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RESEARCH AND EDUCATION

Evaluation of implant abutment screw tightening protocols on reverse tightening values: An in vitro study

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ABSTRACT

Statement of problem. Implant abutment screw loosening is a common prosthetic complication of implant-supported crowns. However, reports that have objectively evaluated the effectiveness of different tightening protocols on reverse tightening values are sparse.

Purpose. The purpose of this in vitro study was to determine the optimal tightening protocol for implant abutment screws.

Material and methods. Fifty Neoss implants were randomly distributed to 5 groups (n=10). The implants received a cover screw and mounted, and the impression coping was tightened. Tightening was measured by using a digital measuring device. Then, the implant abutments were placed and tightened to 32 Ncm by using a Crystaloc screw. In Group 2T10I, the screws were tightened twice with an interval of 10 minutes between the first and second tightening. In Group 2T0I, the screws were tightened twice with no interval time. In Group 1T, the screws were tightened 1 time only. In Group TCT, the screws were tightened, counter-tightened, and then tightened again. In Group TCTCT, the abutment screws were tightened, counter-tightened, tightened, counter-tightened, and then tightened again. All the mounted implants were left in the same environment for 3 hours, and the reverse tightening values were then measured.

Results. The mean reverse tightening values of the first 4 groups ranged from 21.49 Ncm to 22.57 Ncm, whereas the reverse tightening value for the fifth group was 25.51 Ncm. A significant difference was found among the groups ($P<.05$) with reverse tightening data.

Conclusions. No significant difference was found in tightening the abutment screw 2 times with a 10-minute interval time, no interval time, or tightening it 1 time only. However, a significant difference was found in reverse tightening in the 3-time tightening and counter-tightening group. (J Prosthet Dent 2020;■:■-■)

Abutment screw loosening is the most common prosthetic complication with implant-supported restorations,[1] leading to abutment or crown mobility, screw fracture, or even bacterial leakage.[2] Screw loosening can be caused by factors such as inappropriate tightening,[3] poorly machined components, excessive loading, or screw and restoration design.[4,5] To have an optimum outcome, understanding how the screw joint works is essential. The screw is primarily subjected to 2 different types of forces, the force working on separating the parts, called the joint separating force, and the force trying to keep the components together, called the clamping force.[4]

Screw loosening occurs when the joint separating forces are higher than the clamping force.[6] The clamping force is equal in magnitude to the preload, which is the tension created in a screw, especially the threads, when applying a tightening force.[4,7] Excessive screw tightening can be counterproductive, as the screw may deform permanently, the thread become stripped, or the screw may fracture.[4,8,9]

Multiple devices have been used to tighten screws to the implant body,[10] the most commonly used being the mechanical torque-limiting device, which is recommended because of its accurate and precise tightening

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Clinical Implications

The interval time between tightening and retightening the implant abutment screw had no effect on RTV. However, to achieve the optimal RTV, a tighten-reverse-tighten-reverse-tighten protocol should be followed.

application.[11] Many different types of abutment screw materials are available, including the (Gold-Tite; Implant Innovations), (TorqTite; NobelBiocare), (Gold alloy (Ga); Implant Innovations), and (Titanium alloy (Ta); Implant Innovations). Ga screws have been preferred to Ta screws primarily because of the lower frictional resistance between the approximating male and female threads of titanium screws.[12] The lower friction improves seating and provides improved contact between the screw and the implant threads. A gold screw can develop a preload of more than twice that of a Ta screw.[13]

The tightening value is determined by factors that include the tightening force, the surface features of the abutment screw, the screw head design, the lubricant coating, and the abutment screw material.[4,10] Siamos et al[14] recommended retightening the screw after 10 minutes. They evaluated 2 different screw tightening protocols on abutments which were tightened once and abutments which were tightened and then retightened after 10 minutes. Tightening forces of 25, 30, 35, and 40 Ncm were tested. The authors concluded that retightening the abutment screw after 10 minutes should be performed routinely and recommended the tightening value be higher than 30 Ncm. According to the authors, this protocol would help in abutment screw joint stability and would reduce screw loosening.

Other authors have adopted this "tighten and wait 10 minutes, then retighten protocol." Khalili et al[15] examined 2 different retightening protocols, after 10 minutes and after 2 weeks, and the effect on the reverse tightened value. They reported that retightening increased the clamping force but found no significant difference between the 10-minute and the 2-week time. Reports that have objectively evaluated the effectiveness of the interval time between the initial implant abutment tightening and retightening are sparse, and studies on screw tightening protocol have not used a complete clinical screw tightening protocol, which might affect the screw thread morphology and ultimately the preload achievable. The null hypothesis for the present study was that no significant difference in tightening protocol would be found with regard to the reverse tightening value (RTV).

MATERIAL AND METHODS

Fifty 4-mm diameter implants (ProActive; Neoss) were used in this study. Each sample got a number from 1 to 50, then website (Randomizer.org) was used to randomly distribute the implants into 5 groups (Table 1); each group was assigned 10 implants (n=10). The implants were embedded in a light-polymerized composite resin (Triad Trutray; Dentsply Sirona) to ensure the implant would be perpendicular to the applied tightening force during the tests. The angulation of the implants was verified twice for each group. Tightening force was delivered and measured by using a digital torque measuring device (IMADA; model HTG2-4) which was calibrated to a resolution of 0.01 Ncm. The protocol developed was to replicate

Table 1. Tightening protocols

ANOVA	Group Code	Specimen Size
Tightened 2 times with 10-min interval time	2T10I	10
Tightened 2 times with no interval time	2T0I	10
Tightened one time only	1T	10
Tightened, Counter-tightened then Tightened again	TCT	10
Tightened, Counter-tightened, Tightened, Counter-tightened, then Tightened again	TCTCT	10

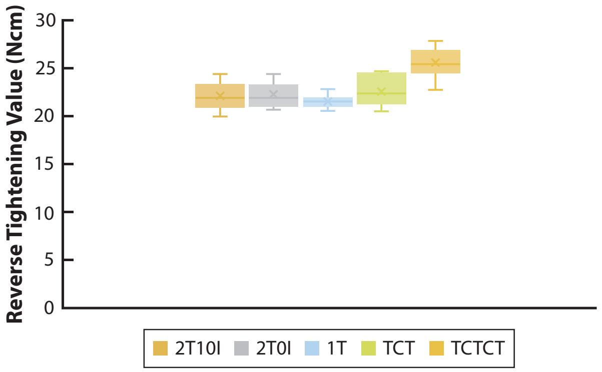

Figure 1. Boxplot graph of reverse tightening value of screw groups.

Figure 2. Tightening abutment screws with digital torque measuring device.

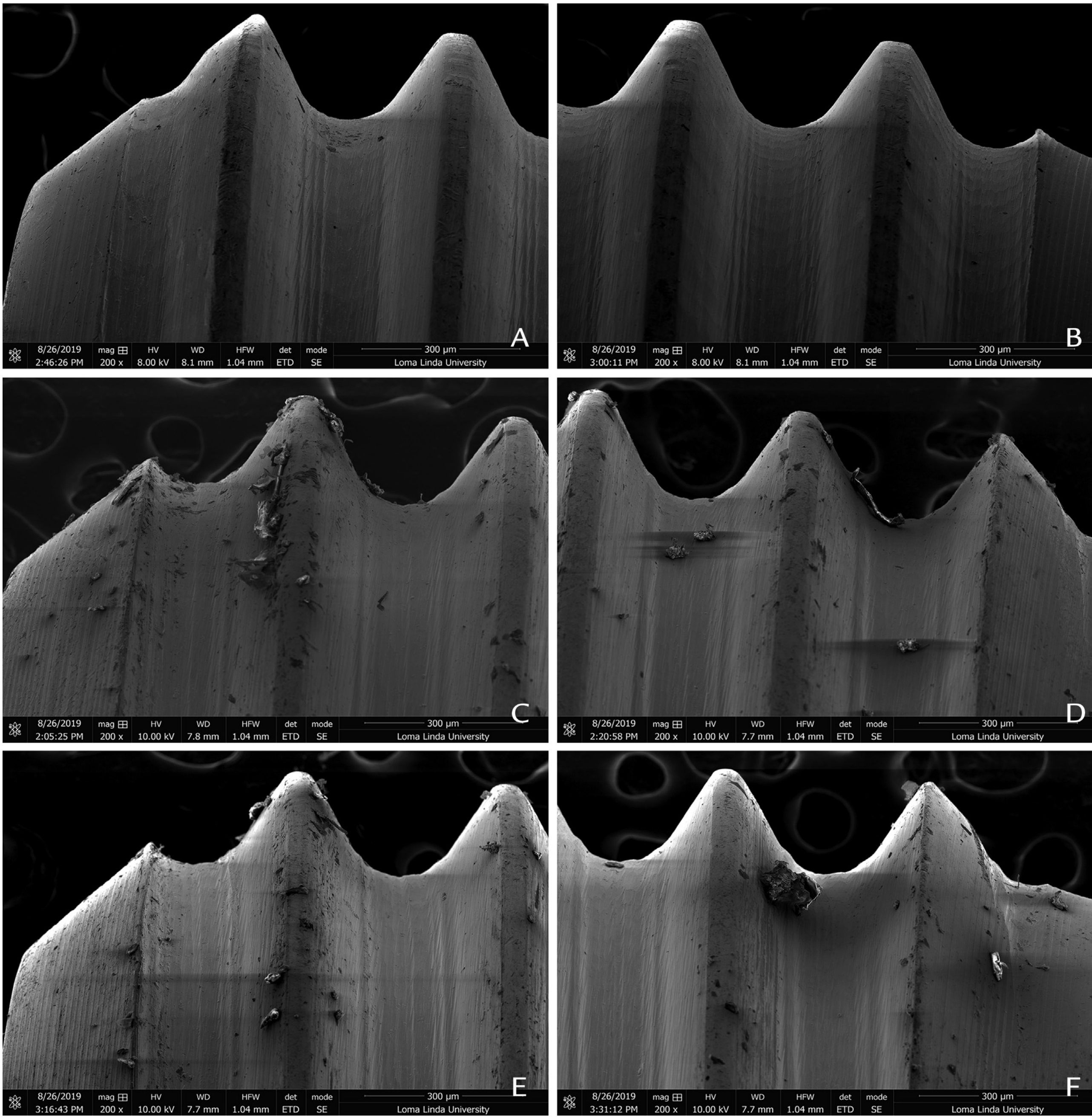

Figure 3. Scanning electron microscope images of abutment screws (Original magnification ×200). A, C, E, Apical part. B, D, F, Coronal part. A, B, New screw. C, D, Screw retightened with no interval time. E, F, Screw tightened-reversed-tightened-reversed, then tightened again.

procedures that are typically encountered during the clinical procedure as it relates to the screw tightening of this implant system. After embedding the implants in the composite resin, this involved tightening the cover screw to 10 Ncm (according to the manufacturer's recommendation). The cover screw was then removed, and the implant open tray impression copings were tightened to 10 Ncm. The impression copings were removed and replaced with prefabricated abutments (Express prefabricated abutment; Neoss). Final abutment screws (Crystaloc; Neoss) were hand tightened initially and then tightened with the tight monitoring device to the manufacturer's recommendation of 32 Ncm (Fig. 2). At each stage of tightening, the input value used was recorded. All implants remained at ambient room temperature (21 °C) for 3 hours before the RTV was measured.

An observational study was conducted where 3 representative screws were examined with a scanning electron microscope (Quanta FEG-250) at ×200 magnification (Fig. 3) to detect any deformities to the screw from tightening. The apical and coronal part of a new

Table 2. Pairwise comparison of groups

Specimen 1 –Specimen 2	Test Statistic	Standard Error	Standard Test Statistic	*P*	Adjusted *P*
1T-2T10I	4.700	6.519	0.721	.471	1.000
1T-2T01	5.700	6.519	0.874	.382	1.000
1T-TCT	-8.700	6.519	-1.335	.182	1.000
1T-TCTCT	-27.400	6.519	-4.203	<.001	<.001
2T10I - 2T01	1.000	6.519	0.153	.878	1.000
2T10I - TCT	-4.000	6.519	-0.614	.539	1.000
2T10I - TCTCT	-22.700	6.519	-3.482	<.001	.005
2T01- TCT	-3.000	6.519	-0.460	.645	1.000
2T01- TCTCT	-21.700	6.519	-3.329	.001	.009
TCT - TCTCT	-18.700	6.519	-2.868	.004	.041

screw (Fig. 3A, 3B), a Group 1T screw that had been tightened 1 time (Fig. 3C, 3D), and a Group TCTCT screw (Fig. 3E, 3F) were examined.

A pilot study indicated that a specimen size of n=10 was adequate for a power of 80% at a significance threshold of α=.05. One-way ANOVA was performed with a statistical software program (IBM SPSS Statistics, v25; IBM Corp) to test the homogeneity of input values that were used for tightening the 5 groups. RTV data were also subjected to 1-way ANOVA. Where differences existed (*P*<.05), pairwise comparisons were carried out (Table 2).

RESULTS

The mean screw initial tightening values recorded for the 5 groups were not statistically different (*P*>.05) (Table 3) and ranged from 32.00 to 32.45 Ncm. The RTVs for the 5 groups after 3 hours are shown in Table 4 and Figure 1, along with mean values; the lowest was Group 1T tightened 1 time with RTV (21.49 Ncm) and the highest Group TCTCT (25.51 Ncm) (Table 2). Group TCTCT was significantly higher than all other groups, and no difference in RTV was seen between any other pairs (*P*>.05).

DISCUSSION

The null hypothesis that no significant difference would be found in tightening protocol with regard to the RTV was rejected. The results of this study indicate that in the first 3 abutment-screw tightening protocols (Group 2T10I, Group 2T0I, and Group 1T), there was no relation between either the time interval between tightening or retightening the screw a second time with regard to RTV. Moreover, tightening a screw 1 time made no significant difference in RTV compared with Group 2T10I and 2T0I. No significant difference in RTV was observed among Groups TCT, 2T10I, 2T0I, and 1T.

For the first 4 groups, no significant differences were found in RTV, whereas a significant difference in the RTV was noted in the Group TCTCT compared with all other groups. This difference could be attributed to the better

Table 3. ANOVA

ANOVA	Sum of Squares	df	Mean Square	F	*P*
Between Groups	99.981	4	24.995	13.418	<.001
Within Groups	38.825	45	1.863		
Total	183.806				

Table 4. One-way ANOVA test

Groups	N	Mean	Standard Deviation	95% Confidence Interval for Mean: Lower Bound	95% Confidence Interval for Mean: Upper Bound	Minimum	Maximum
Group 2T10I	10	22.06	1.41	21.05	23.08	19.96	24.35
Group 2T0I	10	22.22	1.32	21.27	23.17	20.66	24.36
Group 1T	10	21.49	0.70	20.9	21.99	20.49	22.80
Group TCT	10	22.57	1.56	21.46	23.69	20.48	24.56
Group TCTCT	10	25.51	1.62	24.35	26.67	22.72	27.76
Total	50	22.77	1.94	22.22	23.32	19.96	27.76

Alpha=.05. Measurements in Ncm.

resistance offered by more intimate screw-to-implant thread contact and a reduction in the frictional resistance on the internal threads and abutment screw threads during tightening.

Tightening protocols for groups 2T10I and 2T0I, which included an interval time of 10 and 0 minutes, respectively, made no significant difference in RTV. Siamos et al[14] reported that retightening the implant abutment screw after 10 minutes increased the RTV. However, their study had a low specimen size per group (n=2), which might account for the different results. Khalili et al[15] also compared screw tightening at different interval times but did not compare immediate retightening values with those done at time intervals. An actual clinical scenario for component connection was not used, which could have affected the output of the RTV. In the present study, a simulated clinical scenario was used, as repeated tightening and loosening could reduce frictional resistance and influence the outcome.

The screws used were coated with Ga to reduce the frictional resistance to seating and allow the abutment screw threads and the implant internal threads to engage more precisely and intimately than with noncoated screws. However, reducing the friction from the internal threads by following the clinical components connection scenario is apparently not sufficient. Retightening a tightened screw, either immediately or after a time interval, will not significantly increase the RTV.

The surface of the screws was evaluated at both the apical and coronal portions with scanning electron microscope (Fig. 3). The apical portion of the screw revealed the maximal contact area with the internal threads of the implant body because it is the first portion of the screw to engage the implant body. When the apical portion of the screws (Fig. 3A, 3C, 3E) were compared, no significant distortion in the third screw was apparent, although a significant difference in RTV was found. The image of the coronal portion revealed small particles on the screw surface (Fig. 3D-F). An energy-dispersive spectroscopy analysis determined the composition of these particles to be mainly titanium and gold in Group TCTCT (Fig. 3F), indicating wear of the implant surface at the threads. In a new screw and a screw from Group 1T (Fig. 3B, 3D), the particles were predominantly gold.

Limitations of this study included its in vitro design with 1 type of gold-coated implant abutment screw. Other implant systems with different materials may reveal different outcomes. Contamination, which may occur in the clinical setting, was not included in the study design. Additionally, specimens were not subjected to the variation in forces that may be encountered in a clinical setting and an aging test with cyclic loading was not performed to mimic the intraoral environment. Further studies are required to test this protocol with different screw designs and materials.

CONCLUSIONS

Based on the findings of this in vitro study, the following conclusions were drawn:

1. No significant difference was found in the time intervals between the tightening of implant abutment screws.
2. To obtain optimum RTV, implant abutment screws should be tightened, counter-tightened, tightened, counter-tightened, and then tightened.

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