# The Effect of Repeated Torque in Small Diameter Implants with Machined and Premachined Abutments

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ABSTRACT

*Background:* Detorquing value is an important factor in the amount of preload stresses during abutment screw fastening. This study evaluated the percentage of detorque values in two-piece machined titanium and premachined cast abutments in small diameter implants.

*Materials and Methods:* Three groups of five samples were evaluated. Group 1 (G1), machined titanium abutments, group 2 (G2), premachined cast straight abutments that cast with gold-palladium, and group 3 (G3), premachined angled cast abutments that cast with the same alloy, were angled before casting. Each abutment was torque to 24 Ncm according to the manufacturer's instructions and detorqued five times. The means of detorquing and torquing values in all groups were recorded. The mean of detorque in each group as a percentage of the toque value was calculated. The data for all groups were compared and calculated using analysis of variance (ANOVA) and *t*-test.

*Results:* Mean detorque values in G1, G2, and G3 were 88.1 ± 1.69, 93.1 ± 2.68, and 80.9 ± 4.95%, respectively. The ANOVA showed significant differences in mean of applied detorque ($p < .001$) and torque ($p = .06$) tightening among different groups. G2 had significantly greater detorque values ($p < .05$). No significant differences were found between G1 and G2. Surprisingly, abutment screw fracture occurred in three samples of G3.

*Conclusions:* G3 showed significant percentage torque reduction ($p < .05$) and exhibited abutment screw fracture during evaluation. G2 presented the lowest torque reduction. Screw fracture occurred only in G3.

KEY WORDS: detorque, implant abutments, implants, screw fracture

## INTRODUCTION

The development of titanium fixtures has brought several benefits for the rehabilitation of edentulous patients. When biological and mechanical principles are respected, this treatment modality may successfully restore the functional and esthetic impairments caused by tooth loss.[1]

Dental implants can fail as the result of technical complications as well as biological factors. Technical problems can be divided into two groups: those relating to the implant components and those relating to the prosthesis.[2–8] Abutment screw fractures are being noted more frequently. These fractures usually result from undetected screw loosening caused by bruxism and unfavorable superstructure, overloading, or malfunction.[9]

Accepted implant prosthodontic techniques have emphasized that abutment cylinders and superstructure attachments should be tight and that the stability of each of these components should be verified at subsequent recalls.[10] When the screw is tightened, a tightening torque is applied as a moment in newton-centimeter to the head of the abutment screw. The applied moment is transformed along the interface of the abutment screw thread surfaces and the implant bore threaded surfaces. The transformed force then induces the contact force in

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the interface between the abutment and the implant bearing surfaces that are being clamped together.[11] The contact force clamping together the abutment and the implant is called the preload. As the tightening torque is increased above the level of the initial contact force, the preload stress in the abutment-implant interface is increased to a point. This point, called the "optimum preload," is within the material elastic range of the abutment screw.[11,12] When the optimum preload is achieved, the abutment screws experience the entire external load applied to the clamped parts. At this point, the screw joint is said to be protected against external force applications as long as these external loads do not exceed the preload.[11] Thus, the accuracy of the preload reached during screw tightening and clamping of the abutment and the implant together becomes a major and critical subject.

The preload is affected by six factors: (1) torque magnitude; (2) screw head design; (3) thread design and number; (4) composition of metal; (5) surface condition; and (6) diameter of the screw.[13]

Fracture of implant component may be related with the poor fit of the framework, which leads to material fatigue, occlusal overload, and intrinsic material failures.[9,14] The absence of passivity between components has also been shown to increase stress in the screw and results in metal fatigue failure and screw loosening.[7,15,16] Passive fit between prosthesis and implant is important to minimize the stress generated between those structures and allow stress transferring to bone tissue surrounding the implant.[17,18]

Narrow-diameter implants (3.0 to 3.4 mm) were recently developed. Small diameter (SD) implants of 3.0 to 3.3 mm in diameter are structurally weaker in comparison with regular size implants of approximately 4.0 mm.[19] The 20% reduction of implant diameter from 3.75 to 3.0 mm reduced the resistance to fracture by approximately 50%.[20] Implants with smaller diameters have several limitations including less surface area, lower fatigue strength, and higher risk of screw loosening.[21] One millimeter decrease in width of an implant may decrease the surface area of an implant by more than 40%.[22] So, the most common long-term failures reported with these implant supported prostheses are loosening and fracture of retention screws.[7]

The narrower the abutment to implant attachment diameter, the more force applied to the abutment screw during occlusal loading. Previously, it has been shown that preload is significantly reduced when abutment components are cast.[23] Casting often produces irregularities and roughness of contacting surface that may result in greater embedment relaxation and greater loss of preload. This finding supports the notion that casting procedures can decrease detorque values even in premachined cast abutments.[16]

Research has also shown that metal as cast cylinders (cast-to abutments) shows a decrease in preload compared with cylinder abutment preload. Preliminary results indicate an even greater decrease in preload values for abutments produced from plastic cylinder pattern compared with both cylinder and cast-to abutments.[24] These changes could be more evident in SD plastic abutments and premachined cast abutment. That may be affected on passive fit of these abutments, then resulting a greater force on the SD screw abutments in these implants and probability increase of the screw fracture at the final fastening.

The aim of this study was to compare the detorque value in machined titanium abutments with premachined cast abutments in two-piece SD implants (SDIs) (Xive, Friadent GmbH, Mannheim, Germany).

## MATERIALS AND METHODS

Fifteen conical Xive (3.0 × 11 mm) implants (Friadent GmbH) were selected from multiple batches; the 15 implants were divided into three groups consisting of five implants. Five esthetic base angled abutments and 10 premachined cast abutments (Aurobase) were selected from multibatches, to be used with the 3.0-mm implants. Group 1 consists of five machined titanium angled abutments (esthetic base angled, D 3.0/GH 3/A15, Friadent GmbH), and group 2 consists of five premachined cast abutments (Aurobase abutment D3.0 GH3, Friadent GmbH). Aurobase abutments cast with gold-palladium alloy (Degubond 4, DeguDent GmbH, and Germany). Group 3 samples were managed in the same manner of group 2, expect before casting, plastic sleeves of abutments were sectioned and angled to 25° and coated with autopolymerizing acrylic resin (Duralay Reliance Dental MFG Company, Worth, IL, USA). For groups 2 and 3, abutments casting were completed by one individual for consistency. The cast-to abutments were individually invested using phosphate bonded investment (HINRIVEST KB, Ernest Hinricht GmbH, Germany) and cast with gold-palladium alloy (Table 1). After casting, specimens were allowed to bench cool and

**TABLE 1 Casting Alloy Composition (%) and Melting Interval**

| Alloy | Au | Pd | Ir | Ag | Sn | Ga | Melting Interval (°C) |
|---|---|---|---|---|---|---|---|
| Degubond4 | 49.6 | 29.0 | 0.1 | 17.5 | 3.0 | 0.5 | 1160–1280 |

divesting was carefully performed using glass beads with 2.8 bar pressure. No further polishing or finishing was performed. Groups 1, 2, and 3 were tightened with a torque of 24 Ncm according to manufacturer's instructions.

Each implant in line with the long axis of the implant was positioned within the grips of a tohnichi torque gauge (BTG60, Tohnichi American, Tokyo, Japan) (Figure 1).

The abutment was then placed onto the implant and the abutment screw was positioned until the bearing surface of the abutment and the implant were in light contact. The tohnichi gauge was zeroed before the preload tightening force was applied with a torque controller of Xive system (torque wrench). The tohnichi torque gauge registered any torquing force. When the preload was reached according to the torque controller, the tohnichi gauge was read. When the appropriate 24 Ncm preload was reached, the data were collected from the tohnichi torque gauge (Figure 2). After 3 minutes, the screw was loosened and the torque required to loosen the screw was recorded. This procedure was repeated five times for each sample. The torque required to loosen the screw (detorque) was recorded as a percentage of the applied torque. This torquing and detorquing protocol was repeated for each sample in groups. Group means were calculated and compared by analysis of variance (ANOVA) and *t*-test with $p < .05$; *t*-test was used to evaluate detorque values for machined titanium abutments and premachined cast abutments.

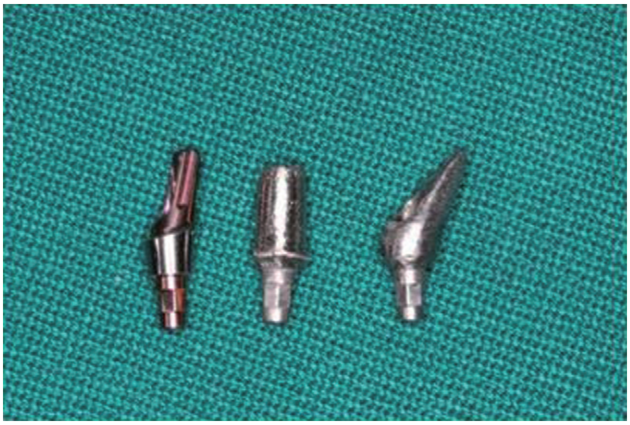

**Figure 1** Machined titanium abutment, premachined cast abutment cast with gold-palladium, and premachined angled cast abutment with gold-palladium.

## RESULT

Because of the differences in preload toque applied to the individual abutment, one would expect differences to exist in the mean tightening torque registered by the torque gauge. To permit comparison between abutments, the mean percentage of tightening torque was calculated.

Table 2 illustrates the mean tighten torque, detorque, and mean screw loosening torque as a percentage of initially applied torque values. One-way ANOVA for the means revealed statistically significant differences among the groups (Table 3).

According to the *t*-test, all groups presented a statistically significant reduction in detorque value ($p < .05$) in comparison to the insertion torque (24 ± 1.26 Ncm). Group 2 exhibited the lowest torque loss (6.9%). Torque loss was higher in group 3, which presented over 19.1% loss. Group 1 showed an 11.9% torque loss. Among these groups, higher relative torque reduction values were obtained by group 3, followed by group 1 and then group 2. There was no significant difference between group 1 and group 2, but there was significant difference between groups l or 2 and group 3.

The surprising result was the abutment screw fracture in three implants in group 3 during screw

**Figure 2** Abutment and implant positioned within grips of tohnichi: BTG6 torque gauge.

**TABLE 2 Mean Tighten Torque, Detorque, and Mean Screw Loosening Torque as a Percentage of Initially Applied Torque**

| | Descriptive Statistics | | | | | |
|---|---|---|---|---|---|---|
| | *n* | Minimum | Maximum | Mean | SD | Percentage |
| Group 1 torque (Ncm) | 25 | 24.0 | 25.0 | 24.2 | 0.29 | |
| Group 1 detorque (Ncm) | 25 | 21.0 | 22.0 | 21.3 | 0.42 | 88.1% |
| Group 2 torque (Ncm) | 25 | 23.0 | 25.0 | 23.8 | 0.38 | |
| Group 2 detorque (Ncm) | 25 | 21.0 | 24.0 | 22.2 | 0.80 | 93.1% |
| Group 3 torque (Ncm) | 22 | 21.0 | 25.0 | 24.1 | 0.77 | |
| Group 3 detorque (Ncm) | 19 | 18.0 | 21.0 | 19.6 | 1.06 | 80.9% |

tightening. In all other implants, screw fracture did not occur during five times of torquing and detorquing (Figure 3).

Among the three screw fracture, one abutment screw was fractured after three times of fastening and the others after four and five times tightening. The mean of detorque value in fracture screw group was the lowest between groups (19.6 Ncm).

## DISCUSSION

The ANOVA showed significant differences in mean of applied detorque among different groups and a borderline difference in mean torque tightening ($p < .001$ and $p = .06$, respectively). Detorque values for all groups were less than the initial tightening torque and ranged from 80.9 to 93.1% of the initial tightening torque.

These results are consistent with finding of Haack and colleagues,[25] Schulte and Coffy,[26] and Kano and colleagues.[27] However, detorque values for the premachined cast abutment (group 2) were higher in our study than detorque values observed by three other investigators.

Haack and colleagues[25] determined detorque values in the ranged of 70 to 80% of the initially torque in gold UCLA abutment. Schulte and Coffy[26] investigated and determined detorque values that ranged from 80 to 93% of tightening torque, which in the titanium UCLA abutment were only 81% of the applied torque. Kano and colleagues evaluated detorque values to be 92.3% in machined titanium abutments and 81.6% in premachined palladium abutment casted with palladium.[27]

The difference in result of detorque values is in accordance with previous studies demonstrating that components from different manufactures may produce different detorque values.[16,24,27] Previously, it has been shown that preload is significantly reduced when abutment components are cast and that this influence can be minimized if the contacting surface is finished and polished.[23]

This finding supports the notion that casting procedure can decrease detorque values even in premachined cast abutments.

**TABLE 3 The Analysis of Variance (ANOVA) Showed Highly Significant Differences in Mean of Applied Detorque among Different Groups and a Borderline Difference in Mean Torque Tightening**

| | | ANOVA | | | | |
|---|---|---|---|---|---|---|
| | | Sum of Squares | *df* | Mean Square | *F* | Sig. |
| Implant open | Between groups | 74.418 | 2 | 37.209 | 61.027 | 0.000 |
| | Within groups | 40.241 | 66 | 0.610 | | |
| | Total | 114.659 | 68 | | | |
| Implant close | Between groups | 1.507 | 2 | 0.753 | 2.865 | 0.064 |
| | Within groups | 18.146 | 69 | 0.263 | | |
| | Total | 19.653 | 71 | | | |

*df* = degrees of freedom.

**Figure 3** Three fractured screws versus unfractured screw in angled cast abutment.

Casting often produces irregularities and roughness of contacting surface that may result in greater embedment relaxation and greater loss of preload.[23,27] Significant differences were found for detorque values of two premachined cast abutments, groups 2 and 3, which were 93.1% in group 2 and 80.9% in group 3. This difference may suggest that material properties of metal component can be altered during casting and showed that the effect of casting in cast-to abutments is manufacturer dependent, where some manufacturer abutments were significantly affected by the casting procedure.[23] There were no significant differences in detorque between group 1 and group 2 in *t*-test, but greater detorque value was in straight casting abutments (group 2). Kano and colleagues[27] evaluated the effect of casting on torque maintenance through detorque measurement of machined titanium abutments, cast abutments, and plastic abutments. The authors reported a detorque mean of 92.3% for machined titanium abutments, 81.6% for the abutment cast with palladium, and 86% for the abutment cast with nickel chromium.

Byrne and colleagues[28] demonstrated that even plastic abutments cast with gold-palladium alloy also exhibited vertical misfit up to 141 μm. According to Millington and Leung,[29] horizontal and angular misfits in screw joints with gaps ranging from 55 to 104 μm generate flexural tension in the components that may cause screw loosening. This difference may suggest that material properties of metal component can be altered during casting.

When the screw is tightened, the initial contact occurs only in some areas presenting microroughness. The deformation of the components results in loss of preload and may cause 2 to 10% loss of preload following screw tightening.[30] Thus, the detorque value measured immediately after tightening is also lower than insertion torque.

In the present study, torque reduces from 6.9 to 19.1%, considering the misfit between abutment and implant. Multiple try-in of an implant prosthesis before the final insertion subject retaining screw to repeated torquing. The effect of repeated torque on the ultimate tensile strength of the screw was unknown. Repeated torquing may alter the mechanical properties and fracture resistance of prosthesis retaining screws.[31]

In this study, fracture surface of the screw was with alveolar like appearance,[18] which characterized final fracture at a single time due to torsion (Figure 4). The ultimate tensile strength of a screw is the resistance to fracture caused by a load that tends to stretch or elongate the screw.[31] There is no research-based evidence of the effect of misfit on osseointegration failure. However, there are evidences that misfit increases the occurrence of mechanic failures of components and/or fracture.[18] Irregularity and misfit produce load on abutment screw that may be because of screw fracture in the two-piece SDI similar to the present study. Al Rafee and colleagues[31] suggested that the manufacturer may have attempted to strengthen the screw to prevent or reduce the incidence of screw fracture, especially in two-piece SDI. Thus, it is suggested that during final abutment tightening it is better to use a new screw that has never been used.

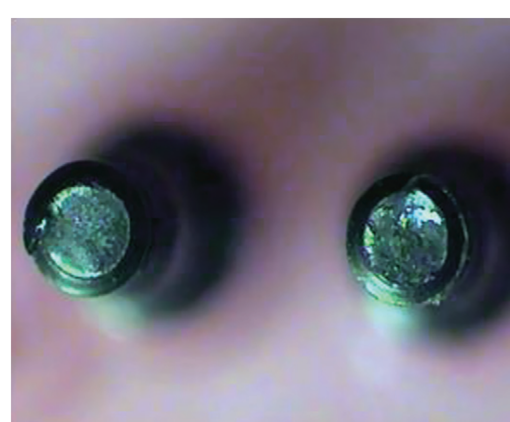

**Figure 4** Photograph of fracture patterns, which characterizes final fracture due to torsion.

## CONCLUSION

Within the limitations of this in vitro study, the following conclusion was drawn:

1. Angled premachined cast abutments showed significant percentage torque reduction ($p < .05$) and exhibited abutment screw fracture during evaluation.
2. Straight premachined cast abutments presented the lowest reduction, but no significant difference was seen with machined titanium abutments (group 2).
3. No screw fracture was shown in groups 1 and 2 after five times during repeated torques.
4. Detorque value was the lowest in times of repeated torque before screw fracture in group 3. A new abutment screw is suggested to be used before final tightening in cast abutment of two-piece SDI.

## CLINICAL IMPLICATIONS

According to the decrease in the percentage of applied torque with angled cast abutments and probability of discrepancy with casting, a new abutment screw is suggested to be used for final tightening in SDI (3.0 mm).

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