The Effect of Torque Application Technique on Screw Preload of Implant-Supported Prostheses

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Purpose: *To examine the effect of different torque application techniques (torqued, retorqued once, and retorqued twice) on the removal torque of implant-supported fixed complete dental prostheses.* ***Materials and Methods:*** *Four Nobel Biocare implants (4.3 × 13 + 3; 13-mm thread height + 3-mm collar height) were stabilized temporarily inside four holes made in an acrylic mandibular master model. A metal framework was constructed, casted, and finished using a standardized technique. A passively fitting framework was achieved by removing the implants from the acrylic master model and hand-screwing them to the metal framework. Then, the whole assembly was restabilized in the acrylic master model. The torque experiment consisted of three protocols: (1) torquing screws to 35 Ncm a single time; (2) torquing the screws to 35 Ncm and then immediately retorquing the same screws to the same value; and (3) torquing the same screws to 35 Ncm three consecutive times. Removal torque was recorded for each implant using a digital torque meter.* ***Results:*** *The highest torque value was recorded for the retorqued-once application technique (29.5 ± 1.5 Ncm); next was the torqued technique (27.9 ± 0.7 Ncm); and, last was the retorqued-twice technique (27.2 ± 1.6 Ncm). The Games-Howell post hoc test showed that the retorqued-once application technique resulted in significantly higher torque values than the torqued and retorqued-twice torque application techniques (P ≤ .05).* ***Conclusion:*** *Retightening abutment screws once after the initial torquing could enhance the removal torque of the screw. Care must be taken when retorquing the screws more than once, as this may inversely affect the removal torque.* INT J ORAL MAXILLOFAC IMPLANTS 2017;32:259–263. doi: 10.11607/jomi.4773

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Today, implant-supported prostheses are considered the treatment of choice to replace missing teeth in partially or completely edentulous patients.[1,2] In the case of completely edentulous patients, the literature has shown that implant-supported fixed complete dental prostheses are a safe treatment method with a high success rate.[3] In a study by Papaspyridakos et al, the success rate for implant-supported fixed complete dental prostheses was as high as 86.7%.[2] In another systematic review, Pjetursson et al reported that the 5-year prosthetic survival rate of implant-supported fixed complete dental prostheses was as high as 95.8%.[1]

Despite the high long-term success rate of dental implants, they are still prone to different types of complications, including mechanical complications.[1,2] A systematic review reported that mechanical complications occurred in 60% to 80% of the studies included.[2] The most frequently reported mechanical complication was screw loosening, with an estimated annual rate of 2.1%.[2] The estimated rates were 10.4% and 20.8% over 5 and 10 years, respectively.[4]

Several factors can play a role in screw loosening, including screw settling and the magnitude of the functional loading. Screw settling—or embedment relaxation—is attributed to the loss of the microroughness of the contacting surfaces (screw and internal threads) under a load.[4–6] The magnitude of the functional loading can cause loosening of the abutment screw if it is equal to or greater than the screw's preload.[5–7] Another factor that can play a role in screw loosening is the inability to apply sufficient tightening force (torque) to the screw.[4,6–9]

The use of screwdrivers to fasten screws manually has proven to provide less accurate torque delivery to the screws and to vary widely in terms of success[4]; therefore, the use of mechanical torque-limiting devices, such as wrenches, has been recommended to ensure consistent and adequate torque delivery to implant screws.[3,9] Dental implant companies recommend that the operator apply force a single time to the manual wrench until the appropriate torque value is reached.[8] However, many dentists apply torque

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two or three times, or even more, to ensure adequate tightening force. To date, the effect of different torque-application techniques on the preload of screws is not known.

The aim of this study was to evaluate the effect of repeating torque application (torqued, retorqued once, and retorqued twice) on the screw's removal torque in implant-supported fixed complete dental prostheses. The null hypothesis was that there would be no differences in the removal torque among the different torque application techniques.

MATERIALS AND METHODS

Construction of the Master Model and Framework

A commercially available soft silicone mold model former (LB38 Model Molds, ZOGEAR) of a completely edentulous mandibular arch was used to construct a mandibular model using polymethyl methacrylate (PMMA) (Orthodontic Resin Liquid Clear, Dentsply). The model former was filled with PMMA using the sprinkle-on method, and the model was processed using the standard technique for processing PMMA. Four RP (4.3 × 13 + 3; 13-mm thread height + 3-mm collar height) internal connection implants (Replace Select TC, Nobel Biocare) were stabilized temporarily inside four holes drilled using an acrylic bur mounted on a paralometer (Paramax II paralleling device, WhaleDent). A long implant driver (29509; Replace Select, Nobel Biocare) mounted in the same paralometer and polyvinyl siloxane (PVS) material (Putty Genie Rapid Set, Sultan Healthcare) were used to temporarily stabilize the implants inside the holes for retrieval at a later stage (Fig 1). A custom tray was used to make an open-tray impression of the model using polyether impression material (Impregum, 3M/ESPE; Fig 2) and the impression was poured using type 4 dental stone (Fujirock EP, GC America).

For the construction of the framework, four non-engaging abutments (GoldAdapt 29011, Replace Select, Nobel Biocare) were hand-screwed to the implant replicas. A GC pattern (Pattern Resin LS, GC America) was used for the fabrication of the connectors using a silicone mold according to standardized dimensions (4 × 2.5 mm). Each resin connector was attached to the plastic part of the abutment using sticky wax (Miltex Stick Wax, Integra). A round wax sprue former was attached to the plastic part of the abutment, and the pattern was removed from the stone cast and mounted on a crucible former base. The pattern and the sprue formers were treated with a surface-tension reducer agent (Wax Pattern Cleaner, Bego). The metal ring (Metal Mould Ring, size 9, Bego) was lined with a paper liner and soaked in water for 1 minute. The pattern was invested with a phosphate-based investment (K&B Investment, YWTI Dental), and the rings were burned out in an oven following the recommended thermal cycle. The one-piece casting process was performed using type 4 gold alloy (Lodestar, Ivoclar Vivadent).

After casting, the rings were allowed to cool for 2 hours before divestment. The framework was divested and sandblasted with a 100-μm particle aluminum oxide stream to avoid damage to the seating regions of the prosthetic cylinders. Sprue formers and small nodules were removed under magnification (Fig 3). To ensure that the framework fit passively, the implants were reassembled into the framework (Fig 4) and then attached permanently to the acrylic arch model by using some additional PMMA (Fig 5). The implants were held in place by the paralometer until the additional PMMA set completely. The materials and method for the construction of this framework were documented in a previously published article by the first author.[10]

The Torque Experiment

The master acrylic model was stabilized on a square 15 × 15 × 2.5-cm glass slab using cyanoacrylate glue (Loctite Instant Adhesive, Henkel). The glass slab was then stabilized on the lab bench using the same cyanoacrylate material. After that, the metal framework was placed on the implants.

The implants were numbered starting with the most terminal implant on the left to the most terminal implant on the right. For all torque protocols, the sequence used was implant number 2, 3, 4, and 1, respectively. A new set of screws was placed in each implant and torqued to 35 Ncm, which is the torque value recommended by the manufacturer (Replace Select TC, Nobel Biocare) using a manual screwdriver (UniGrip 29149, Nobel Biocare). A digital torque meter (BTGE, Tohnichi) was used to accurately apply the required torque (Fig 6). The torque meter was calibrated just before the beginning of the experiment using a calibration tool specifically designed for the digital torque meter (BTGCL Calibration Kit, Tohnichi).

The torque experiment consisted of three protocols, each representing one of three torque-application techniques commonly used by practitioners. The first protocol involved torquing each screw to 35 Ncm a single time (ie, the technique recommended by the manufacturer). The second protocol consisted of torquing all screws to 35 Ncm, immediately followed by retorquing them to the same value. The third protocol consisted of torquing all screws to 35 Ncm three consecutive times. Every time the target torque value was reached, the torque gauge was held in place for

Fig 1 Complete edentulous mandibular model with four implants temporarily stabilized inside it.

Fig 2 Custom tray with polyether impression.

Fig 3 Metal framework with the cast poured from the impression.

Fig 4 Implants reassembled into the framework.

Fig 5 Implant reassembly with the framework attached permanently to the acrylic arch model.

Fig 6 Digital torque meter.

5 seconds (holding time) and then released. When retorquing was performed, the torque gauge was released for 5 seconds (releasing time) before retorquing was performed.

One trained clinician conducted the experiment, in which each torque technique was repeated five times. During each repetition, a new screw was used for each implant. The total number of screws used was 60.

For the detorquing part of the experiment, the screws were detorqued in the same sequence (2, 3, 4, and 1). Every time a screw was loosened, the removal torque was recorded for each implant using the same digital torque gauge. One operator conducted the experiment, and intra-examiner reliability was calculated.

The data were analyzed using statistical software (SPSS v16.0, IBM). The effect of torque application techniques on the removal torque was analyzed using one-way analysis of variance (ANOVA). Games-Howell post hoc test was used to compare the three different torque application techniques, with a P value set at $\leq .05$. A paired-sample Student t test was used to examine the difference between the applied torque and removal torque for each torque application technique ($P \leq .05$).

RESULTS

At $\alpha = .05$ and sample size equal to 20 for each torque technique, the power of the study was estimated to be 90%. The intraclass correlation coefficient (ICC) was equal to 99%. Table 1 shows the mean and standard deviation of the applied torque and removal torque for all three torque application techniques. The total number of removal torques recorded was 60 values. The ANOVA showed that the torque application technique (torqued, retorqued once, or retorqued twice) had a significant effect on the removal torque ($df = 2$; mean = 26.15; F = 15.45; $P \leq .000$).

The highest torque removal value was recorded for the retorqued-once application technique (29.5 ± 1.5 Ncm). Next was the torqued technique (27.9 ± 0.7 Ncm) and last was the retorqued-twice technique (27.2 ± 1.6 Ncm) (Table 1). The Games-Howell post hoc test showed that the retorqued-once technique resulted in significantly higher torque values than the torqued and retorqued-twice application techniques ($P \leq .05$; Table 2).

The mean removal torque was lower than the applied torque for all three torque application techniques (Table 1); the paired sample Student t test revealed

Table 1 Mean and SD of the Applied Torque and Removal Torque for Three Torque Application Techniques

Torque technique		Mean	SD
Torqued	Applied torque	35.30	0.18
	Removal torque	27.91	0.73
Retorqued once	Applied torque	35.29	0.11
	Removal torque	29.45	1.46
Retorqued twice	Applied torque	35.25	0.09
	Removal torque	27.17	1.59

Table 2 Games-Howell Post Hoc Test to Compare Removal Torque of Three Different Application Techniques

	Torqued	Retorqued once	Retorqued twice
Torqued		–1.54*	0.74
Retorqued once	–1.54*		2.27*
Retorqued twice	0.74	2.27*	

*Statistically significant difference ($P \leq .05$).

Table 3 Paired Samples Student *t* Test to Compare Between the Mean Applied Torque and Mean Removal Torque

Torque technique	Mean	SD	Significance (two-tailed)
Torqued	7.39	0.78	≤ .000*
Retorqued once	5.84	1.42	≤ .000*
Retorqued twice	8.07	1.57	≤ .000*

*Statistically significant difference ($P \leq .05$).

Table 4 Percentage Reduction in the Removal Torque Compared to the Applied Torque

Torque technique	Percentage reduction
Torqued	20.93%
Retorqued once	16.55%
Retorqued twice	22.89%

that the difference between the applied torque and the removal torque was statistically significant for all three torque application techniques (Table 3). Table 4 shows the percentage reduction between the removal torque and the applied torque.

DISCUSSION

Manual screwdrivers are the most commonly used tool to initiate the screw-tightening process.[4,9] However, this method is not recommended for final screw tightening, as it delivers inconsistent torque values and it is difficult to generate more than 20 Ncm of torque manually.[8,9] The expected error rates with manual screwdrivers ange from 15% to 48%.[11] Therefore, mechanical or electrical torquing drivers are necessary to reach the desired torque value.[2]

Mechanical torque-limiting devices (MTLDs), such as wrenches, are categorized as spring-style or friction-style.[8] Studies have shown that spring-style MTLDs more accurately delivering target torque values.[4,8] However, studies have also shown that the use of these wrenches varies significantly among practitioners, which thus affects the accuracy of the final preload.[8,11]

Based on the results obtained in this study, the null hypothesis was rejected. The different techniques for using wrenches significantly affected the removal torque obtained.

In general—regardless of the torque-application technique used—removal torque values were found to be lower than tightening torque values. This finding is consistent with other studies reported in the literature.[5,12–14] In this study, removal torque was 79.87% of the applied torque. This is in agreement with Saboury et al, who reported removal torques of 80.9% to 93.1% of the initial torquing values for single crown prostheses.[14] This reduction can be attributed to the phenomenon of the settling effect.[5,13,15] The settling effect occurs because no surface is completely smooth, which causes the presence of high spots on the internal threads of implants and screw threads. These high spots become flattened because they are the only contacting surfaces upon application of the initial tightening torque. Consequently, the torque required to remove a screw is lower than the torque initially used to place it.[15,16]

The results of the current study showed that the retorqued-once application technique resulted in significantly higher removal torque values compared to those of the torqued and retorqued-twice techniques. This can be explained by the fact that when torque is applied for the first time, some of the applied torque is used to flatten surface microroughness on the implant internal threads and the screw surface.[5,15] The second time torque is applied, the torque will generate the desired preload, and this may explain why the retorqued-once application technique resulted in higher removal torque values than the torqued technique.

Several authors have recommended retorquing screws after a predetermined interval to overcome the problem of preload loss.[15,17–19] However, repeating the retorquing more than once did not seem to enhance the preload of the screw, because the retorqued-twice application technique had the lowest removal torque values of all three techniques. This result is in agreement with a study conducted by Byrne et al, who found that the final preload decreased with the number of times the gold screws were tightened.[5] Conversely, another study found that when gold screws were exposed to different numbers of cycling periods, retightening the screws as many as 10 times did not affect the joint's stability.[13] Retorquing screws several times can overflatten the mating surfaces, and this may cause slippage between the threads, leading to significant loss of the preload.[5,20]

It is worth mentioning that this study was performed under controlled conditions in which neither saliva nor function were replicated by cyclic loading. It was found that the preload could be affected by the presence of oral fluids (saliva, blood, and sulcular fluid), as well as by the amount and the quantity of these fluids.[12] Further investigations of the effects of the torque application technique on the preload must be conducted under simulated clinical settings.

CONCLUSIONS

Within the limitations of this study, it was concluded that retightening of the abutment screws a single time after initial torquing could enhance the removal torque of the screw. Care must be taken when retorquing the screws more than once, because this may inversely affect the removal torque.

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