

Comparative Analysis of Screw Loosening in Titanium and Zirconia Implant-Supported Abutments-An *In vitro* Study

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Abstract

Background: Compare of the screw loosening in two different implant-supported abutments (titanium and zirconia) and the influence of repeated application of torque on the fixation screw.

Methods: The torque of the titanium screw loosening was analyzed with two different implant-supported abutments: Titanium (n = 10) and Zirconia (n = 10). These screws/abutments were fixed for the test using external hex implants. A low-load robot (*KUKA KR-16 2*) with a high precision torque sensor (Industrial Automation Technologies) and a square key were used to measure force of the reverse torque. Each screw/abutment was repeatedly tightened (TR1-TR10) on the implants with a torque of 30 Ncm. The reverse torque values were recorded in a database using Kuka System Software V5.X. The Mann - Whitney and the Wilcoxon test were also performed.

Results: A statistically significant difference was not found only in the sample 3 (p = 0.05) in the comparative analysis between both materials (Ti and Zr). The mean reverse torque applied to loss the preload was 26.3 Ncm for Ti and 22.6 Ncm for Zr. The difference between the initial reverse torque (TR1) and final (TR10) was determined TR1 had an average of 24.8 Ncm (Ti) and 20.8 Ncm (Zr); TR 10 had an average of 27.4 Ncm (Ti) and 23.9 Ncm (Zr).

Conclusion: The titanium abutment showed higher resistance to the loosening of the titanium screw compared to the zirconia abutment. The first preload applied tended to loosen more easily than the last torque applied in the same screw.

Keywords: Zirconia; Titanium; Torque; External hex implants

Introduction

Screw loosening is the most common problem in implant-supported prostheses, which causes discomfort and insecurity among patients. Once the screws have loosened, they may break or lead to a fracture of other elements of the prosthesis. Loosening of screws and consequently, of the prosthesis may irritates soft tissue, causes inflammation and often pain [1-3].

Customizable metal or ceramic abutments are positioned directly above the implants [4-6]. Metal abutments such as titanium alloys offer excellent stability and are resistant to distortion. Results from clinical studies have shown excellent survival rates for this type of

abutment in supported restorations [7]. The disadvantage is the dark-grey color that can reflect a grayish coloration in the peri-implant mucosa, thus negatively affecting the esthetic outcome [8].

Currently, it is possible to obtain ceramic abutments from ceramics reinforced with alumina or zirconia [9]. These ceramic abutments have esthetic benefits due to their color [10], as well as a lower bacterial adhesion [11]. The disadvantage of ceramic abutments include a lower resistance to tension forces, and micro-structural defects of the material, which may cause fissures and result in fractures [12].

Loosening of fixation screws occurs more commonly in the first year and decreases in subsequent years. This phenomenon can be explained by the period of adaptation after the initial delivery of the prosthesis [13].

The abutment and the implant form a rigid union. The preload generated in the screw aims to promote a clamping force and compression between the assembly of the implant (abutment/implant). Thus, the preload seems to be proportional to the fixation force [3]. This compression offers resistance to external shear loads and improves resistance to fatigue in the abutment/implant ensemble [14].

The looseness of the fixation joint and the seating of the ensemble also depend on the presence of irregular points on the surface contact, the solidity of the implant surface, optimal fixation between screw and the abutment, as well as the load applied to the system as a whole. When there is a relaxation of the clamping, tightening torque is applied in order to recover the preload [2].

This study was conceived because of a question related to the different mechanical performances of titanium and zirconia abutments on external hex implants. The aim of the present study was to analyze screw loosening in two different implant-supported abutments (Ti and Zr) and the influence of repeated application of torque on the fixation screw, while observing the amount of reverse torque required to the loosen of the preload.

The null-hypothesis considered was that the screw loosening would be different between the two different prosthetic implant-supported abutments and that repeated application of torque on the fixation screw would have an influence on the value of the loosening of the preload.

Materials and Methods

The present study was lead in the Laboratory of Mechatronics, Department of Mechanical Engineering, University of São Paulo (USP; Sao Carlos, SP, Brazil). Twenty titanium screws with a square key size of 1.27 mm (Conexao Sistema de Protese; Sao Paulo, SP, Brazil) and twenty abutments (n = 10 Ti; n = 10 Zr) were analyzed. The abutments were divided into two groups: Group 1: pre-fabricated titanium abutments (Conexao Sistemas de Protese; Sao Paulo, SP, Brazil) and Group 2: zirconia CAD/CAM abutments.

The abutments with the respective screws were fixed for testing using an external hex implant (\emptyset 3.75 x 11.5 mm, Conexao Sistemas de Protese; Sao Paulo, SP, Brazil). The implants were embeded perpendicular to the horizontal plane in auto polymerizing acrylic resin (Duralay; Reliance Dental MFG Company, Illinois, United States) in a standardized manner, using a delineator together with an adapted device.

A low-load robot (KUKA KR-16 2 KUKA Roboter of Brazil Ltda; Sao Paulo, Brazil) was used to apply the torque. A torque sensor together with the square key (Conexao Sistema de Protese; Sao Paulo, SP, Brazil) was attached to the robots extremities to measure the torque and reverse torque of the fixation screws. The sensor is composed of a transducer, a highly flexible protected cable and an intelligent data acquisition system.

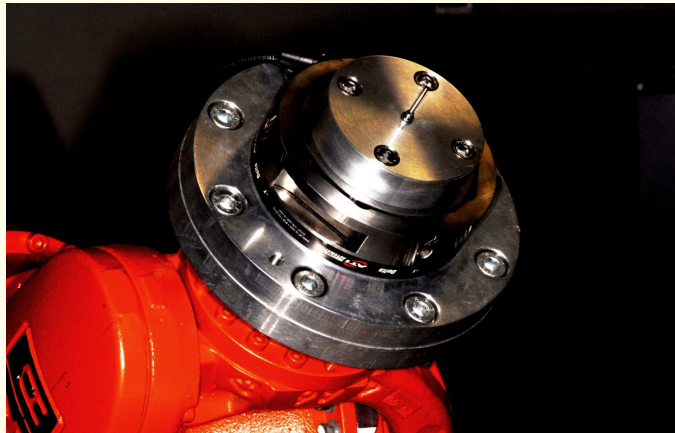


Figure 1: Robot (KUKA KR-16 2) with a torque sensor and the square key were attached to apply torques and reverse torques.

Each fixation screw and the respective abutment (Ti and Zr) were tightened repeatedly on the implants by a specifically created program. Initial torque of 30 Ncm; waiting five minutes (time required for an initial elastic and plastic deformation of the material) and a new torque of 30 Ncm was performed, waiting five minutes again. After that a reverse torque was applied, and the abutments were removed. Ten cycles of insertion/removal were performed with each abutment. The torque and reverse torque values were recorded in a database using Kuka System Software V5.X. (KUKA Roboter of Brazil Ltda; Sao Paulo, SP, Brazil).

Descriptive analysis was performed with the data, exhibiting central tendency measures (mean and median) of reverse torque according to the different materials (Ti and Zr). The Mann - Whitney non-parametric statistical test was performed to determine the difference in the reverse torque values.

In order to test the difference between the initial and final reverse torque values, the Wilcoxon non-parametric test was conducted [15]. The groups were considered to be significantly different when the p-value was less than 0.05.

Results

The central tendency measures (mean and median) of the reverse torque according to the different materials (Ti and Zr) are presented in the Table 1.

A statistically significant difference was not found only in the sample 3 ($p = 0.05$) in the comparative analysis between materials. The mean reverse torque applied to loss of preload was 26.3 Ncm for titanium and 22.6 Ncm for zirconia abutments.

The mean and median difference between the initial reverse torque (TR1) and the final (TR10) were to: TR1 Titanium 24.8 Ncm and 25.8 Ncm; And to the Zirconia 20.8 Ncm and 21.7 Ncm. TR10 had for Ti 27.4 Ncm and 28.1 Ncm, and for Zr 23.9 Ncm and 23.4 Ncm respectively. The first torque applied to the samples tends to loose more easily the preload when compared to the last torque (Figure 2).

Reverse Torque	Titanium		Zirconia		Value*
	Median	Mean (SD)	Median	Mean (SD)	
Sample 1	25,80	24,81 (-5,70)	21,78	20,88 (-6,12)	0,03
Sample 2	25,50	26,04 (-2,88)	22,32	21,15 (-6,45)	0,02
Sample 3	27,30	24,45 (-7,98)	22,86	22,86 (-3,75)	0,05
Sample 4	27,96	27,45 (-2,85)	23,76	23,37 (-3,60)	0,01
Sample 5	26,97	25,44 (-5,16)	22,17	22,20 (-3,60)	0,04
Sample 6	27,54	26,34 (-3,84)	22,77	22,56 (-3,72)	0,01
Sample 7	28,68	26,37 (-5,61)	22,77	23,10 (-4,32)	0,04
Sample 8	28,86	27,84 (-2,82)	23,34	23,07 (-3,54)	0,00
Sample 9	29,31	26,85 (-5,85)	24,33	23,43 (-3,84)	0,01
Sample 10	28,14	27,45 (-3,57)	23,43	23,94 (-4,14)	0,04

Table1: Measures of central tendency and dispersion of successive removable torques according to the type of the material.

* Test of Mann-Whitne.

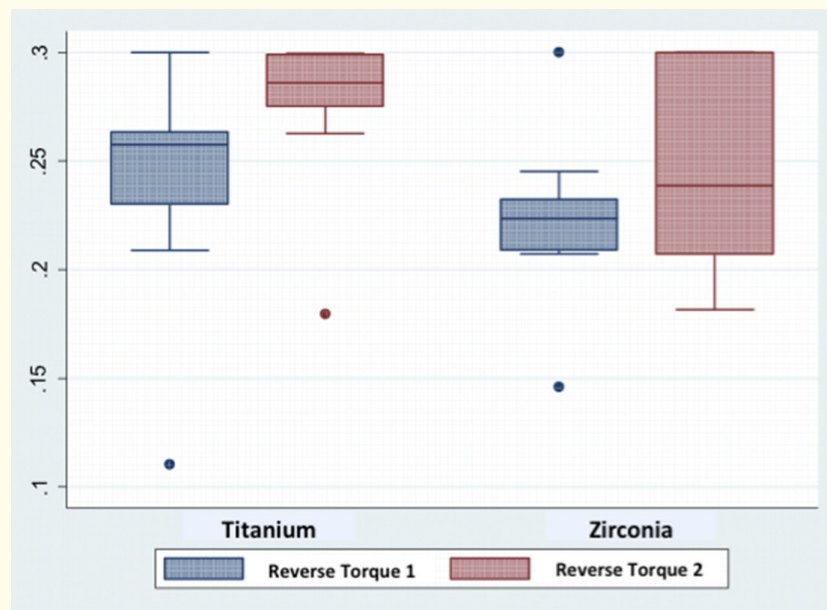


Figure 2: Box-plot of the first and the last reverse torque comparing the material type.

* Wilcoxon.

Discussion

The present study evaluated the screw loosening in two different implant-supported abutments and the influence of repeated application of torque on the fixation screw, observing the amount of reverse torque required to loosen the titanium screws. The null-hypothesis considered is that the screw loosening would be different between the two abutments and that repeated application of torque on the fixation screw would have an influence on the value of the loosening of the preload.

Implant supported prosthesis have already been successfully established. However, they often present mechanical and biological problems. One of the mechanical problems, typified in the present study, is the screw loosening [1,2]. And the most frequently mainly loosening occurs during the first two years after the rehabilitation on the traditional external hex implants [1,16].

The stability of the external connection of the abutments/implant and the implant was improved by changing the alloys of screws and applying adequate torque values to establish a greater preload [17]. Therefore, external hex implants exhibit the least favorable mechanical performance and the highest percentage of screw loosening in abutments. Also, this type of implant still with a high range of use in the global market.

The screws alloy routinely used in clinics are made of titanium with a torque applied at 30 Ncm for both titanium and zirconia abutments. According to McGlumphy *et al.* [18], when a screw unites two parts, loosening of the screw can only occur when the external forces applied are greater than the internal forces (tightening torque).

Haack *et al.* [19] stated that the preload maintains the threads of the screw in close contact with the threads of the implant, generating a force of union between the head of the screw and the abutment fitting surface, and from the abutment fitting surface to the platform of the implant. A reduction in the preload values is expected in the first seconds or minutes after the application of the torque, due to the deformation of the fitting contact surfaces between the assembly. Therefore, many authors recommend a second torque with the same value of the initial torque applied [16].

The phenomenon called sedimentation is based on the fact that any surface is completely flat and that all machined surfaces exhibit some degree of roughness. Therefore, when a fixation screw is screwed into an implant for the first time, there is a slight adjustment between the irregularities of the fitting surfaces, which we can understand as screw adaptation or seating. It is estimated that the mean preload values are reduced between 2% and 10% after the plastic deformation of these irregularities [2,14]. The screw will loosen more easily in the first preload due to plastic deformation and greater settlement of the material [13,20].

In 1991, Jemt [14] assessed 391 prostheses in edentulous jaws and mandibles and found that 120 (30.6%) of them exhibited loose screws two weeks after insertion. Three months later, the 120 prostheses that had required retightening of the screws exhibited 94% stability.

However, a number of factors may affect the stability of screws and probably will cause the loosening due to the tension. These factors are as follows: 1) geometric design and precision of the adaptation in the union of the components; 2) passive adaptation of the abutment to the implant; 3) difference in the coefficient of friction of screws which in turn, depends on the toughness of the thread material and the finishing of surfaces; 4) the shape of the screws; 5) the torque application system used and the quality control of the manufacturer, among others [21,22].

Currently, personalized abutments can be fabricated from different metal or ceramic materials. Metal alloys, such as titanium, offer stability and produce clinical results with excellent longevity rates [23]. The disadvantage is a grayish coloration, which may, in some cases, reflect in the peri-implant mucosa, with a negative esthetic effect [8].

Ceramic abutments can be used as an alternative in situations that, above all, require an esthetic result. The defect of ceramic material is the weakness: it exhibits less resistance to tensile forces as well as a number of micro-structural defects. However, reconstructions with zirconia structures have recorded clinical successes [24].

In a clinical study randomly controlled test (RCT) using zirconia and titanium abutments on posterior crowns, a survival rate of 100% was recorded for ceramic abutments after three years [25]. Curiously, loosening of fixation screws was one of the few technical complications that occurred with zirconia abutments [24].

Zirconia abutments have esthetic advantages but, even when designed by a CAD/CAM system to improve the adaptation to the implant platform, they usually exhibit lower reverse torque levels than titanium abutments. This result may be a consequence of the greater rotational mismatch of the components, even those obtained by a CAD/CAM system, in comparison to abutments with a metallic base [19]. Furthermore, according to Binon [5], ceramic abutments cannot be machined to the same degree of precision as metal abutments.

A systematic review displayed that there were no statistically significant differences in the general performance of ceramic and metal abutments. Ceramic abutments exhibit similar survival rates and complications to metallic abutments [25]. The present study found that zirconia abutments are more frequently associated with loosening of fixation screws, due to the availability of a lower preload after application, in comparison with titanium abutments.

Conclusion

Our research concluded that titanium abutments showed high resistance to screw loosening when compared to the zirconia abutments, suggesting that the type of material comprising on a implant prosthetic will influence the amount of torque required to cause screw loosening. The first preload applied to the screw tends to loosen more easily than the last torque applied in the same screw.

Conflict of Interest

None of the authors had any financial or personal conflict of interest with regard to this study.

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Bibliography

1. Weiss EI, et al. "Effect of repeated closures on opening torque values in seven abutment-implant systems". *The Journal of Prosthetic Dentistry* 84.2 (2000): 194-199.
2. Jorneus L, et al. "Loads and designs of screw joints for single crowns supported by osseointegrated implants". *The International Journal of Oral and Maxillofacial Implants* 7.3 (1992): 353-359.
3. Versluis A, et al. "Numerical analysis of a dental implant system preloaded with a washer". *The International Journal of Oral and Maxillofacial Implants* 14.3 (1999): 337-341.
4. Lewis SG, et al. "The UCLA abutment: a four-year review". *The Journal of Prosthetic Dentistry* 67.4 (1992): 509-515.
5. Binon PP. "Implants and components: entering the new millennium". *The International Journal of Oral and Maxillofacial Implants* 15.1 (2000): 76-91.
6. Taylor TD and Agar JR. "Twenty years of progress in implant prosthodontics". *The Journal of Prosthetic Dentistry* 88.1 (2002): 89-95.
7. Andersson B, et al. "Alumina ceramic implant abutments used for single-tooth replacement: a prospective 1 to 3 year multi-center study". *International Journal of Prosthodontics* 14.5 (2001): 432-438.

8. Jung RE., et al. "In vitro color changes of the covering mucosa caused by restorative materials". *The International Journal of Periodontics and Restorative Dentistry* 27.3 (2007): 251-257.
9. Garine WN., et al. "Measurement of the rotational misfit and implant-abutment gap of allceramic abutments". *The International Journal of Oral and Maxillofacial Implants* 22.6 (2007): 928-938.
10. Jung RE., et al. "A systematic review of the 5-year survival and complication rates of implant-supported single crowns". *Clinical Oral Implants Research* 19.2 (2008): 119-130.
11. Scarano A., et al. "Bacterial adhesion on commercially pure titanium and zirconium oxide disks: an in vivo human study". *Journal of Periodontology* 75.2 (2004): 292-296.
12. Belser UC., et al. "Outcome analysis of implant restorations located in the anterior maxilla: A review of the recent literature". *The International Journal of Oral and Maxillofacial Implants* 19.Suppl (2004): 30-42.
13. Lee J., et al. "Wave analysis of implant screw loosening using an air cylindrical cyclic loading device". *The Journal of Prosthetic Dentistry* 88.4 (2002): 402-408.
14. Jemt T. "Failures and complications in 391 consecutively inserted fixed prostheses supported by Bränemark implants in edentulous jaws: a study of treatment from the time of prosthesis placement to the first annual checkup". *The International Journal of Oral and Maxillofacial Implants* 6.3 (1991): 270-276.
15. Kirkwood BR and Sterne JAC. "Medical statistics". Massachusetts: Blackwell, 2003.
16. Merz BR., et al. "Mechanics of the implant-abutment connection: An 8-degree taper compared to a butt joint connection". *The International Journal of Oral and Maxillofacial Implants* 15.4 (2000): 519-526.
17. Siamos G., et al. "Relationship between implant preload and screw loosening on implant-supported prostheses". *The Journal of Oral Implantology* 28.2 (2002): 67-73.
18. McGlumphy EA., et al. "Implant screw mechanics". *Dental Clinics of North America* 42.1 (1998): 71-89.
19. Haack JE., et al. "Elongation and preload stress in dental implant abutment screws". *International Journal of Oral & Maxillofacial Implants* 10.5 (1995): 529-536.
20. Shigley JE. et al. "Mechanical engineering design". 3rd ed. New York: McGraw Hill (1977): 240-245.
21. Burguete RL., et al. "Tightening characteristics for screwed joints in osseointegrated dental implants". *Journal of Prosthetic Dentistry* 71.6 (1994): 592-599.
22. Tan KB and Nicholls JI. "Implant-abutment screw joint preload of 7 hex-top abutment systems". *International Journal of Oral & Maxillofacial Implants* 16.3 (2001): 367-377.
23. Andersson B., et al. "Single-tooth restorations supported by osseointegrated implants: results and experiences from a prospective study after 2 to 3 years". *International Journal of Oral & Maxillofacial Implants* 10.6 (1995): 702-711.
24. Glauser R., et al. "Experimental zirconia abutments for implant-supported singletooth restorations in esthetically demanding regions: 4-year results of a clinical study". *International Journal of Prosthodontics* 17.3 (2004): 285-290.
25. Zembic A., et al. "Randomized controlled clinical Trial of customized zirconia and titanium implant abutments for single-tooth implants in canine and posterior regions: 3-year results". *Clinical Oral Implants Research* 20.8 (2009): 802-808.

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