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RESEARCH AND EDUCATION

# Removal torque and force to failure of non-axially tightened implant abutment screws

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## ABSTRACT

**Statement of problem.** Components have been introduced that allow the screw channel of an implant crown to be angled lingually and the screws to be tightened in a non-axial direction to the implant. Information is lacking as to how the removal torque value (RTV) and force to failure (FTF) of these components compare with those of conventional screws.

**Purpose.** The purpose of this in vitro study was to evaluate and compare the RTV and FTF values of cyclically loaded implant-supported restorations. Specifically, values for conventional axially tightened gold screws were compared to those for non-axially tightened screws aligned at 3 different angulations.

**Material and methods.** A total of 28 external hexagon implants were embedded in acrylic resin and divided into 4 groups. Simulated restorations were fabricated on abutments capable of different screw channel angulations. Dynamic abutments (DA) were waxed at different angulations and then cast. Simulated restorations were placed on the implants and tightened: group 0GS: 0-degree angulation gold screw tightened to 35 Ncm (control group); group 0DAS, 0-degree angulation with dynamic abutment (DAS) screw; group 20DAS: 20-degree angulation with DA screw; group 28DAS: 28-degree angulation with DAS screw. In groups 0DAS, 20DAS, and 28DAS, the DAS screw was used and tightened to 25 Ncm. Screw removal torque values were recorded by using a digital torque gauge at baseline and, after reaching cyclic fatigue, by using a dual-axis mastication simulator for 1 200 000 cycles. The fracture strength (FS) of the implant restorations was tested under compression until failure by using a universal testing machine. Differences between baseline and removal torque ($\Delta$RT) were calculated. Statistical analysis was performed by using 1-way ANOVA for $\Delta$RT and FS separately ($\alpha$=.05).

**Results.** $\Delta$RT and FS values were not significantly different among the groups ($P$>.05). The screw fractured in 5 of 28 specimens (17.8%); the remaining specimens failed with fracture of the implant.

**Conclusions.** The removal torque and FS values of the angulated abutment screw were comparable to those of the gold screw. Angulation of the abutment had no significant influence on the screw removal torque values. (J Prosthet Dent 2018;■:■-■)

Screw retention may be preferred to cement retention as residual cement has been identified as a common cause of peri-implant disease.[1,2] However, the anatomy of the site may make placing an implant with an orientation that permits the screw access channel in a nonvisible location problematic.[3] In the past, the implant site might have been augmented to accommodate a screw-retained restoration, an intermediary preangled abutment might have been used which required the implant to be placed more apically,[4] or a cemented restoration might have been provided. Multiple studies have described and supported the use of angled abutments by comparing them with standard abutments. No significant differences have been reported regarding the survival of implants restored with angled and standard abutments.[5-9]

Other studies[10,11] have compared removal torque values (RTVs) of different abutments after dynamic cyclic loading and found that angled abutments had significantly higher RTVs than straight abutments or gold premachined customized abutment groups. Fatigue testing is an accepted method for generating data for fracture strength (FS) and longevity of implants and abutments and for simulating in vivo conditions. The load is applied 30 degrees off-axis according to the

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## Clinical Implications

Angulated abutments can alter the screw channel angulation and have a screw design that can accommodate being tightened non-axially. These abutments offer clinical advantages, and their mechanical behavior is comparable to that of the conventional gold screw.

International Organization for Standardization (ISO) standard for fatigue testing implants and abutments (ISO 14801) and to previous studies.[12,13]

Recently a titanium abutment screw (dynamic abutment screw [DAS]; Dynamic Abutment Solutions) that can be tightened non-axially has been introduced. Nonaxial tightening is due to the hexalobular screw driver and compatible screw head as seen in Figure 1. The corresponding abutment (dynamic abutment [DA]; Dynamic Abutment Solutions) allows a screw-retained restoration to be placed and fastened to an implant while allowing a nonaxial screw channel. This has the advantages of not requiring an intermediary abutment or additional restorative space or mucosal thickness to hide the implant components. A clinical report[14] has been published recently, but a search of published studies did not identify data about this angulated abutment and screw system. Therefore, the purpose of this study was to evaluate and compare the effects of RTV and force to failure on cyclically loaded implant-supported restorations. The hypotheses tested were that the gold square screw would achieve higher RTV and be more resistant to fracture than the DAS at 28 degrees and that the DAS at 0 degrees would not be statistically different from the DAS at 20 and 28 degrees.

## MATERIAL AND METHODS

Twenty-eight specimens were fabricated by using titanium external hexagon implants (Osseotite; Zimmer Biomet) that were embedded in autopolymerizing methyl methacrylate (Technovit 4000; Kulzer) by means of a custom-made positioning device. These specimens were then divided into 4 groups: control group 0GS (0 degrees and Gold square screw; UNISG; Zimmer Biomet); group 0DAS (0-degree and DAS); group 20DAS (20-degree and DAS); and group 28DAS (28-degree and DAS) as test groups.

The castable DA for a 4.1-mm external hexagon implant was used for all specimens. In groups 0GD and0 DAS, the DA was positioned at 0 degrees angulation; group 20DAS at 20 degrees angulation; and group 28DAS at 28 degrees angulation (Fig. 2). All angulations were measured relative to the long axis of the implant, verified by using a parallelometer with a protractor, and confirmed by 2 investigators (J.G. and T.L.).

Each abutment was waxed to the anatomic contour of a left maxillary incisor crown (Fig. 3) by using a custom-made polyvinyl siloxane mold (Elite Double 22 Fast; Zhermack SpA) and cast in a Ni-Cr alloy (Tilite; Talladium Intl) in an automated casting machine (KDF; Neo Super Cascom) (Fig. 4). Once the abutments had been devested and polished, a small dimple was made on the mesiolingual area with a #4 round tungsten carbide bur (Brasseler USA) to create a point for consistency during loading.

Once all specimens were fabricated, the restorations were screwed onto the implants. To establish a baseline for the RTV, we inserted and removed each screw 3 times while recording the torque and removal torque values by using a digital torque gauge (MTT03-12;MARK-10). The

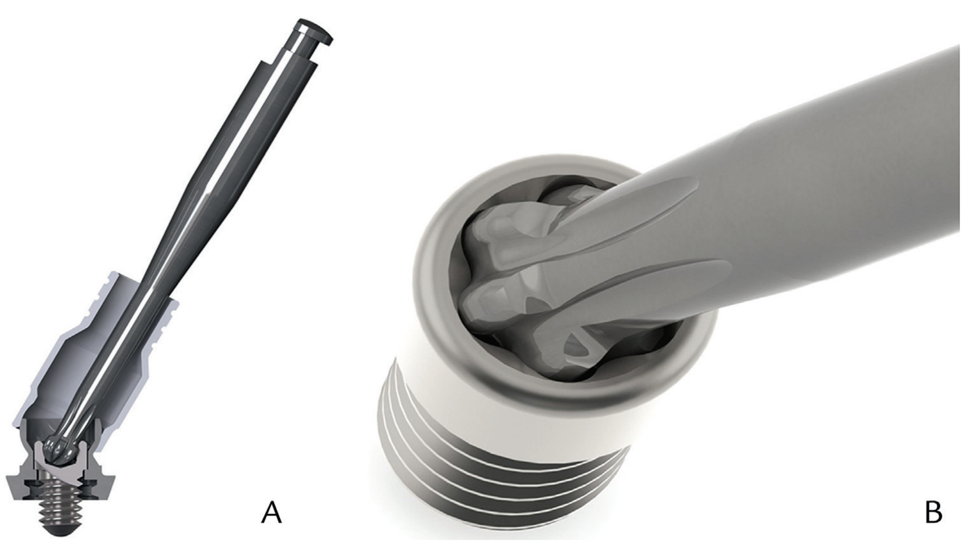


**Figure 1.** A, Dynamic abutment. B, Hexalobular screw driver and screw head.

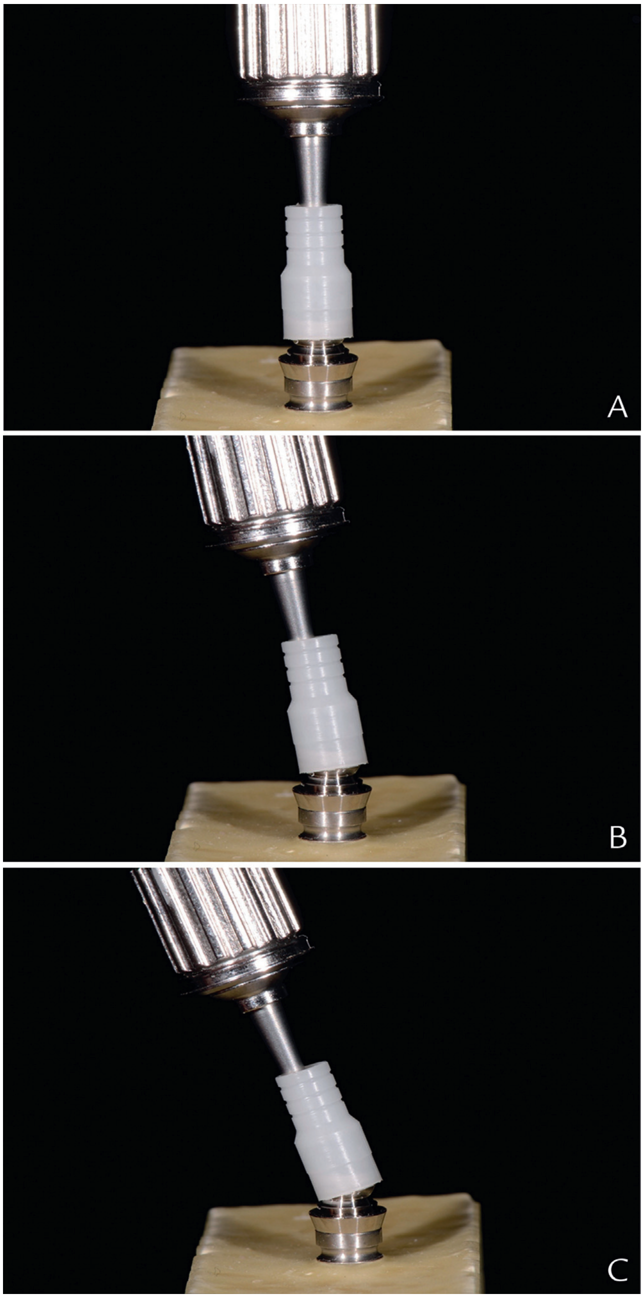


**Figure 2.** Model with castable dynamic abutment. A, 0-degree angulation. B, 20-degree angulation. C, 28-degree angulation.

gold screws for group 0GS were tightened to 35 Ncm, whereas screws for the 0DAS, 20DAS, and 28DAS groups were tightened to 25 Ncm according to the manufacturers' recommendations. Subsequently, all screws were tightened again to the recommended values prior to loading into a dual-axis mastication simulator (CS4-8; SD Mechatronik) with an antagonistic stainless steel ball under an axial load of 40 N for 1 200 000 cycles. All specimens were retightened at 9205 cycles to compensate for loss of initial preload due to settling effects.[15-19] After cyclic fatigue was reached in the dual-axis mastication simulator,

**Figure 3.** Model with anatomic contour waxing on dynamic abutment.

final screw RTVs were recorded in the same way as the baseline values, using the digital torque gauge.

A universal mechanical testing machine (Model 5965; Instron) was used to test the FS for each specimen. A rigid clamp system was used to hold the implants at a 30-degree angle while the specimens were loaded under compression at a crosshead speed of 1 mm/min until failure or obvious deformation. Peak loads were recorded in newtons, and the testing protocol was based on ISO recommendations (ISO 14801).

All data were entered into a spreadsheet (Excel; Microsoft Corp), and mean baseline and final RTVs were calculated. Differences between baseline and removal torque ($\Delta$RT) values were calculated and compared the DAS at different angulations with those of the conventional gold square screw. Statistical analysis was performed by using 1-way ANOVA for $\Delta$RT and FS separately ($\alpha$=.05), using statistical software (IBM SPSS Statistics v19; IBM Corp). Prior to performing the 1-way ANOVAs, we confirmed normality and homoscedasticity of the data (Kolmogorov-Smirnov test, $P$>.05; Levene test, $P$>.05).

## RESULTS

$\Delta$RT and FS values are shown in Table 1. Analysis of the one-way ANOVA showed that there were no significant differences in variances between and within the groups for each tested parameter, as the $P$ value was >.05, the F-value was .800, and the degrees of freedom (*df*) were 3 between the groups and 24 within the groups.

Five screws fractured in 28 specimens (17.8%) in the 0GS group; 2 screws fractured in the 0DAS group; 2 screw fractured in the 20DAS group; and 1 screw fractured and none for 28DAS (Figs. 5, 6). Differences in patterns of fracture were also noted among the groups; the remaining specimens failed by damaging the implant platform, whereas the screw became deformed or loosened. All crowns stayed intact, but the implant platform was severely deformed or fractured.

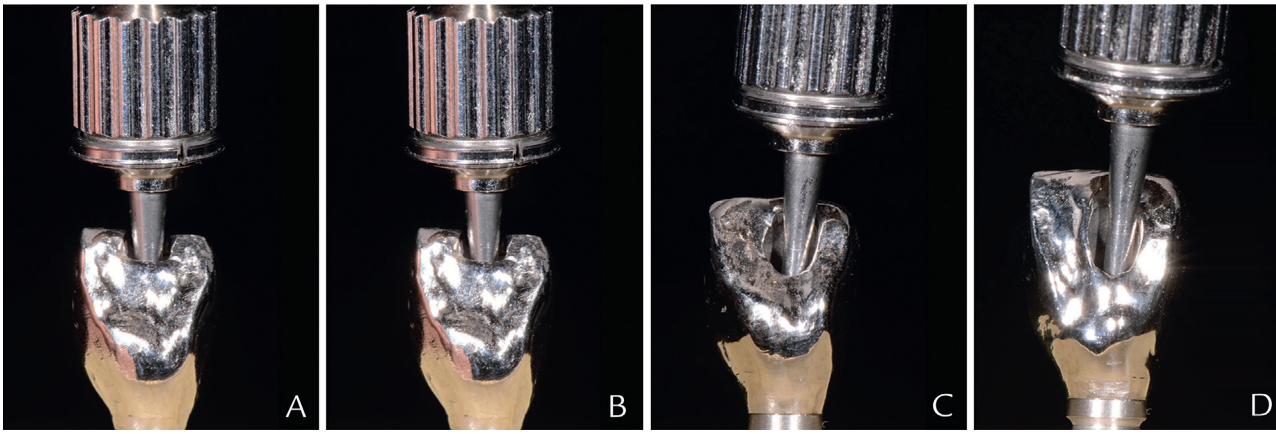


**Figure 4.** Cast specimens. A, 0-degree gold screw. B, 0-degree dynamic abutment screw. C, 20-degree dynamic abutment screw. D, 28-degree dynamic abutment screw.

**Table 1.** Group comparison of mean ±SD ΔRT and FS values (N/group=7)

| | Group 0GS | Group 0DAS | Group 20DAS | Group 28DAS |
|---|---|---|---|---|
| ΔRT (Ncm) | −1.04 ±4.33 | 1.09 ±4.92 | −0.51 ±3.24 | −2.57 ±5.11 |
| FS (N) | 989.01 ±401.29 | 869.59 ±164.52 | 715.88 ±101.79 | 789.84 ±153.60 |

ΔRT, removal torque; 0DAS, 0-degree dynamic abutment screw; 0GS, 0-degree gold screw; 20DAS, 20-degree dynamic abutment screw; 28DAS, 28-degree dynamic abutment screw; FS, fracture strength; SD, standard deviation.

## DISCUSSION

Results indicated that the first hypothesis should be rejected: the 0GS group did not achieve a higher RTV and was not significantly more resistant to fracture than the 28DAS group. The second hypothesis was accepted, as the 0DAS group was not statistically different from the 20DAS and 28DAS groups.

Although the fact that axial loads are not detrimental to the integration of the implant to bone is well documented,[5-9] nonaxial loads can increase the occurrence of abutment screw loosening due to the continued bending forces applied to the screw during function.[15-18] This in vitro test was designed to simulate 5 years of use (1 200 000 cycles of cyclic loading), to measure the removal torque values of the different angulations of screws, and then to determine the force necessary to fracture the screws after simulated loading.[20]

A maxillary single tooth restoration was tested as it is normally vulnerable to loosening of the retaining screw because of the relationship of the maxillary to the mandibular incisors which leads to non-axial loading and, therefore, bending forces to the screw.[15] The specimens were cast in a Ni-Cr alloy because that was recommended by the manufacturer of the castable DAS. For standardization purposes. The alloy was used for all groups. The average FS for the 0GS group was 989.01 N, 869.59 N for the 0DAS group; 715.88 N for the 20DAS group; and 789.84 N for the 28DAS group. Furthermore, the removal torque for the 28DAS was −2.57 Ncm,

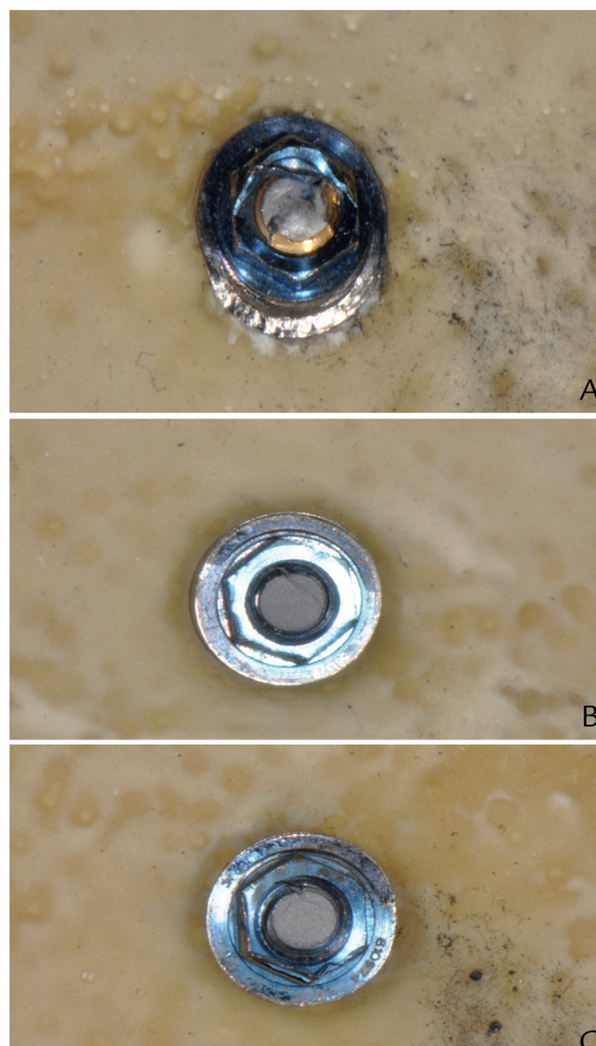


**Figure 5.** Representative screw fracture patterns after testing. A, 0-degree gold screw fracture with damage to implant platform. B, 0-degree dynamic abutment screw fracture without damage to implant platform. C, 20-degree dynamic abutment screw fracture with minimal damage to implant platform.

**Figure 6.** Representative specimen after fracture of dynamic abutment screw at a 28-degree angulation. Note intact platform of implant.

indicating that the removal torque of the specimens was the lowest. This is consistent with increased tensile forces to the screw with more severe nonaxial loading. The FS of the gold screw was greater than that in the DAS specimens; however, the difference was not statistically significant. This indicates that the DAS in differing angulations has the potential to withstand forces after cyclic loading that may be clinically satisfactory; furthermore, in only 5 specimens did any screws fracture before the implant failed mechanically.

External connection hexagon implants were tested because they have a weaker connection than internal connection implants.[21,22] Therefore, more tensile force was applied to the screw to test it to the limit without the biomechanics of an internal connection potentially influencing the final results. In this study, the static force was applied in a vertical direction only, whereas in a clinical situation, forces would be applied in multiple directions during the mastication process. However, clinical trials are recommended to support these in vitro findings.

## CONCLUSIONS

Within the limitations of this in vitro study, the following conclusions were drawn:

1. The removal torque and FS of the dynamic abutment screw are comparable to those of the gold screw.
2. Angulation of the abutment had no significant influence on screw removal torque values.

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