

Evaluation of removal torque values for titanium screws of prosthetic abutments after different torque application techniques: in vitro study

Avaliação dos valores de torque de remoção para parafusos de titânio de abutments protéticos após aplicação de diferentes técnicas de torque: estudo in vitro

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ABSTRACT

Objective: To evaluate the removal torque values on abutment screws after different torque application techniques. **Materials and Methods:** Thirty specimens of an external hexagon implant, a prefabricated abutment and a titanium screw were distributed randomly in three groups. In group 1, the screws received a torque of 30 N.cm; group 2 received a torque of 30N.cm and a second torque after 10 min, in accordance with the technique proposed by Breeding et al. and Dixon et al.; in group 3, a torque of 30 N.cm was applied and maintained for 20 s, in accordance with the technique recommended by Sella et al. The specimens were attached to a universal testing machine and a digital key was coupled to the load cell in order to control the torque value at a velocity of 1 N.cm/s. Removal torque was performed 10 minutes after torque application. Values were statistically analysed using one-way ANOVA and Tukey's HSD test ($\alpha = 0.05$). **Results:** The mean and standard deviations (\pm SD) of removal torque values found were 27.95 ± 0.99 N.cm for group 1, 28.32 ± 0.68 N.cm for group 2 and 26.89 ± 1.03 N.cm for group 3. Groups 1 and 2 exhibited statistically higher values of torque than group 3 ($p < 0.05$). **Conclusion:** The technique recommended by Breeding et al. and Dixon et al. seemed to be the best option when considering the removal torque values of external hexagon implants.

RESUMO

Objetivo: Avaliar os valores de torque de remoção em abutments parafusados após aplicação de diferentes técnicas de torque. **Materiais e Métodos:** Trinta espécimes de implante hexágono externo, abutment pré-fabricado e parafuso de titânio foram distribuídos randomicamente em três grupos. No grupo 1, os parafusos receberam um torque de 30 N.cm; no grupo 2 receberam um torque de 30N.cm e um segundo torque após 10 min, de acordo com a técnica proposta por Breeding et al. e Dixon et al.; no grupo 3, um torque de 30 N.cm foi aplicado e mantido por 20 s, de acordo com a técnica recomendada por Sella et al. Os espécimes foram inseridos na máquina de teste universal e uma chave digital foi acoplada a célula de carga para controlar o valor de torque e a velocidade de 1N.cm/s. O torque de remoção foi realizado 10 min após o torque de aplicação. Os valores foram estatisticamente analisados usando 1-way ANOVA e Tukey HSD test ($\alpha = 0,05$). **Resultados:** As médias e desvio padrão (\pm SD) dos valores de torque de remoção encontrados foram $27,95 \pm 0,99$ N.cm para o grupo 1; $28,32 \pm 0,68$ N.cm para o grupo 2 e $26,89 \pm 1,03$ N.cm para o grupo 3. Os grupos 1 e 2 exibiram valores estatisticamente mais altos de torque quando comparados ao grupo 3 ($p < 0,05$). **Conclusão:** A técnica recomendada por Breeding et al. e Dixon et al. pareceu ser a melhor opção quando considerado os valores do torque de remoção de implantes hexágono externo.

KEYWORDS

Abutment screw; Dental implants; Removal torque.

PALAVRAS-CHAVE

Abutment parafusado; Implantes dentários; Torque de remoção.

INTRODUCTION

Although rehabilitation with implants has a 98% success rate [1], the literature has been emphatic in researching and reporting the main causes of failure and biological or mechanical complications [2-6]. Mechanical complications are constantly related to loosening and/or fracture of the screws [7-11], with the most common issue, especially in the first year of rehabilitation with prostheses, being the screw loosening [4,8,12], mainly in molars and premolars [13,14]. Several factors can cause this type of mechanical complication, such as: inadequate preload screw or prosthetic design, settling of roughened surfaces (a phenomenon characterized by up to a 10% reduction in the preload in the first seconds or minutes after application of the torque, occurring due to a lack of intimate contact between the internal threads of the implant and the screw threads, with contact only due to surface irregularities of the implant and screw threads), mechanical loading or instability of the abutment/implant interface [2,4,15].

Screw loosening occurs when separation forces (centric, eccentric and excursive contact) are greater than the clamping force (preload), thereby compromising the stability of the screw joint, which is the unit formed by the two components [16-18]; this mechanical complication can occur in two stages: 1 – external transverse or lateral forces are applied on the screw joint during chewing, leading to a reduction in the surface friction of the threads, which contributes to preload loss; and 2 – there is a continuous loss of preload to critical levels, threatening the stability of the system and causing screw loosening [16,19]. The mechanism for obtaining appropriate preload

involves the application of torque, with removal torque indirectly proportional to the amount of preloading. This means that the value of the applied torque will not always generate the same preload value due to the coefficient of friction which acts on the screw head, abutment, screw threads and the internal threads of the implant, creating a loss of initial force (torque). The coefficient of friction depends on the hardness of the material of the surface finish of the threads, the quantity and quality of the lubricant, and the tightening speed [15].

Preload torque recommendations vary from 10 to 35 N.cm, depending on the screw material and fabrication of the implant/abutment [17]: an insufficient torque can cause separation of the screw joint and result in loosening of the screw, while excessive torque can cause failure or screw fracture, due to permanent deformation of the screw stem, resulting from fatigue from masticatory forces [2,18,20]. Higher torque usually leads to greater preload values [21]. Thus, the application of adequate torque is fundamental in reducing screw loosening and avoiding screw fracture [18,22-24]. To prevent this mechanical complication, modifications can be used, including modification of the implant body abutment interface (external or internal hexagon or octagon), the use of gold screws, torque-controlling devices, screw cements and modifications of the torque technique, as suggested by Breeding et al. [25], Dixon et al. [2] and Sella et al. [18]. The first two authors suggested a modification of the standard torque process by adding a new application of the standard torque after 10 minutes. These authors based this new technique on the fact that, when the torque is first applied to the screw, there is a significant loss of strength due to the contact between the threads of the implant and screw

occurring only due to the surface roughness. These authors believe that a reduction of 2 to 10 % preload occurs within the first few seconds or minutes after tightening, as a result of a relaxation phenomenon known as “sedimentation”. The reduction of friction between these surfaces could increase screw speed and therefore the preload. The technique of tightening the screw with the same value of initial torque after 10 minutes on the day of installation of the prosthesis could optimize the preload values [20,21]. Sella et al. [18] analysed whether different durations of torque application on titanium screw abutments for dental implants would have any influence on the removal torque values when compared with the conventional fastening technique (instantaneous torque application), suggesting maintenance of the 30 N.cm torque for 20 s.

Studies [10] have indicated that, when the abutment used was not a prefabricated abutment, a decrease in removal torque values was caused due to the casting process. Consequently, changes in the final stability of the screws could be found, and prefabricated abutments generated larger preloads and the highest values in the loosening torque [10]. This current study aims to research the removal torque values of customized titanium abutments on external hexagon implants, comparing three techniques of torque application: the conventional technique, the technique proposed by Breeding et al. [25] and Dixon et al. [2], and the technique proposed by Sella et al. [18].

MATERIAL AND METHODS

In this present study, each sample ($n = 30$) was composed of an external hexagon implant (3.75 mm x 10 mm, Master Screw, 123691, Conexão Sistemas de Implantes, São Paulo, Brazil), a customizable prefabricated abutment (AR 5.0 x 1.0 Hex. Ext. 3.75 / 4.0, 121657, Conexão Sistemas de Implantes, São Paulo, Brazil) and a square titanium screw (Ti-6Al-4V, Grade 5, Metric thread M 2.0, pitch: 0.4 mm, 123902, Conexão Sistemas de Implantes,

São Paulo, Brazil). The abutments were fixed on the implants with titanium screws using a digital handheld screw driver (Mean Square Digital Key, 1.27, Conexão Sistemas de Implantes, São Paulo, Brazil) until resistance was felt. However, torque was not applied with the digital handheld screw driver.

The specimens were randomly assigned to three groups according to the technique used to perform the torque ($n = 10$). In group 1, the screws received a torque of 30 N.cm, based on the conventional technique; in group 2, the technique proposed by Breeding et al. [25] and Dixon et al. [2] was used, with an initial application of 30 N.cm and a second torque of 30 N.cm after 10 min; and in group 3, a torque of 30 N.cm was applied and maintained for 20 s, in accordance with the technique recommended by Sella et al. [18]. The specimens were fixed to a metal base that was attached to a universal test machine (BME 0540180120/ATMB, Brasvalvulas, São Paulo, Brazil) (Figure 1). The handheld screwdriver was coupled to a metal load cell, which had sensors that were controlled by the computer software ATMP2.2 (Lynx, Brazil). This software maintained a steady torque and was programmed to perform a torque of 30N.cm at a speed of 1N/cm per second, according to the technique of each experimental group. The data were recorded in the software, and evaluated with AqDanalysis 7.0 (Lynx, Brazil) to confirm whether the correct torque value was applied.

Ten min after applying torque, based on the specifications of each technique, the testing machine was programmed for the application of removing the screws, which was conducted with the same devices as for the torque application at a speed of 1 N.cm/s. The torque application sequence was repeated eight times, according to the specifications of each technique. The removal torque values were recorded using a computer program (Excel 2007, Microsoft, USA). All procedures were performed in a closed environment and at a controlled temperature ($24.0^{\circ}\text{C} \pm 0.8^{\circ}\text{C}$). The statistical analysis included

calculation of the means and standard deviations of all groups, which were then submitted to ANOVA, and comparisons of the mean removal torque values between groups were evaluated using the Tukey HSD test.



Figure 1 – The specimen was attached to the universal test machine and received torque at a speed of 1 N.cm/s. Techniques referenced in the literature (conventional technique, technique proposed by Breeding et al. [25] and Dixon et al. [2], technique proposed by Sella et al. [18]) were used to perform the torque.

RESULTS

The mean removal torque values were 27.95 (0.99) N.cm for group 1, 28.32 (0.68) N.cm for group 2 and 26.89 (1.0) N.cm for group 3. ANOVA indicated significant differences among groups ($P < 0.05$). Post hoc comparisons were made using the Tukey HSD test ($P < 0.05$), which indicated a statistically significant difference for group 3. Groups 1 and 2 were statistically similar (Table I).

Table I – Mean removal torque values, SD and post hoc comparisons using the Tukey HSD test ($P < 0.05$) for groups 1, 2 and 3

Group	Mean Torque Values (N.cm)	SD	Statistical Category*
1	27.95	0.99	A
2	28.32	0.68	A
3	26.89	1.03	B

* Identical letters indicate that the values were statistically similar.

DISCUSSION

Loosening of the screw is the most common failure of implant prosthetics, as reported in the literature [4,10]. This type of failure can lead to complications that include: inflammation of the peri-implant tissues due to micromovements at the implant/abutment interface, allowing the entry of micro-organisms into the implant interface [18], and mechanical complications, such as screw and/or abutment fracture [2,7,10,12]. Additionally, screw fractures should be considered a warning sign, since all fractured implants presented several episodes of screw loosening [10]. Laboratory studies have shown that the torque directly influences the preload [5,18]. Analyses have been conducted to verify that the maintenance and/or repetition of torque influences the removal torque values [5,11,18,25,26]. This is an indirect way of evaluating the obtained preload; however, research results have been contradictory, and there is no consensus on a protocol that guarantees the best clinical results.

In this present study, removal torque values were assessed by comparing three torque application techniques: the conventional technique, the technique proposed by Breeding et al. [25] and Dixon et al. [2] and the technique proposed by Sella et al. [18]. The mean values obtained from the removal torque values were lower than the torque application values for all tested groups, which is in line with the results found in other studies [18,23]. This is because, in the first sequence of application of torque and detorque, there is contact between the micro roughness of the surfaces of the screw and the internal threads of the implant, resulting in a loss of up to 10% of the initial torque, a phenomenon known as “sedimentation” [25]. In addition, when a titanium surface contacts another metal of the same hardness, there is a progressive increase in the coefficient of friction between the surfaces and, as a result of torques and detorques that are repeated, there is a resulting decrease in preload [24,27].

This progressive friction increase can be explained by a phenomenon known as “adhesive wear”. This occurs as a result of “pullout” points of the materials and the transport of fragmented particles of the implant or screw. This increases the roughness of the surface and the coefficient of friction between both surfaces. For this reason, the titanium has a high coefficient of wear and high friction coefficient [6]. On the other hand, when the mean removal torque values were analysed, larger and smaller values of standard deviation were observed when compared to those found in the literature [23]. Variables that directly influence the preload, such as the speed of the applied torque [28], were controlled during the application of torque and detorque in this study. However, a comparison with other studies is difficult, mainly due to the variety of manufacturers, screw designs, materials, methodological design of the studies and different equipment used.

Among the groups analysed, the technique proposed by Breeding et al. [25] and Dixon et al. [2] demonstrated numerically higher values of removal torque than the conventional technique. There was a significant difference when comparing the values obtained by the technique proposed by Sella et al. [18] and the other two groups. The sedimentation phenomenon was the reason why Breeding et al. [25] and Dixon et al. [2] recommended retightening the screws after 10 minutes. Similar studies have stated that this procedure increases the removal torque values or preload [5,11,25]. In the results found by Sella et al. [18], the torque maintenance groups had higher removal torque values, which was not observed in this current study. This can be explained by the method used in both studies, in which the original study utilized a manual torque wrench, although these authors confirmed the applied torque and removal torque values obtained by a digital torque measurer.

Manual torque wrenches have an inaccuracy of up to 30% when measuring

preload. Depending on the operator that will perform the test and whether the threads of the screws are lubricated or not, the error can be reduced by half. The use of an electronic torque wrench, which is considered to have an error margin of 10%, to record the torque is applied in other studies, such as Goheen et al. [22]. In order to confirm the recommended torque in each of the samples, a testing machine that had sensors on a load cell was used in the present study, in which a digital key was set and used to perform the 30 N.cm of torque and analyse detorque using a speed of 1 N.cm/s. The torque wrench was calibrated with a maximum error of 0.63%, and variables such as clenching speed and detorquing screws were controlled in all specimens.

In addition, the results of Sella et al. [18] showed a loosening torque that was 60% lower than the initial torque, which is not in line with the literature, which considers up to 30% screwed prosthesis without being subjected to mechanical cycling or up to 31% after several sequences of tightening and loosening [24]. All results found in this present study had loosening torque values that were 10% lower than the initial torque. Therefore, the uniformity and low indices of standard deviation attest to the reliability of the specimens.

When possible, prefabricated abutments are the first option of choice in the selection of prosthetic components. Cast abutments show a decrease of removal torque values due to the smelting process, resulting in changes in the final stability of the components and the screws, thereby increasing the chances of screw loosening [14]. In this current study, pre-made, customizable abutments indicated for cemented prostheses were selected because screw loosening is catastrophic for these implant types, as one of the great disadvantages of screw loosening in cemented implant prostheses is the destruction of the crown in order to gain access to the screw. Therefore, it is essential that the screw does not loosen during the life of a

cemented prosthesis [11].

The composition of the alloy; whether titanium or gold, produces different effects on the connection stability of prosthetic screws. Gold screws help lower the friction coefficient, obtaining higher preload values during torque application than titanium screws. However, due to properties of the material (ductility and malleability), gold screws may exhibit a decrease in preload due to greater plastic deformation when subjected to repeated torque [21]. Another factor influencing the preload characteristics is the shape of the screw head. Hexagonal screws are popular, since they allow for a good locking with the screw head and an efficient transfer of torque [21]. However, it has been suggested that a square head performs better because it allows for higher torque values and therefore higher preload values.

The results of this current study demonstrate that the technique recommended by the manufacturer achieves appropriate preload values. Due to the limitations of this study, future research should be conducted to investigate the effect of the tested techniques when subjected to mechanical loading and the effect of lubricants on the screw joint.

CONCLUSIONS

According to the results obtained in this study, we can conclude that:

- Values obtained from removal torque values were lower than the initial torque values for all tested groups.
- The technique proposed by Breeding et al. and Dixon et al. (group 2) showed the highest removal torque values; however, no statistical difference was observed when compared to the conventional technique (group 1).
- The technique proposed by Sella et al. (group 3) presented statistically significant lower removal torque values.

DISCLOSURE

The authors claim to have no financial interest, either directly or indirectly, in the products or information presented in the article.

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