JO JOURNAL OF OSSEOINTEGRATION periodontics and prosthodontics

Effect of changes in implants and cyclic loading in the abutment screw loosening

M. G. S. VALENTE[1], A. C. L. FARIA[2], R. F. RIBEIRO[3], S. S. ROCHA[4]

[1]MSc in Dentistry, Federal University of Goias, Goiânia, Brazil
[2]DDS, MSc, PhD, Laboratory Specialist, Dept. of Dental Materials and Prosthodontics, School of Dentistry of Ribeirao Preto, University of Sao Paulo, Brazil
[3]DDS, MSc, PhD, Titular Professor, Dept. of Dental Materials and Prosthodontics, School of Dentistry of Ribeirao Preto, University of Sao Paulo, Brazil
[4]DDS, MSc, PhD, Associate Professor, Department of Oral Rehabilitation and Prevention, School of Dentistry, Federal University of Goias, Goiânia, Brazil

TO CITE THIS ARTICLE
Valente MGS, Faria ACL, Ribeiro RF, Rocha SS. Effect of changes in implants and cyclic loading in the abutment screw loosening. J Osseointegr 2020;12(2):167-171.

DOI 10.23805 /JO.2020.12.02.13

ABSTRACT

Aim The aim of this study was to evaluate the effects of internal torque at external hex implants and cyclic loading in the abutment screw loosening.

Materials and methods Twenty external hex implants associated with estheticone abutments were divided into two groups: ten conventional, and ten internal torque. Torque loss were evaluated with digital torquemeter before and after 74,000 cycles of cyclic loading at 4.4 Hz frequency. One sample of implant/abutment assembly of each group was analyzed by scanning electron microscope. The data were analyzed by linear mixed model with a significance level of 5%.

Results All abutments presented torque loss. Prior to cycling loading, torque loss was 31.51% for conventional implants and 28.14% for internal torque ones. After cyclic loading, torque loss increased significantly for both conventional (59.27%, $p=0.002$) and internal torque (62.22%, $p<0.05$) implants sets. There was no significant difference between the implants before ($p=0.742$) and after ($p=0.805$) cyclic loading.

Conclusion Changes in external hexagon implant for internal torque connection did not interfere with abutment screw loosening.

KEYWORDS Cyclic loading, Dental implants, Torque.

INTRODUTION

Screw loosening has been a problem in implant-supported prosthesis, especially in single crowns (1-4), possibly leading to fracture of the abutment screw, abutment and implant, as well as resorption of the peri-implant bone (5). There are multiple reasons for screw loosening, but non axial loading in the prosthesis is the most evident. Then, appropriate implant-abutment connection, implant position and occlusion are recommended to control or avoid screw loosening, extending prosthesis prognosis. An event that predictably leads to loosening is the mechanical loading that chewing forces exert on prosthesis and screwed connections (6).
Understanding biomechanical aspects involved in the prosthesis/abutment/implant connection (5) is necessary to manage screw loosening and avoid gaps for bacteria passage, which can lead to inflammatory reactions in the peri-implant soft tissues (7).
Studies that have focused in the screw loosening of external hexagon implants observed a decrease in detorque when screws are submitted to tightening/retightening and/or cyclic loading (5,8). The cyclic loading is used to simulate chewing, approaching to the oral environment. Then, this methodology allows the reproduction of clinical conditions predicting the performance of implants and their components (9).
To improve the prognosis of implant-supported prostheses, implant/abutment connections have been researched to develop different designs and implant systems (10), as the external hexagon implants (EH) with internal torque, for example. The EH implants with internal torque were created to overcome a limitation of conventional EH implants, whose installation performed with the aid of an assembler could deform faces of the hexagonal platform depending on the applied torque, impairing the

anti-rotational effect and fit of a single prosthesis (11,12). David et al. (2008) (12) recommend the use of EH implant of internal torque when implant placement can generate a torque higher than 60 Ncm. These implants of internal torque present reduced length of the internal threads for installation of adaptation key, but it is unknown if this reduction of threads interferes with stability of abutments and resistance of prosthetic screws.

Thus, the aim of this study was to evaluate if there is difference at abutment screw loosening between conventional and internal torque external hexagon implants before and after cyclic loading. The null hypothesis is that abutment screw loosening is not affected by internal torque external hexagon implants or cyclic loading.

MATERIALS AND METHODS

In the present study, 20 external hexagon implants (EH) measuring 10 mm in length and 3.75 mm in diameter (Titanium Fix, São José dos Campos, Brazil) were used with 20 abutments of 1.0 mm trans-mucosal height (Estheticone, Titanium Fix, São José dos Campos, Brazil). They were divided into two groups: conventional (n=10), to be used with assembler; and internal torque (n=10).

The implants were embedded in a stainless-steel cylinders measuring 26 mm diameter x 24.5 mm height with an orifice whose internal walls matched implant dimensions. Abutments were installed at the implants with digital torquemeter (TQ-680, Instrutherm, São Paulo, Brazil) mounted on a device developed by the Department of Dental Materials and Prostheses of the School of Dentistry of Ribeirão Preto, University of São Paulo (Brazil). A torque of 20 N.cm was applied, and 5 minutes later, the removal torque was analyzed (T0). Then, a torque was applied again, samples were submitted to cyclic loading and the removal torque after cyclic loading was evaluated (T1). Torque loss was evaluated as percentage of loss before (T0) and after cyclic loading (T1).

The implant/abutment assemblies were submitted to cyclic loading using an equipment developed by the Department of Dental Materials and Prostheses of the School of Dentistry of Ribeirão Preto, University of São Paulo (Brazil). This equipment simulates masticatory movements through a lever arm that moves an acrylic recipient, where assemblies were immersed, with a 265 cycles/min speed and a 10 mm course, resulting in a linear speed of 88 mm/s. Over the acrylic recipient, there is a pole with a vertical adjustment; when released, the pole could rest over the implant/abutment assembly. A 26 mm diameter x 18.2 mm height stainless-steel cylinder was prepared to be installed in the lower tip of the pole; the base of the cylinder was machined into a 30° conical shape, simulating the cuspal inclination of an antagonist tooth. Once the pole was completely released, a total weight of 2 kg was applied over the implant/abutment assembly. During the tests, the implant/abutment assemblies and the antagonist device were completely immersed in deionized water. This mechanical loading device was designed according to the norm ISO/TS 14569-2 (Dental Materials – Guidance on testing of wear – Part 2: Wear by two – and/or three body contact, 2001) under the Freiburg Method. Each mechanical loading test was carried out for 20,5 h, performing a total of 74.000 cycles, which corresponded to 3 months of oral function.

The percentage of torque loss before and after cyclic loading was analyzed by mixed linear model where groups are independent, but torque loss before and after cyclic loading are grouped and independence of results cannot be assumed. For this, the statistical software IBM SPSS Statistics 20 was used (IBM SPSS software, IBM Corporation) and a significance level of 5% (α = 0.05) was assumed.

For qualitative analysis of implant/abutment/screw interface, one implant/abutment assembly of each group was embedded in polystyrene resin, longitudinally sectioned and analyzed in a scanning electron microscope (Leo Stereoscan 420i, Leica Electron Optics, Cambridge Instruments, Cambridge, United Kingdom). One implant/abutment assembly of each group that were not submitted to cyclic loading, was analyzed for comparison with an assembly submitted to cyclic loading.

Groups		N	Torque loss means (SD)
	T0	10	31.51 (18.69)
Conventional	T1	10	59.27 (25.35)
	T0	10	28.14 (25.76)
Internal torque	T1	10	62.22 (27.31)

TABLE 1 Mean and standard deviation of torque loss (%) of groups. After cyclic loading (T1) both conventional and internal torque presented bigger torque loss than before cyclic loading (T0).

RESULTS

The torque loss of the groups, before and after loading, are shown in Table 1.

Conventional and internal torque implants were statistically similar (p=0.983), but cyclic loading increased torque loss of abutments (p<0.05). Considering that groups cyclic loading was not significant (p=0.577), both groups presented the same behavior, increasing torque loss after cyclic loading (Fig. 1).

Figure 2 presents micrographs of the implant/abutment/screw interfaces of assemblies submitted or not to cyclic loading. Before cyclic loading, there is no difference between conventional (Fig. 2A) and internal torque (Fig.

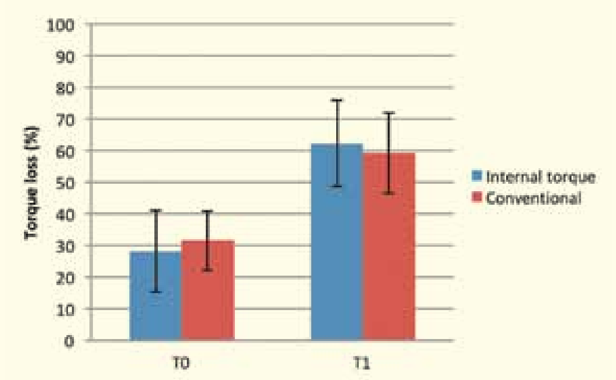

FIG. 1 Percentage of torque loss of conventional and internal torque implants, before and after cyclic loading.

2B) in the interface of screw abutment and internal threads of the implant. After loading (Fig. 2C, 2D), images suggest that conventional implants deform in the apical region of the screw (Fig. 2C, arrow).

DISCUSSION

The null hypothesis was partially rejected because no significant difference of torque loss was noted between conventional and internal torque EH implants, but cyclic loading increased the percentage of torque loss.

The stability of the abutment/implant connection and susceptibility to screw loosening are influenced by the preload. A greater preload increases resistance to loosening and joint stability. When a screw is tightened, the torque applied in the screw head is transferred to the interface between abutment screw threads and the implant bore threads, called preload (13). In this process, the screw act as a spring, elongating and placing the stem and threads in tension, and the screw elastic recovery creates the force responsible to maintain the abutment joined to the implant (14-17). Preload can be influenced by many factors such as screw coefficient of friction, surface composition, metallurgic properties and torque applied (15).

When torque is applied to a new screw, the coefficient of friction is higher and part of the energy is expended in smoothing surface irregularities for maintaining the surfaces (5,10,15).

The present study showed that there was significant torque loss in both the conventional and internal torque groups, before and after cyclic loading (Table 1, Fig. 1). These results corroborate other studies that observed a decrease in screw detorque after submitting to successive tightening and loosening, followed or not by cyclic loading (5,8,18-21).

Contrarily, Tsuge et al. (22) observed higher values of detorque in abutments after 106 cycles. This difference can be attributed to methodological differences once the authors tested different implant connections (EH and IH - internal hexagon), the composition of screws is different (titanium and gold), the cyclic loading used is different (centric and eccentric movements), and the presence of a structure cemented on the abutments.

Similarly, Tzenakis et al. (23) found a higher preload after repeating 10 times the tightening of the same screw, recommending the used prosthetic screw. However, these authors used gold screws that presents a coefficient of friction smaller than titanium (14) used in the present

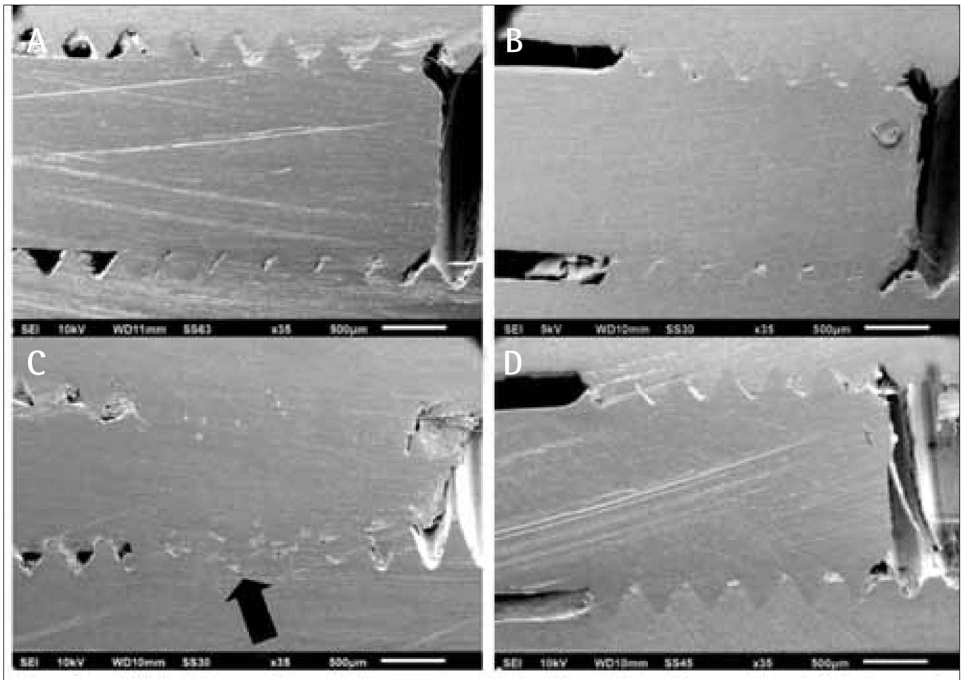

FIG. 2 SEM images of the implant/abutment/screw assemblies at a 35X magnification.
A: Conventional EH before loading;
B: Internal torque EH before loading;
C: Conventional EH after loading;
D: Internal torque EH after loading.

study. Additionally, the gold screws were lubricated to reduce the coefficient of friction.

In the present study, torque loss of conventional group (31.51%) prior to cyclic loading can be considered high (Table 1). Barbosa et al. (2011) (2) showed a torque loss of 50.71% for new screws submitted to the first tightening/untightening cycle. This torque loss in the first detorque can be partially explained by smoothening of the screw surfaces, as evidenced by scanning electron microscopy (Fig. 2) (20,24).

There were no statistically significant differences between groups before (p=0.052) or after (p=0.356) cyclic loading. Then, the structural difference between conventional and internal torque EH implants, that is the number of internal threads, did not affect torque loss. Although there is a reduction of six threads, which represents 46%, in the internal torque connection, the torque loss was not reduced. The results suggest that the reduced number of internal threads of internal torque connection did not influence screw loosening, confirming the null hypothesis that screw torque loss was not affected by conventional and internal torque EH implants. The results of the present study show that there are other factors more related to preload loss (screw lubrication, new or used screw, the material type, the abutment connection type and applied torque) (25,26) than the number of threads.

The coefficient of friction is inversely proportional to the preload and depends on thread hardness, surface finish and tightening speed. The presence and quantity of lubricant (saliva, peri-implant fluid, and/or blood) between the implant's connecting components, which is clinically unpredictable, can also affect the coefficient of friction (14).

The abutments used in this study remained in the preload condition for 5 minutes after each application of torque, following a protocol used in previous studies (8,23,27). Although other studies published a time of 10 minutes for screw stabilization (20,22), Tzenakis et al. (23) argue that a longer time might even further reduce the preload by means of the screw elongation process, but this reduction would not be significant.

Abutments were submitted to cyclic loading without a crown. Then, the direct action probably exacerbated the impact of loading, encouraging a smaller number of cycles when compared to other studies (18,19,22). Ricciardi Coppedê et al. (27) simulated less time of masticatory function, approximately 4 days, and considered sufficient to promote increased retention of abutments in Morse cone implants that were submitted to cyclic loading in comparison to those that were not.

The microscopic analysis (Fig. 2) of the implant/abutment/screw interface showed greater deformation of conventional EH implants after cyclic loading, corroborating other studies that also observed modifications in the screws submitted to mechanical tests (19,20).

Modifications implemented to the internal torque EH implants showed advantages over conventional ones. They preserve dimensions of implant platform for an adequate prosthesis fit, while conventional EH implants that use their platforms for their insertion can compromise abutment stability. In addition, Davi et al. (12) recommended the use of internal torque EH implants when implant placement can generate high torques.

This *in vitro* study is limited to simulate the complexity of the oral environment, but it is important to guide professionals about the dynamic principles involved in the installation and function of prosthetic abutments. However, further studies are necessary to investigate other factors that may interfere with the torque loss of the abutment screws, including coefficient of friction, type of material of the components and applied torque, especially under the effect of cycling loading.

CONCLUSION

Within the limitations of this *in vitro* study, it is possible to conclude that the modifications of the internal torque EH implants did not influence the torque loss of the abutments in relation to the conventional EH, and the torque loss occurred before and after cycling loading, regardless of implant type, but cyclic loading increased torque loss.

Acknowledgments:

We gratefully acknowledge Titanium Fix (São José dos Campos, Brazil) for providing the implant components examined in this study.

Contributions

All authors contributed equally to the work.

Conflict of interests:

The authors declare no potential conflict of interests.

REFERENCES

1. Goodacre CJ, Bernal G, Rungcharassaeng K, et al. Clinical complications with implants and implant prostheses. J Prosthet Dent 2003;90:121-32.
2. Naert I, Quirynen M, van Steenberghe D, et al. A study of 589 consecutive implants supporting complete fixed prostheses. Part II: Prosthetic aspects. J Prosthet Dent 1992;68:949-56.
3. Schwarz MS. Mechanical complications of dental implants. Clin Oral Implants Res 2000;11:156-8.
4. Winkler S, Ring K, Ring JD, et al. Implant screw mechanics and the settling effect: overview. J Oral Implantol 2003;29:242-5.
5. Weiss EI, Kozak D, Gross MD. Effect of repeated closures on opening torque values in seven abutment-implant systems. J Prosthet Dent 2000;84:194-9.
6. Khraisat A, Abu-Hammad O, Al-Kayed AM, et al. Stability of the implant/abutment joint in a single-tooth external-hexagon implant system: clinical and mechanical review. Clin Implant Dent Relat Res 2004;6:222-9.
7. Calcaterra R, Di Girolamo M, Mirisola C, et al. Effects of Repeated Screw Tightening on Implant Abutment Interfaces in Terms of Bacterial and Yeast Leakage in Vitro: One-Time Abutment Versus the Multiscrewing Technique. Int J Periodontics Restorative Dent 2016;36:275-80.
8. Cardoso M, Torres MF, Lourenço EJ, et al. Torque removal evaluation of prosthetic screws after tightening and loosening cycles: an in vitro study. Clin Oral Implants

Res 2012;23:475-80.
9. Rangel PM, Paulo GP, Gonçalves MC, et al. Torque de remoção de parafusos em pilares protéticos com conexão tipo hexágono interno após ciclagem mecânica. Cienc Odontol Bras 2007;10:76-81.
10. Binon PP. The effect of implant/abutment hexagonal misfit on screw joint stability. Int J Prosthodont 1996;9:149-60.
11. Bozkaya D, Müftü S. Mechanics of the tapered interference fit in dental implants. J Biomech 2003;36:1649-58.
12. Davi LR, Golin AL, Bernardes SR, et al. In vitro integrity of implant external hexagon after application of surgical placement torque simulating implant locking. Braz Oral Res 2008;22:125-31.
13. Byrne D, Jacobs S, O'Connell B, et al. Preloads generated with repeated tightening in three types of screws used in dental implant assemblies. J Prosthodont 2006;15:164-71.
14. Burguete RL, Johns RB, King T, et al. Tightening characteristics for screwed joints in osseointegrated dental implants. J Prosthet Dent 1994;71:592-9.
15. Haack JE, Sakaguchi RL, Sun T, et al. Elongation and preload stress in dental implant abutment screws. Int J Oral Maxillofac Implants 1995;10:529-36.
16. Jörnéus L, Jemt T, Carlsson L. Loads and designs of screw joints for single crowns supported by osseointegrated implants. Int J Oral Maxillofac Implants 1992;7:353-9.
17. Wang RF, Kang B, Lang LA, et al. The dynamic natures of implant loading. J Prosthet Dent 2009;101:359-71.
18. Assunção WG, Barão VA, Delben JA, et al. Effect of unilateral misfit on preload of retention screws of implant-supported prostheses submitted to mechanical cycling. J Prosthodont Res 2011;55:12-8.
19. Delben JA, Gomes EA, Barão VA, et al. Evaluation of the effect of retightening and mechanical cycling on preload maintenance of retention screws. Int J Oral Maxillofac Implants 2011;26:251-6.
20. Guzaitis KL, Knoernschild KL, Viana MA. Effect of repeated screw joint closing and opening cycles on implant prosthetic screw reverse torque and implant and screw thread morphology. J Prosthet Dent 2011;106:159-69.
21. Siadat H, Najafi H, Alikhasi M, Falahi B, Beyabanaki E, Zayeri F. Effect of lateral oblique cyclic loading on microleakage and screw loosening of implants with different connections. J Dent Res Dent Clin Dent Prospects 2018;12:183-9.
22. Tsuge T, Hagiwara Y. Influence of lateral-oblique cyclic loading on abutment screw loosening of internal and external hexagon implants. Dent Mater J 2009;28:373-81.
23. Tzenakis GK, Nagy WW, Fournelle RA, et al. The effect of repeated torque and salivary contamination on the preload of slotted gold implant prosthetic screws. J Prosthet Dent 2002;88:183-91.
24. Barbosa GS, Silva-Neto JP, Simamoto-Júnior PC, et al. Evaluation of screw loosening on new abutment screws and after successive tightening. Braz Dent J 2011;22:51-5.
25. Guda T, Ross TA, Lang LA, et al. Probabilistic analysis of preload in the abutment screw of a dental implant complex. J Prosthet Dent 2008;100:183-93.
26. Jörn D, Kohorst P, Besdo S, et al. Influence of lubricant on screw preload and stresses in a finite element model for a dental implant. J Prosthet Dent 2014;112:340-8.
27. Ricciardi Coppedê A, Mattos MG, Rodrigues RC, et al. Effect of repeated torque/mechanical loading cycles on two different abutment types in implants with internal tapered connections: an in vitro study. Clin Oral Implants Res 2009;20:624-