

RESEARCH AND EDUCATION

Abutment screw loosening in angulation-correcting implants: An in vitro study



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Implant-retained prostheses represent a clinically beneficial and predictable treatment option for replacing a single missing tooth, but they are not without the risk of biological, technical, and esthetic complications. Of the technical complications, abutment screw loosening is one of the most common, with a reported incidence ranging from 2% to 45% but more usually in the range of 5% to 10%.¹⁻³

The principles of screw mechanics involve applying a torque force to produce elongation and tension that in turn develops a force within the screw known as 'preload.' The elastic recovery of the screw then pulls the components together, resulting in a clamping force. The screw will loosen or fracture if external separating forces acting on the implant-abutment joint are greater than the clamping forces keeping the abutment and the implant together.^{4,5}

The angle at which occlusal load is applied to implant-retained restorations has not been specifically investigated, but it is apparent that anterior dental implants rarely receive solely longitudinal axis forces. Methods of correcting angulation to enable a screw-retained crown include angled abutments, angulated

ABSTRACT

Statement of problem. Techniques that allow angulation correction for screw-retained implant-supported restorations are now available. However, whether angulation correction built into the head of the implant affects abutment screw loosening is unclear.

Purpose. The purpose of this in vitro study was to assess abutment screw loosening in angulation-correcting implants and straight implants subjected to simulated nonaxial occlusal loading.

Material and methods. Seven external connection 12-degree angulation-correcting implants and 7 straight implants were embedded in an acrylic resin housing, and titanium abutments were secured with titanium screws tightened to 32 Ncm. Each specimen was secured in a tooth wear machine and subjected to 1 000 000 cycles of 50-N nonaxial load to simulate 1 year of clinical service. The mean abutment screw removal torque values were calculated, and the association between number of cycles and the abutment screw removal torque was analyzed using a linear mixed-effects model and statistical software ($\alpha=.05$)

Results. The mean abutment screw torque loss was 59.8% for the angulation-correcting implant group and 68.7% for the straight implant group. A statistically significantly greater mean abutment screw removal torque was recorded in the angulation-correcting implant group compared with the straight implant group after 1 000 000 cycles ($P=.019$).

Conclusions. A significant loss of abutment screw torque was found in both implant groups with increased cycles of occlusal loading. The angulation-correcting implants resisted screw loosening significantly more than the straight implants because of the reduced angle of abutment screw loading. (J Prosthet Dent 2019;121:151-5)

screw channels, or angulated prosthetic platforms incorporated into the implant.

Finite element analyses, photoelastic stress analyses, and strain gauge studies have found that angled abutments adversely affect how stresses are distributed to the surrounding bone and prosthetic components.^{6,7} Angulation-correcting implants incorporate an angle correction within the implant head rather than at the abutment level. The Co-Axis implant (Southern Implants) has either 12-, 24-, or 36-degree angulation

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Clinical Implications

Abutment screw loosening occurs frequently and is a significant consideration in implant-retained crowns. The angulation-correcting implant, where angulation correction is built into the head of the implant, provides a convenient method of facilitating direct-to-implant screw retention while also resisting screw loosening more than conventional straight implants.

correction option in the implant head, allowing implant placement in the often proclined maxillary alveolar bone while the prosthetic platform is aligned to enable a screw-retained restoration (Fig. 1). The authors are unaware of research that has specifically investigated the technical complications of angulation-correcting implants.

This study assessed abutment screw loosening in angulation-correcting implants and straight implants subjected to simulated nonaxial occlusal loading. The null hypothesis was that the abutment screw torque would be similar in angulation-correcting implants and straight implants.

MATERIAL AND METHODS

Seven angulation-correcting implants (Co-Axis 12-degree external hexagonal 5×11.5 mm; Southern Implants) and 7 straight implants (external hexagonal 5×11.5 mm) (Fig. 2) were positioned using a custom jig in autopolymerizing acrylic resin (Vertex Self-Curing; Vertex-Dental BV) contained in a stainless steel cylinder. Each specimen was mounted with the implant head level with the acrylic resin in accordance with the manufacturer's guidelines so that the implant threads remained within the acrylic resin to simulate ideal implant placement in the anterior esthetic zone.

A hemispherical titanium fatigue abutment was used to allow for loading at different angles⁸ (Fig. 3). A new abutment was attached to each implant with a new grade 4 titanium abutment screw (Southern Implants) and tightened to 32 Ncm using a calibrated torque gauge (model BTG36CN; Tohnichi Mfg Co Ltd) in accordance with the manufacturer's recommendations. The abutment screw was retightened to the same initial torque value after 10 minutes to account for the screw-settling effect.^{5,9}

Each specimen was mounted in a customized stainless steel housing fabricated to allow loading of the fatigue abutment at 30 degrees to the long axis of the implant⁸ (Fig. 4). Given the 12-degree angulation correction of

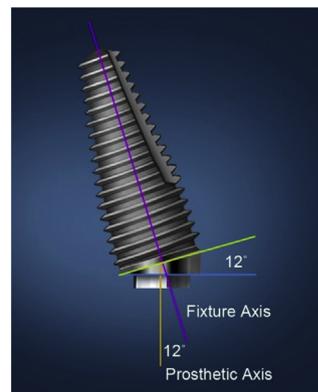


Figure 1. Twelve-degree Co-Axis implant.¹⁴



Figure 2. Straight and 12-degree test implants.

the Co-Axis implants, loading was at 18 degrees to the long axis of the implant (Figs. 4, 5). Each specimen was positioned in a custom mechanical tooth wear machine and subjected to 1 000 000 cycles of 50 nonaxial loads to simulate 1 year of clinical loading.¹⁰ At 250 000, 500 000, 750 000, and 1 000 000 cycles, a torque gauge was used to perform a torque audit to evaluate the abutment screw removal torque. The torque gauge was then used to confirm that the abutment screw was tightened to the last recorded torque audit value before cyclic loading resumed until the next torque audit was conducted.

The mean abutment screw removal torque values were calculated at each torque audit, and the association between the number of cycles and the abutment screw removal torque was analyzed using a linear mixed-effects model and statistical software (SAS v9.4; SAS Institute Inc) ($\alpha=.05$).

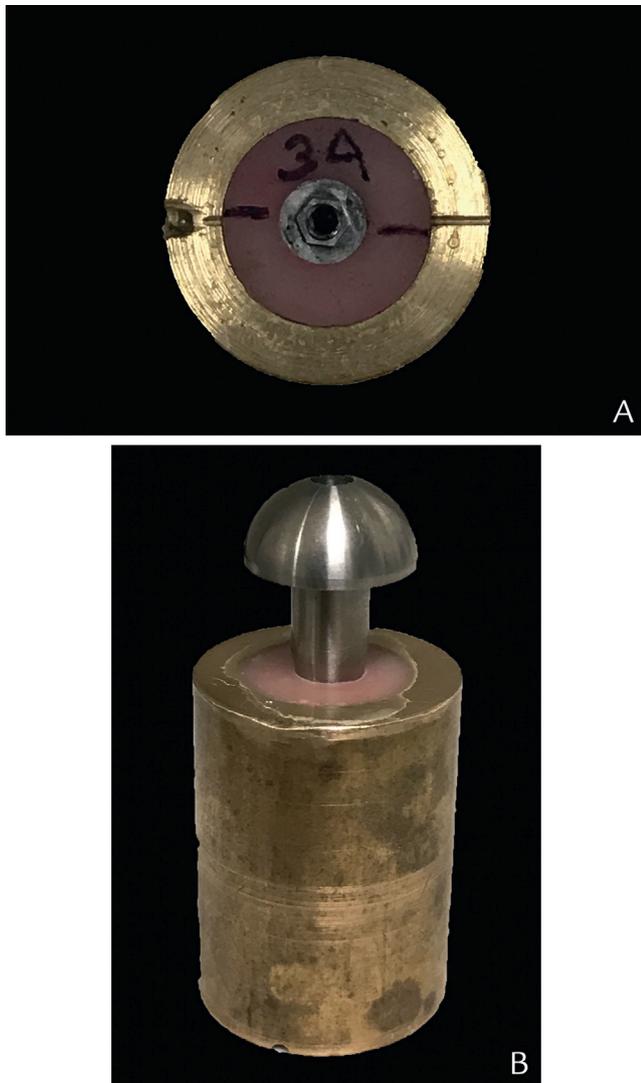


Figure 3. Implant embedded in acrylic resin within cylinder. A, Coronal view of external hexagon connection. B, Fatigue abutment attached.

RESULTS

The mean abutment screw removal torque at each torque audit for the angulation-correcting and straight implant groups is shown in Figure 6. In all specimens in both implant groups, the abutment screw removal torque decreased from its previous value at each torque audit. After 1 000 000 cycles, a statistically significantly greater mean abutment screw removal torque was noted in the angulation-correcting implant group compared with the straight implant group ($P=.019$).

The total abutment screw torque loss for each specimen after 1 000 000 cycles and the mean total abutment screw torque loss for the angulation-correcting and straight implant groups are presented as percentages in Table 1. The mean abutment screw torque loss was 59.8% (range=50%-68.7%) in the angulation-correcting

implants and 68.7% (range=59.4%-85.9%) in the straight implant specimens. No abutment screw fractures were observed during cyclic loading.

DISCUSSION

The mean abutment screw removal torque values observed in both implant groups represented a significant reduction from the initial torque and may have been caused by the magnitude of the applied load, external hexagon implant connection, choice of screw material, and nature of the repeated cycling loading process. Comparisons with other studies are limited because the authors are unaware of a study assessing the loss of abutment screw torque in angulation-correcting implants; however, the findings of the present study are in agreement with those of research investigating loss of abutment screw torque over time in loaded and unloaded implant abutments.¹¹

The findings suggest that the angulation-correcting implants resisted screw loosening significantly more than straight implants after extended numbers of loading cycles. Therefore, the null hypothesis was rejected. The finding may be explained by the reduced angle of cyclic loading to the abutment screw, which is at least part of the consequence of the implant design. The angulation-correcting implants resulted in the abutment screw being loaded at 18 degrees compared with 30 degrees in the straight implants. The angulation differential in loading between the abutment screw and implant long axis in the angulation-correcting implants was a significant factor in this study and could provide a clinical advantage.

The fatigue abutment selected in reference to the International Organization for Standardization standard has also been used by other authors, but the hemispherical abutment shape can be justified only by experimental convenience and did not represent an anatomic tooth.^{6,8} The fatigue abutments showed some signs of surface wear that did not equate with the observed abutment screw removal values.

The clinical consequences of abutment screw loosening range from gross changes, such as mobility and separation, to microscopic changes, such as micromotion of the implant-abutment joint and bacterial microleakage.^{12,13} In a clinical environment, such problems can be challenging and beyond simple repair and may sometimes necessitate treatment revision.

As with most in vitro studies, the current study is limited in its application to the in vivo environment but can still provide essential information to inform clinical decisions. The number of cycles used in this study was based on an estimation of 1 year of clinical function, and the off-axis forces represented worst-case scenario testing and may be larger than those seen clinically.⁸

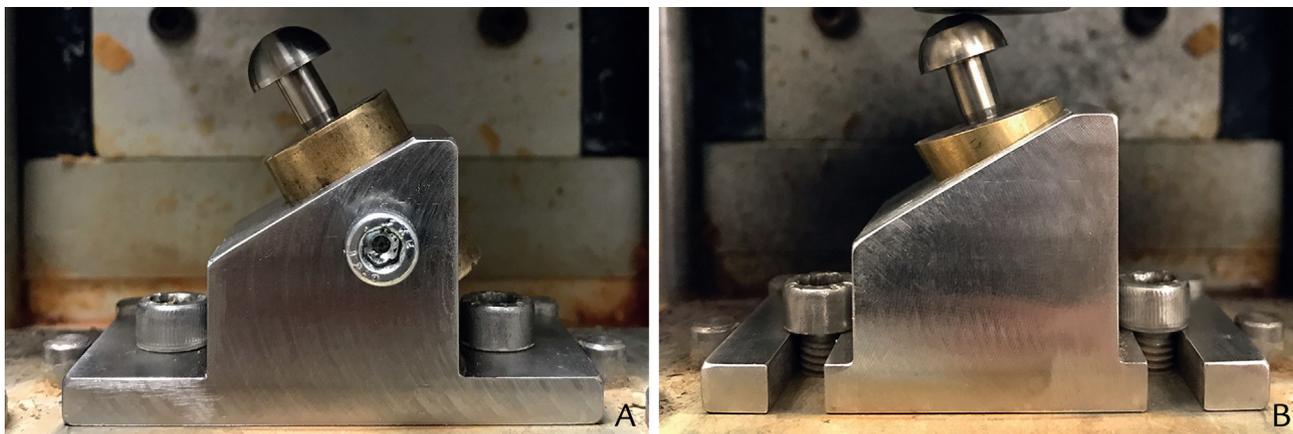


Figure 4. Custom housing and abutment attached to implant. A, 30 degrees to applied load, straight implant. B, 18 degrees to applied load, angulation-correcting implant.

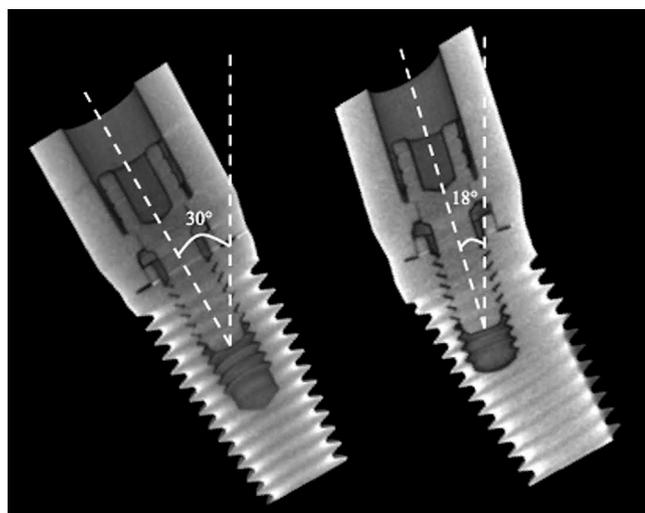


Figure 5. Reconstructed microcomputed tomography images of loading angulations for straight and angulation-correcting implants.

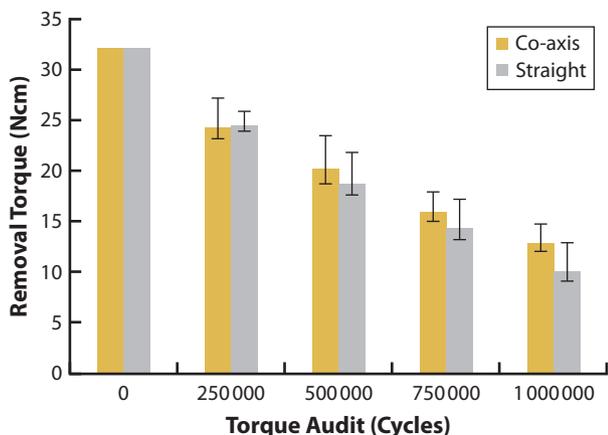


Figure 6. Mean abutment screw removal torque at each torque audit.

Simulated occlusal loading is just one factor that contributes to component fatigue in the multifactorial oral environment.

Table 1. Total abutment screw torque loss for each specimen after 1 000 000 cycles and mean total abutment screw torque loss for angulation-correcting and straight implants

Specimen	Total Abutment Screw Torque Loss, %	
	Angulation-Correcting Implants	Straight Implants
1	60.9	85.9
2	50.0	73.4
3	64.1	67.2
4	56.3	60.9
5	59.4	59.4
6	59.4	67.2
7	68.8	67.2
Mean torque loss	59.8	68.8

Some of the experimental conditions may have influenced the results, including the method of measurement. The torque gauge was calibrated to an accuracy of $\pm 3\%$, a single direction of cyclic load was applied, the sample size was limited, and the 2 implant groups were loaded at different angles. Future studies could overcome some of these limitations by using alternate methods of measuring torque that do not involve retightening after each audit, such as the use of strain gauge sensors and digital torque indicator units. Also, replicating this study design with larger sample sizes would provide a more accurate representation of the clinical setting.

CONCLUSIONS

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

1. A significant loss of abutment screw torque was found in both implant groups with increased cycles of occlusal loading.
2. The angulation-correcting implants resisted screw loosening significantly more than the straight implants after 1 year of simulated occlusal function

because of the reduced angle of abutment screw loading.

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