**Efficacy of Several Retightening Protocols for Maintaining Clamping Force in the Implant-Abutment Joint: An In Vitro Pilot Study**


**Purpose:** Stability of an implant-supported restoration is an ultimate measure of the success of the procedure. It has been recommended by some to retighten the abutment screw for maintenance of the crown on the implant. The purpose of this study was to evaluate the usefulness of two retightening protocols to maintain the clamping force. **Materials and Methods:** Three groups of slip-fit implants (MIS 4.3 by 10.5) were compared. The first group was only tightened once (group C). In the second group (group R10M), the screw was retightened after 10 minutes. The third group (group R2W) was retightened after 2 weeks of simulated functional loading. After completion of individual protocols, all specimens were loaded for 100,000 cycles. After the loading, all specimens had the remaining torque audited. **Results:** The mean torque loss for group C was 6.10 (± 5.13) Ncm. Group R10M was 2.03 (± 3.018) Ncm, and group R2W was 0.30 (± 0.483) Ncm. A one-way analysis of variance (ANOVA) recorded significant differences among the groups (P = .003). Multiple pairwise comparisons between groups by Tukey test recorded significant differences between group C vs group R10M (P = .035) and group C vs group R2W (P = .002). There was no significant difference in torque loss between groups R10M and R2W (P = .509). **Conclusion:** Within the parameters of this in vitro investigation, it was concluded that both retightening after 10 minutes (P = .035) and after 2 weeks (P = .002) was equally effective. Int J Oral Maxillofac Implants 2019;34:1084–1090. doi: 10.11607/jomi.7426

**Keywords:** clamping force, embedment relaxation, preload, slip fit connection, torque

Stability of the abutment/crown assembly is necessary for successful implant prostodontic treatment. Tightness of the screw connecting the implant and abutment therefore has been considered an important issue.1 While the technology of the implant-abutment interface has been considerably improved, particularly with the conical connection that is a precisely fitting interface, the internal slip-fit connection, which has been employed for many years, has enjoyed much success, although the interfaces generally are shallower and have a less precise fit.2 Related to this, there is now a greater understanding of the factors that influence the stability of the joint and concomitantly tightness of the screw.

The first of these is the type of interface between the implant and the abutment. Interfaces that are deeper and fit more precisely, including the conical connection, allow force transfer directly from the abutment through to the implant shielding the screw.3 Shallow slip-fit connections allow micromovement of the abutment and crown relative to the implant, particularly with off-axis occlusal contacts. This may result in force transfer with slight bending of the screw and partial or complete loss of the clamping force that keeps the system together.4

The second is the topography of the milled surfaces of the implant-abutment. This will influence the degree of embedment relaxation that occurs.5 Embedment relaxation has been defined as eburnation of milled

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irregularities in metal surfaces that are flattened as a result of pressure or movement of contacting surfaces over each other during tightening of the screw. These surfaces include the underhead of the screw against the abutment, the axial wall contacts of the abutment and the implant, and the contacts of the screw threads with the internal threads of the implant. As a result of the relaxation, the clamping force is reduced, and 2% to 10% of the initial preload is lost. The amount of embedment relaxation or settling that occurs depends on the number of rough spots on the contacting surfaces, the surface hardness of the implant and the screw, and the amount of load applied to the system.

The third is the design of the screw. The head of the screw is stabilized against the shelf inside the abutment. The screw threads are apically stabilized against the internal threads of the implant. Tightening results in stretching of the midportion of the screw, termed the shank. The stretching, the preload, is opposed by an equal but opposite force between the abutment and the implant described as the clamping force. The diameter of the shank and the modulus of elasticity of the screw material largely determine the amount of tightening, ie, torque, that is needed to establish the required preload in the screw.

However, there is not a one-to-one relationship between torque and preload. As the screw is advanced, part of the energy applied is lost overcoming friction both in the underhead of the screw vs the abutment shelf and in the threads of the screw vs the internal threads in the implant. The actual preload, however, is important in that it must be enough to prevent the forces from occlusion, applied to the abutment/crown, causing loosening or back rotation of the screw, thereby reducing the preload. The consequences of this may be loose abutments/crowns.

The clinician is not able to directly measure the preload. The implant manufacturers have provided recommendations for the required torque. It is assumed that these recommendations result in sufficient preload to provide stability to the crown-abutment assembly without any loosening. However, at times loose crowns occur. It is likely that these are associated with either off-axis loading of restoration or embedment relaxation. The off-axis loading is associated with occlusal design. Frequently, modifying the occlusal anatomy to eliminate excursive contacts is helpful. However, for management of embedment relaxation resulting in loss of preload, it has been suggested that the screw be retorqued to the value initially recommended by the manufacturer.

Two strategies have been proposed. The first is to retorque the screw 10 minutes after the initial torque application. In this case, it compensates for the embedment relaxation almost exclusively. In the second, the retorquing is done some time after occlusal loading. In the second protocol, it is assumed that the preload loss results from a combination of embedment relaxation and slight deformation of the component parts of the joint, with a closer adaptation between the component parts. In both cases, it must be recognized that because the preload cannot be directly measured in the patient, the torque value is used. Also, as noted before, the preload value is always less than the torquing force but serves to correlate preload with torque. The purpose of this research was to compare the effectiveness of the two retightening protocols to maintain the manufacturers’ recommended torque values after initial occlusal loading. The null hypotheses were as follows:

- **Null hypothesis 1:** After cyclic loading, there will be no significant difference in loss of torque between the group that was retorqued after 10 minutes and the control group (no retorquing).
- **Null hypothesis 2:** After cyclic loading, there will be no significant difference in loss of torque between the group that was retorqued after early functioning (2 weeks), compared with the control group (no retorquing).
- **Null hypothesis 3:** After cyclic loading, there will be no significant difference in loss of torque between the group that was retorqued after 10 minutes compared with the group that was retorqued after early function (2 weeks).

### MATERIALS AND METHODS

#### Equipment

The equipment used was as follows:

- A custom torque angleometer comprising a 120-degree rotary variable inductive transducer (Lucas RVIT 15-60), attached to a torque driver (CDI-MT-10) mounted in a custom frame.
- An MTS-810 closed loop servo hydraulic universal testing machine, with a digital MTS-Flex Test 40 controller running in load control mode at 20 Hz, with a mean value of 100 N and an amplitude of 100 N.
- DasyLab (manufacturer) acquisition software used to monitor the tightening process by accepting both torque and angle data and plotting them together.

#### Specimens

MIS Implants with a slip-fit internal hex connection (Seven, MIS) with 10-mm-high prefabricated abutments were used. Specimens were prepared by potting individual MIS implants in GC pattern resin.
(manufacturer) in a 13-mm diameter, 19-mm-long cylindrical cup (Figs 1 and 2). One millimeter of the collar was left exposed. Each specimen was stabilized in a holder for insertion in the MTS testing machine. The abutment and screw then were inserted onto the implant and torqued to the recommended value (Fig 3). All specimens of each group then were subjected to the appropriate protocol.

The groups were as follows:

- **Group C**: Initial torque at the time of abutment placement only (control group) (n = 10)
- **Group R10M**: Initial torque at the time of abutment placement and retorque after 10 minutes (n = 10)
- **Group R2W**: Initial torqueing at the time of abutment placement, early functional loading with 20,000 cycles of 150 to 200 N at 20 Hz, offset by an angle of 30 degrees simulating 2 weeks of masticatory loading. After the initial conditioning, these specimens were retorqued to 35 Ncm.

All torque procedures were performed according to the manufacturers’ recommended value by using a RSDM custom torque angleometer.

**Protocol**

After completion of the appropriate treatment, all groups were subjected to cyclic loading for 100,000 cycles at a 200-N load at a 20-Hz rate (Fig 4). After completion of the specific protocol for each specimen, a tightening torque turn analysis was performed to determine the residual torque value using calibrated Vishey data acquisition software.

The tightening-torque auditing procedure is demonstrated in Fig 5. Curve A shows the initial tightening of the MIS abutment screw into its implant/abutment. It traces a line with a slope of 1.3 N/deg. Curve B represents the audit of a tight screw. Curve C demonstrates retightening of a partially loosened screw. Curves A and B each display two different components. The initial parts up to approximately 13 Ncm with the slope of 0.81 N/deg is an adaptation of the torque driver to the screw head. In the second part, the preload is being established. Note that Curve A has a shallower slope because the initial embedment relaxation is occurring.

**Statistical Analysis**

The residual torque values for all specimens in each group were summed, and the means and standard
deviations were calculated. The mean values of each group were compared by using one-way analysis of variance (ANOVA) with the post hoc Tukey test for paired comparisons.

RESULTS

The means and standard deviations of groups C, R10M, and R2W are described in Table 1. Group C, the control, recorded a maximal loss of 17 Ncm and a minimum of 0 Ncm, which demonstrated the greatest loss of torque (mean: 6.10 ± 5.13). Group R10M recorded a maximal loss of torque of 10 Ncm and a minimum of 0 Ncm (mean: 2.03 ± 3.02). Group R2W recorded a maximal loss of 1 Ncm and minimum of 0 Ncm (mean: 0.30 ± 0.483).

The ANOVA indicated a significant difference among groups (P = .003) (Table 2). Multiple pairwise comparisons between groups using the Tukey test (Table 3) indicated significant differences between groups C and R10M (P = .035) and between C and R2W (P = .002). However, between groups R10M and R2W there was no significant difference. For group R10M, after the 10-minute waiting period without loading, there was a small loss of torque. Similarly, for group R2W after 2 weeks of functional load, prior to retightening, there was a small loss of torque as well.

DISCUSSION

The findings of this study demonstrated that retorquing of the abutment screw reduces the incidence of subsequent screw loosening. For both of the methodologies examined in this study, for a slip-fit implant-abutment interface, retightening after 10 minutes or following 2 weeks of simulated function produced similar results.

Minimizing screw loosening is important because the screw serves to hold together the implant-abutment connection. Two stages of screw loosening have been described (Fig 6). The first involves slippage of the joint surfaces when joint separating forces are large enough to cause disengagement of mating threads of the implant and screw. This has been termed the critical bending moment, which is the bending...
moment at which slippage occurs.\textsuperscript{11} The second phase occurs when the preload has reduced to the point that external forces and vibration cause mating threads to turn, leading to the screw backing out.\textsuperscript{12}

According to Shoberg, the results of a tightening audit are directly related to the preload achieved. His experimental studies done during the past several years have shown that the most useful torque reading that can be obtained with a hand torque audit occurs at a point just prior to the start of the motion in a tightening direction.\textsuperscript{10} Another audit, termed a loosening audit, has also been utilized to evaluate the hypothetical joint stability. It is accomplished by unscrewing the joint. Although there are many studies in dental literature that have evaluated joint stability through loosening audits, the audit does not reproduce the process of screw loosening as outlined in Fig 6, which is related to the angle of tooth contact during the masticatory cycle that has an off-axis component. A further difficulty with either tightening or loosening audits is that the preload is not directly related to the torque. As noted earlier, none of the current instrumentation allows direct clinical determination of the preload. Without this information, the preload and thus the clamping force of the joint can only be estimated.

Luke recently reported a study in which the screw preload was measured directly using a force washer. He observed that the preload values differed considerably from system to system, although the basic screw designs were similar. All the screws in the study were torqued to 35 Ncm. This emphasizes the difficulty of the clinician to appreciate the preload generated for implant-abutment restorations.\textsuperscript{13}

The results of this study suggest that retorquing of the screw is effective to maintain the preload. However, there may be concern that retightening the screw could affect its physical properties. Regarding a study by Tsuruta et al, in which repeated tightening was done, although removal torque was measured, both the slip-fit and conical fit implant abutment specimens had similar values. This is particularly interesting because in the conical connection, the screw receives little or no direct stress. This observation by Tsuruta et al suggests that there is little or no effect from multiple torquing of the screw.\textsuperscript{14}

A number of authors have recommended that applying a retightening torque will stabilize the joint. Retightening was recommended by Siamos et al and Bakaeen et al, who consider embedment relaxation an important clinical factor.\textsuperscript{7,15} They both recommend retorquing after 10 minutes as a routine clinical technique.\textsuperscript{15} Siadat et al demonstrated that there is additional slight loss of torque after 5 minutes of applying a retorque with a 10-minute interval.\textsuperscript{16} This finding is in agreement with other studies that reported initial torque loss after 2 to 3 minutes and after 15 hours.\textsuperscript{17–19}

Bacchi et al evaluated the influence of retightening after 10 minutes on the loosening torque after 10\textsuperscript{6} cycles of loading in vitro at 130-N load. They did not examine the factor embedment relaxation alone but observed that tightening after 10 minutes increased the value of the loosening torque after application of the loading cycles. They concluded that the retightened joints were more stable.\textsuperscript{20}

In addition, factors of precision of fit of a multiunit prosthesis, the interfaces of the abutment and implant, or the screw threads will all influence the magnitude of the torque. Spazzin et al and Farina et al examined the effects of misfit, retorque, and screw material on the loosening torque of the abutment screws. They utilized an in vitro model of a prosthesis supported by five implants. Spazzin et al examined the effects of embedment relaxation alone. Then, screws were tightened, retightened after 10 minutes, and the loosening torques measured after 24 hours. They concluded that misfit was the most significant factor. However,

<table>
<thead>
<tr>
<th>(I) Group</th>
<th>(J) Group</th>
<th>Mean difference (I-J)</th>
<th>SE</th>
<th>P</th>
<th>95% CI</th>
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<tr>
<td>1</td>
<td>R10M</td>
<td>4.0700*</td>
<td>1.5420</td>
<td>.035</td>
<td>0.247 – 7.893</td>
</tr>
<tr>
<td>2</td>
<td>C</td>
<td>–4.0700*</td>
<td>1.5420</td>
<td>.035</td>
<td>–7.893 – 0.247</td>
</tr>
<tr>
<td>3</td>
<td>C</td>
<td>–5.8000*</td>
<td>1.5420</td>
<td>.035</td>
<td>–9.623 – 1.977</td>
</tr>
<tr>
<td>4</td>
<td>R10M</td>
<td>–1.7300</td>
<td>1.5420</td>
<td>.509</td>
<td>–5.553 - 2.093</td>
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\*The mean difference is significant at the .05 level.

Group 1 = C; Group 2 = R10M; Group 3 = R2w.
retorquing the screws of the misfit group significantly improved the residual torque; therefore, retorquing should be a routine procedure. Farina et al, using the same experimental model, loaded the prostheses for 1 year. The residual torque was measured at the completion of the loading cycles. In this experimental design, retorquing of the screws after 10 minutes significantly improved the loosening torque values recorded after the loading protocol. In this experiment, the screw stability was influenced by the effects of prosthesis loading as well as by embedment relaxation.

As a confirmation, Pardal-Peláez et al suggested that in addition to retightening after 10 minutes and application of torque value above that recommended by the manufacturer, other factors that can stabilize the torque value of the screw include implant-prosthesis design and materials such as type of connection, screw, and internal thread of the implant.

In addition to retightening to manage embedment relaxation, other strategies to prevent screw loosening, such as lengthening of the screw, changing the thread and groove shape, and altering the number of screw threads should be considered. Additionally, microscopic factors such as the roughness of the screw surface and interposition of lubricant may influence the joint stability.

Bulaqi et al examined the effects of the two factors of surface roughness and the speed of tightening. They concluded that the loosening torque value was inversely related to the generated torque. On the other hand, when the speed of tightening was increased, the coefficient of friction was decreased, resulting in increased residual torque. Upon retightening, the seating effect was lessened but the preload was minimally increased.

Other occlusal factors influencing screw loosening are crown-implant ratio, the location of the surface occlusal contacts, and cantilevered loading. Siadat et al examined the influence of increased abutment collar height on abutment screw loosening in single-unit dental implants. They concluded that an increase in height of the abutment collar increased the torque loss of implant-abutment screws after cyclic loading. An additional strategy suggested by Bakaeen et al is that screw loosening can be reduced by narrowing the occlusal table.

Kirov and Stoichkov, in a review of 116 implant-supported restorations, identified factors of off-axis centric contacts, parafunctional habits, cantilevered restorations, crestal bone loss, nonbalancing occlusion, and removable prosthesis as associated with screw loosening for prostheses in function for between 2 and 9 years.

Komiyama et al reported bruxism as a significant risk factor for biomechanical complications, including screw loosening due to repeated static and dynamic loading. Such loadings can be both along the long axis as in clenching the teeth and laterally in less favorable lateral directions in grinding the teeth. The increased loading was reported to lead to fatigue and subsequent loosening and fracture of the abutment screw.

Finally, there are issues with direct clinical application of the findings of this study. To isolate the effects of embedment relaxation, a crown was not inserted over the abutment. While other studies cited earlier with longer cycling times found similar results, the loading was only carried to 100,000 cycles. Factors of the oral cavity including variations in direction of closure, moisture, and temperature and the rate of loading were not considered. Nevertheless, this research provides critical information regarding the importance of considering embedment relaxation when inserting implant-supported prostheses.

CONCLUSIONS

Retightening after 10 minutes or after 2 weeks statistically significantly reduced torque loss after simulated intraoral function when compared with the control group (no retightening). There was no statistically significant difference in the reduction in torque value after retightening after 10 minutes or after 2 weeks.

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