Original Article

Evaluation of original and non-original abutment screw with reverse torque values after dynamic loading: an in-vitro study

Chia-Chen Chang, DDS, MDS[ab]
Hung-Shyong Chen, MS[c]
Aaron Yu-Jen Wu, DDS, MS[d*]

[a]Department of Dentistry, Kaohsiung Chang Gung Memorial Hospital
[b]Department of Dentistry, Kaohsiung Municipal Feng Shan Hospital-Under the management of Chang Gung Medical Foundation.
[c]Department of Mechanical Engineering, Cheng Shiu University, Kaohsiung 833, Taiwan
Center for Environmental Toxin and Emerging-Contaminant Research, Cheng Shiu University, Kaohsiung 833, Taiwan
[d]Department of Dentistry, Kaohsiung Chang Gung Memorial Hospital and Chang Gung University College of Medicine, Kaohsiung, Taiwan.

Running title: reverse torque using different screws

***Corresponding author:**
Aaron Yu-Jen Wu, DDS, MS
Department of Dentistry, Kaohsiung Chang Gung Memorial Hospital
No. 123, Ta-Pi Road, Kaohsiung 833, Taiwan
Tel : +886-7-7317123 ext 2378
Fax: +886-7-7317123 ext 8288
Email: dentwu@hotmail.com

DOI: 10.6926/JPI.202403_13(1).0001

Abstract

Objective: *This in vitro study aimed to assess how eccentric cyclic loading affects abutments and screws in internal hexagon implant systems from different manufacturers.*

Materials and methods: *The internal hex implant system, Biomet 3i, was tested. The experiments were performed using original screws, replica screws, original abutments, and replica abutments. Nine combinations (three samples from each of three groups) were assessed. The implant body was firmly held in a special jig and the abutment screws were tightened to the manufacturers' recommended torque with a digital torque gauge. A cyclic loading of 400 N was applied at 30 degrees to the implant for 50,000 cycles. The reverse torque value (RTV) of the abutment screw was measured before and after the loading process. The data were analyzed with one-way analysis of variance and post hoc tests, with the significance level set to $P < 0.05$.*

Results: *The post-loading RTV was significantly higher than the initial pre-loading RTV. The groups with original abutments and replica screws had the highest RTV whether measured before or after loading.*

Conclusions: *This study shows that the screw material has an impact on the RTV. Scanning electron microscopic(SEM) analysis showed that the replica screws were made of a material similar to that of the original screws. The test groups using replica screws demonstrated higher RTV than those using original screws. Therefore, replica screws could be an alternative for clinical use.*

Key words: Dental implant screw fracture, reverse torque value, non-original, original, screw

Introduction

Dental implant treatment has greatly improved the edentulous patient's masticatory, aesthetic, and phonetic functions compared to traditional prostheses.[1,2] Implant technology certainly provides better options for clinicians and patients. However, for implantologists, implant screw loosening or fracture is a difficult clinical complication to deal with when making a single implant-supported prosthesis. In addition, longitudinal follow-up studies show that abutment screw loosening is surpassed by loss of osseointegration as the main cause of failure of implant-supported restorations.[3] In previous studies, the rate of incidence of abutment screw loosening reached 5.3% in the first year after loading[4] and 5.8–12.7% after the five-year follow-up.[5] Dental implant screw loosening and fracture complications can be as high as 45% over a 10-year period. Such loosening is an indicator of inadequate biomechanical design and/or occlusal overload.[6]

An important mechanical factor that prevents abutment screw loosening and fracture is screw joint preload. When the screw is tightened, tension force is generated between the abutment and inner connector of the implant along the screw thread surfaces; this force is a direct determinant of clamping force.[7] The optimum preload of the screw is generally believed to occur when the screw is elongated without exceeding its yield strength. The preload is related to the implant screw material. The most common materials for dental screws are titanium and gold alloys. The friction between the metallic surface of screws and abutments reduces the preload; therefore, lubrication or gold-coated abutment screws are commonly used to minimize the preload loss.[8]

Because of the current advancements in replication technology, such as CAD/CAM , replica screws or abutments provide the benefits of cost saving and accessibility to clinical dentists. Park et al.[9] compared the torque loss of four abutment groups and found that the torque loss of the original abutments was significantly lower than that of the imitations. Alonso-Pérez et al.[10] found that the internal fit of the connection was crucial to the mechanical behavior of the assembly and suggested that the original components could be surpassed . However, there is little discussion in the literature about the feasibility of original screws or non-original screws for implant treatments. The purpose of this in-vitro study was to evaluate the performance of screws and abutments from different manufacturers by comparing reverse torque values (RTVs) before and after loading.

Material & methods

The imitation screws and abutments in the experiment were from aftermarket manufacturers (JingGang, Tainan, Taiwan). Implants (ϕ 4.1 × 10 mm Osseotite®, Biomet 3i, USA) and screws (Gold-Tite®, 3i Implant Innovations, Inc. West Palm Beach, FL, USA) were selected. Then, the test groups were divided into three smaller sub-groups: IA was the control group using an original titanium

Figure 1. Digital torque gauge (TOHNICHI BTGE50CN-G) (Tokyo, Japan, Tohnichi Mfg.)

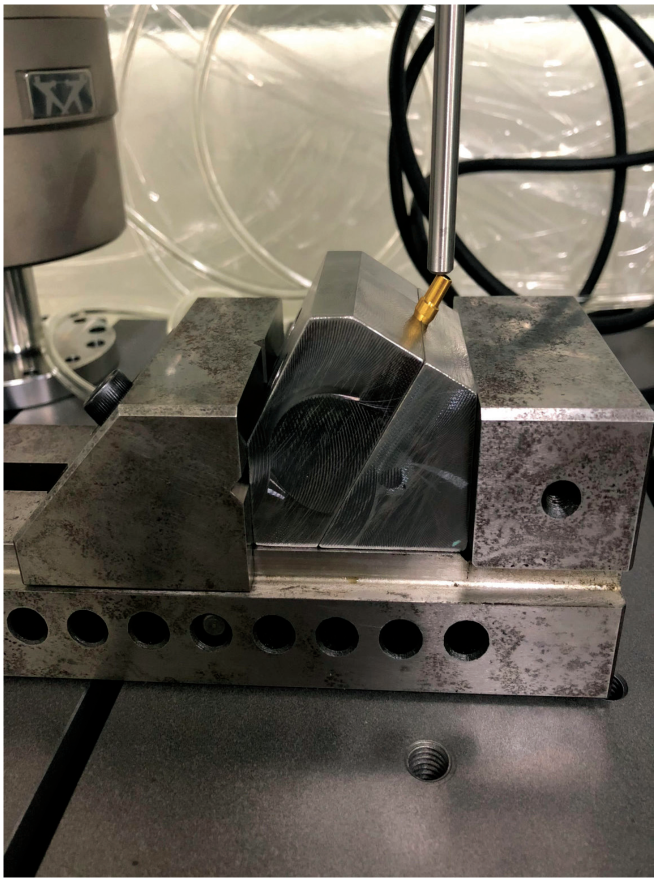

Figure 2. Testing machine (INSTRON E3000) (Norwood, MA, USA, Instron corporation)

alloy abutment and original screw; the IB group used an original titanium abutment with a factory-replicated screw; and the IC group used a factory-replicated titanium abutment with a factory-replicated screw. Each sub-group was measured three times to obtain a total of nine samples.

The RTVs of each set of samples were recorded before applying the load with a torque wrench with 20 N-cm torque to tighten the implant abutment screw and after 10 minutes, to re-tighten it again at the same torque value. Then, after another 5 minutes, a digital torque meter (Fig. 1) was used to measure the peak of the RTV, defined as RTV (T), prior to applying stress.

Each set of samples was fixed with a metal jig, and a force was applied using a servo-driven load cell-type testing machine (Fig. 2). At room temperature, a cyclic load of 400 N was applied to the test groups at a tilted direction of 30 degrees. The load was applied at a frequency of 2 Hz for a total of 50,000 cycles. After the cyclic load process was completed, RTV (T) was measured with the same digital torque meter after applying the load.

Statistical analysis

The factors associated with changes in RTV were statistically analyzed at an alpha value of 0.05. Linear model analysis was performed for all RTVs measured for each sample. One-way analysis of variance (ANOVA) and post hoc tests were also performed to examine the effects of screws and abutments from different manufacturers on the RTV before and after loading. The Sphericity Assumed Test was performed to examine the changes in the RTV prior to and following cyclic loading in the 3i test groups.

Results

The abutments and screws, including their surfaces and cross-sections, were analyzed using energy-dispersive X-ray spectroscopy (EDS) (JEOL Ltd., Ota, Tokyo, Japan). The composition of their materials is shown in Table 1.

Table 2 shows the RTVs before and after loading measured with a digital torque meter. The RTV (T) of all test samples prior to applying stress was less than the original tightening torque value of 20 N. Group IB (original abutment/duplicated screw) showed the highest T value, followed by group IC (duplicated abutment/duplicated screw). Group IA (original abutment/original screw) had the smallest T values, which were almost reduced by half (45%). ANOVA showed a statistically significant difference in the RTVs before loading between the three groups ($P < 0.001$).

Table 1. Material Composition of Biomet 3i® Abutment and Screw/ Duplicated Abutment and Screw

Biomet 3i®	Material Composition (%)
Original abutment	Ti87% Al8% Si2% V3%
Duplicated abutment	Ti87% Al9% Si1% V2%
Original screw (section)	Fe60% Cr20% Ni13% Mo3% Mn2% Si2%
Original screw (surface)	Au85% Fe3% C10% Cr2%
Duplicated screw	Ti89% Al7% Si1% V1%

Table 2. Initial and post-loading reverse torque values (RTV) of Groups, and the differences between initial and post-loading RTV

Group	Implant system	Abutment/Screw	Applied torque	Initial RTV Ncm(%)	Post-loading RTV Ncm (%)	Difference between initial and post-loading RTV (Ncm)
IA	3i®	Original/original	20	9.13(45%)	12.56(62%)	3.43
IB	3i®	Original/duplicated	20	15.57(77%)	19.58(96%)	4.01
IC	3i®	Duplicated/duplicated	20	13.17(68%)	16.16(84%)	2.99

Unit: Ncm, ( ): Percentage Change

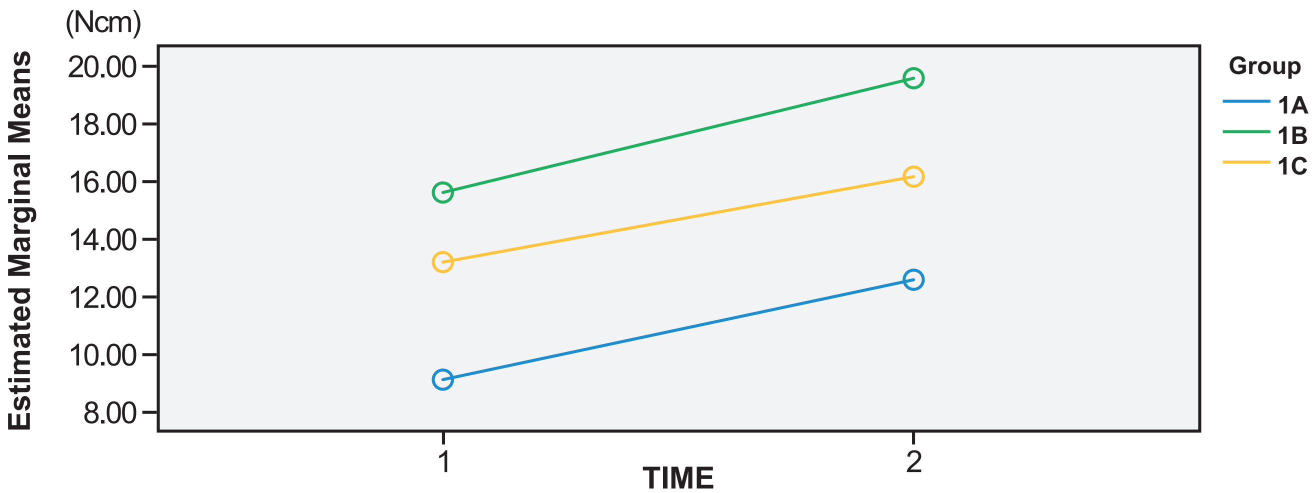

Figure 3. Distribution of reverse torque value before and after loading of 3I group. Time 1: Before loading, Time 2: After loading

The RTVs were higher after the mechanical loading process than before loading. The RTV (T) after loading differed significantly between the three groups (P < 0.001). The RTV (T) of IB was the highest, followed by that of IC, with IA having the lowest value. The RTV of IA before loading was 45% of the set value (20 N), and it increased by 17% after loading.

The results of ANOVA to evaluate the differences between test sets showed that RTV differed significantly between pre-loading and post-loading. The post-loading RTV was significantly greater than the pre-loading RTV (Fig. 3). Post hoc tests showed that the RTV differed significantly between the three sub-groups both before and after loading (P < 0.05).

Discussion

According to Bickford,[11] the screw loosening process has two stages. The first stage is initial tensile deformation of the screw, leading to a reduction in the clamping force. In the second stage, as the clamping force is further reduced, the fretting of the implant abutment interface intensifies, resulting in an unstable connection and ultimately screw loosening. Currently, two methods are described in the literature to estimate the preload force. One method uses a tension machine to measure the tension force generated by the tightening of the screw.[8] Although this method is more accurate, detectors cannot be fitted on the actual implant surface due to size constraints. Most researchers believe that the preload force and screw-tightening torque forces are closely correlated. Therefore, the common practice is to use the RTV to assess the change in the preload force. Some researchers[12, 13, 14, 15] have suggested that the screw should be retightened after the initial tightening in order to reduce the preload loss caused by the creeping movement of all the metal-contacting surfaces after being tightened together by the screw. This study also performed the procedure for retightening the screw with 20 N-cm torque 10 minutes after the first tightening.

During the experiment, all samples had a pre-loading RTV lower than the applied locking force of 20 N-cm. We accounted for the settling effect by relocking the screw after 10 minutes of the initial tightening. This phenomenon occurred because the friction between the abutment and the screw or the friction between the screw and the internal interface of the implant, as well as the resilience of the metal material, offset part of the applied force.

It is generally believed that a smaller friction coefficient of the screw results in higher preload with the same settling torque,[8] so coated screws or lubricants, like Gold-Tite® Screw, are used. However, our study found that the RTV of group IA (original abutment and original screw) was the lowest among the three groups, both before and after loading. These results are similar to the findings of Tsuge and Hagiwara,[7] but different from those of Martin et al.,[16] who reported that preload in gold alloy abutment screws was significantly greater than that in titanium alloy abutment screws. The gold alloy abutment screws used in the two studies might have had some differences. This study analyzed the surface and inner layer of screws and abutments using SEM and EDS. The surface area of the Gold-Tite® screw was coated with gold, but internally it was mainly composed of iron and chromium. The composition of the screws also differed between the two studies. The screw used in Martin et al.'s study contained 80% Pd alloy, whereas the screw used in Tsuge and Hagiwara's study was composed of 60% Au alloy. However, our results showed that the pre-loading RTV of gold-coated abutment screws dropped significantly compared to the original locking force (45%). We believe that the gold coating on screws prevented preload loss by reducing friction between the screw and abutment during tightening. However, it also decreased removal torque due to less wear.

The SEM analysis shows that our replica screws and Tsuge and Hagiwara's titanium alloy screws were composed of very similar materials. Therefore, if the material compositions of screws, such as titanium alloy screws and replica screws, are highly similar, their RTV data would be closely matched. Of course, third-party mechanical manufacturing capability would also have to be better or similar to the capabilities of the manufacturers of the original screws.

According to Huang et al.,[17] structural variability of the abutment may influence the stability of the implant abutment connection and, thus, preload loss. This would eventually lead to screw loosening. In the case of implant abutment materials, Jo et al.[18] compared the stability of joints made of three different titanium alloys. The preload and compressive bending strength values were significantly higher in the group made with Ti-6Al-4V compared to those made with pure grade 3 titanium or pure grade 4 titanium. Jo et al. analyzed abutment components, both original and duplicated, made of Ti-6Al-4V. Results showed original abutments had better preload stability than duplicated ones. In Park et al.'s study,[9] the removal torque of the original Straumann abutment was significantly higher than those of the copy abutments. Alonso-Pérez et al.[10] also showed that the internal fit of the connection was crucial to the mechanical behavior of the assembly, so the original components were superior.

Conclusions

The factors that contribute to the loosening of screws in implant abutment components are complex and include abutment connector and screw design, material, tightness, additional torque magnitude, and biomechanical factors. Loosening torque values in the laboratory are for informational purposes only and do not represent the actual clinical situation. This study aimed to determine whether parts manufactured by replication methods can be used clinically. The quality of original factory abutments is relatively stable, and titanium alloy screws present stable reverse torque values under both initial- and post-loading conditions.

References

1. Ring ME. A thousand years of dental implants: A definitive history—Part 1. Compend Contin Educ Dent 1995;16:1060, 1062, 1064.
2. Bornstein MM, Halbritter S, Harnisch H, Weber HP, Buser D. A retrospective analysis of patients referred for implant placement to a specialty clinic: Indications, surgical procedures, and early failures. Int J Oral Maxillofac Implants 2008;23:1109–16.
3. Hoyer SA, Stanford CM, Buranadham S, Fridrich T, Wagner J, Gratton D. Dynamic fatigue properties of the dental implant-abutment interface: joint opening in wide-diameter versus standard-diameter hex-type implants. J Prosthet Dent 2001;85:599-607.
4. Pjetursson BE, Thoma D, Jung R, Zwahlen M, Zembic A. A systemic review of the survival and complication rates of implant-supported fixed dental prostheses (FDPs) after a mean observation period of at least 5 years. Clin Oral Implants Res 2012;23 Suppl 6:22-38.
5. Pjetursson BE, Brägger U, Lang NP, Zwahlen M. Comparison of survival and complication rates of tooth-supported fixed dental prostheses (FDPs) and implant-supported FDPs and single crowns (SCs). Clin Oral Implants Res 2007;18 Suppl 3:97-113.
6. Patterson EA, Johns RB. Theoretical analysis of the fatigue life of fixture screws in osseointegrated dental implants. Int J Oral Maxillofac Implants 1992;7:26–33.
7. 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.
8. Stüker RA, Teixeira ER, Beck JC, da Costa NP. Preload and torque removal evaluation of three different abutment screws for single standing implant restorations. J Appl Oral Sci 2008;16:55-8.
9. Park JM, Baek CH, Heo SJ, et al. An in vitro evaluation of the loosening of different interchangeable abutments in internal-connection type implants. Int J Oral Maxillofac Implants 2017;32:350-5.
10. Alonso-Pérez R, Bartolomé JF, Ferreiroa A, Salido MP, Pradíes G. Original vs. non original abutments for screw-retained single implant crowns: an in vitro evaluation of internal fit, mechanical behavior and screw loosening. Clin Oral Implants Res 2018;29:1230-8.
11. Bickford J. An introduction to the design and behavior of bolted joints. 4th ed., CRC Press., New York, 1995; pp 24-35.
12. Haack JE, Sakaguchi RL, Sun T, Coffey JP. Elongation and preload stress in dental implant abutment screws. Int J Oral Maxillofac Implants 1995;10:529-36.
13. Binon PP. The external hexagonal interface and screw joint stability: a primer on threaded fasteners in implant dentistry. Quint Dent Technol 2000;23:91-105.
14. Barbosa GA, Bernardes SR, das Neves FD, Fernandes Neto AJ, de Mattos Mda G, Ribeiro RF. Relation between implant/abutment vertical misfit and torque loss of abutment screws. Braz Dent J 2008;19:358-63.
15. Spazzin AO, Henrique GE, Nóbilo MA, Consani RL, Correr-Sobrinho L, Mesquita MF. Effect of retorque on loosening torque of prosthetic screws under two levels of fit of implant-supported dentures. Braz Dent J 2010;21:12-7.
16. Martin WC, Woody RD, Miller BH, Miller AW. Implant abutment screw rotations and preloads for four different screw materials and surfaces. J Prosthet Dent 2001;86:24-32.
17. Huang Y, Wang J. Mechanism of and factors associated with the loosening of the implant abutment screw: A review. J Esthet Restor Dent 2019;31:338–45.
18. Jo JY, Yang DS, Huh JB, Heo JC, Yun MJ, Jeong CM. Influence of abutment materials on the implant-abutment joint stability in internal conical connection type implant systems. J Adv Prosthodont 2014;6:491-7.