of a morse taper connection screw, revealing the length of the threaded portion and the distance between the thread pitches.

This study revealed that there was no statistically significant difference in the torque loss of internal hexagon and morse taper connection screws after simulating one year of masticatory function. However, some studies have shown superiority of the morse taper connection, mainly in relation to a lower torque loss of the screw after fatigue testing [12,13,15,17,26–29].

In some research the morse taper connection has shown an increase in the removal torque value of the prosthetic abutment screw after fatigue testing [21,30,31] which may imply greater clinical stability of the prosthesis over the implant, in the long term [15,31]. This finding may be due to the metal composition of the screw made of titanium alloys that tend to loosen less [10,20]. In this work the alloy composition of the components used for both the internal hexagon and the morse taper implants were also made of titanium alloys. However, when the implants of the internal hexagon system were subjected to occlusal loading, in a finite element study, the higher stress concentration was exhibit around the implant neck, and only a small stress concentration is concentrated in the prosthetic abutment screw. This simulation suggests that internal hexagon connections protect the prosthetic abutment screw from accumulated stress, exposing the implant walls to this stress[32].

In view of the findings of this study, both types of connection, morse taper and internal hexagon, behaved similarly concerning the removal torque in fatigue tests.

Due to the fact that screws that receive a lower or inadequate preload exhibit greater micromovement at the implant-abutment interface, retightening the screw to the same torque value ten minutes after the initial torque is recommended to ensure that the preload is maintained [12,33,34], and this exact protocol was used in this research.

To prevent screw loosening, in this research it was used prosthetic components of the same manufacturer of the implants, since prosthetic components from different manufacturers have different chemical and physical characteristics, which may lead to screw loosening[35,36].

It is known that the greater the variation in the angle of the intermediate to the implant, the greater the stress on the structures and bone tissue[37]. So, to evaluate the moment of the extreme force of the load on the analyzed structures, the direction of compressive loading on the specimens was perpendicular to the insertion axis of the implant components, according to the proposal described by Khraisat et al, (2002)[24]. However, even though the loading simulated an extreme condition, there was no fracture of the screws or components of the samples analyzed. However, some specimens from the morse taper group showed a small micromovement during the retorquing phase of the abutments. In fact, the variability in this group was three times higher compared to the internal hexagon. The significant difference observed between the length of the threads of the internal hexagon screws compared to the morse taper abutments ones, is probably due to the large number of threads on the internal hexagon screws. This may be because in the case of the internal hexagon connection implant, a two-piece component was used and in the morse taper connection implant only a single body prosthetic abutment was used. It should be noted, however, that although there may have been an effect of fatigue on the screw thread length and the distance of the screw

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threads of the prosthetic components, this evaluation would depend on the analysis of the samples also at a time prior to the fatigue test.

Regarding the distance of the screw thread pitch the data show that there was no deformation in the thread morphology of the screws and abutments analyzed, although a slight wear of the screw and prosthetic abutment material was observed.

In clinical practice, the success of a prosthetic rehabilitation from the patient’s point of view depends on masticatory function and aesthetics, but another very important criterion in treatment planning would be the mechanical stability of the prosthesis. Therefore, torque loss of prosthetic component screws seems to be always linked to mechanical complications related to the prosthesis on implant[2,9,10,17]. In order to increase the predictability of rehabilitative procedures from the point of view of the effect of fatigue, this study showed that there was no difference in the removal torque value between the connections studied and revealed that there were no fractures of the components, even in the face of the significant difference between the length of the threads of the screws and abutments. However, further research to evaluate the maintenance of preload during fatigue tests would be interesting.

4. CONCLUSION

The thread portion of screws in the internal hexagon connection was larger than that of screws in the morse taper connection. However, the distance between thread pitches and the removal torque values under fatigue testing were similar for screws in both types of connections.

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