THE EFFECT OF ABUTMENT HEIGHT ON SCREW LOOSENING IN SINGLE IMPLANT-SUPPORTED PROSTHESES AFTER DYNAMIC CYCLIC LOADING

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Statement of problem. One of the common problems of dental implant prosthesis is the loosening of the screw that connects each component, and this problem is more common in single implant-supported prostheses with external connection.

Purpose. The purpose of this study was to examine the changes of detorque values of abutment screws with external connection in different abutment heights.

Materials and methods. After cyclic loading on three different abutment heights, detorque values were measured.

Abutments were retained with titanium abutment screws tightened to 30 Ncm (30.5 kgmm) with digital torque gauge as recommended by the manufacturer. Replacing abutments, implants and titanium abutment screws with new ones at every measurement, initial detorque values were measured six times. In measuring detorque values after cyclic loading, Avana Cemented Abutments of 4.0 mm collar, 7.0 mm height (Osstem Co., Ltd., Seoul, Korea) were used with three different lengths of 5.0, 8.0, 11.0 mm. Shorter abutments were made by milling of 11.0 mm abutment to have the same force-exercised area of 4.5 mm diameter. Sine curve force (20N-320N, 14Hz) was applied, and detorque values were measured after cyclic loading of 2 million times by loading machine. Detorque values of initial and after-loading were measured by digital torque gauge. One-way ANOVA was employed to see if there was any influence from different abutment heights.

Results. The results were as follows :

1. The initial detorque value was 27.8 ± 0.93 kgmm, and the ratio of the initial detorque value to the tightening torque was 0.91(27.8/30.5).
2. Measured detorque values after cyclic loading were declined as the height of the abutment increased, that was, 5.0 mm; 22.3 ± 0.82 kgmm, 8.0 mm; 21.8 ± 0.93 kgmm, and 11.0 mm; 21.3 ± 0.94 kgmm.
3. One-way ANOVA showed no statistically significant differences among these ($p>0.05$).
4. Noticeable mobility at the implant-abutment interface was not observed in any case after cyclic loading at all.

Key Words

Dental implant, Abutment, Screw loosening, Cyclic loading, Detorque value

Since Brånemark and his colleagues had introduced the concept of osseointegration,[1] dental implant has been successfully used for edentulous patients. The use of single endosseous osseointegrated implant to support dental replacement has continued to increase and become refined. However, prosthetic problems such as screw loosening, fracture, and other component failures have been observed during a long period of follow up.

In a multi-center study, Laney et al[2] placed single-implant prostheses in 82 patients and screened them for three years. They recorded several types of complications, such as abutment screw fracture, soft tissue penetration, mucosal inflammation and screw loosening.

One of the common problems of dental implant prosthesis is the loosening of the screw that connects each component, and the problem is especially more common in single implant-supported prostheses with external connection.[3-6] When it occurs, patients complain soreness at the interface between soft tissue and the implant, swelling and/or fistula formation, difficulty in chewing, and prosthetic instability as a results of a poor fit in the interface zone of the prosthesis and the implant.[7]

Fastening the screw inside the implant body results in a secure butt-joint connection between the prosthesis and the implant. This connection produces a load, which is known as preload.[8] A properly preloaded abutment screw should be strong enough to resist torques from occlusal loadings for implant-supported prostheses. However, according to several reports, screw have loosened in 1 to 57 percent of single-tooth implant restorations.[9-16]

Reasons for loosening include inadequate preload, inappropriate implant position, inadequate occlusal scheme or crown anatomy, variations in hex dimension coupled with equal variations in the abutment counterparts, slight differences in fit and accuracy, tension on abutment and cylinder from ill-fitting restorations, improper screw design, and excessive occlusal forces.[7,17,18]

While there have been many experiments on screw loosening, but not many studies on vertical cantilever. The purpose of this study was to examine the changes of detorque values of abutment screw with external connection in different abutment heights by performing comparative analysis of detorque values. After cyclic loading on three different abutment heights, detorque values were measured to find the differences among heights.

In this protocol, 3 assumptions[19] were necessary: (1) the abutment screws were all loaded with the same preload after initial tightening, (2) the detorque value was a measure of the remaining preload in the abutment screw, and (3) any differences in the detorque value from specimen to specimen after fatigue testing were related to abutment height between three specimens.

MATERIALS AND METHODS

1. MATERIALS

(1) Implant

Twenty four Avana Self Tapping Implant, machined surface (Osstem Co., Ltd., Seoul, Korea) ø 4.0 × 11.5 mm were used (Fig. 1).

(2) Abutment screw

Twenty four titanium screws (Osstem Co., Ltd., Seoul, Korea) were used (Fig. 1).

(3) Abutment

Avana Cemented Abutments of 4.0 mm collar, 7.0 mm height (Osstem Co., Ltd., Seoul, Korea) were used with three lengths of 5.0, 8.0, 11.0 mm. 11.0 mm abutment was milled for 5.0, 8.0 mm

- lengthened abutments to have the same force-exercised area of 4.5 mm diameter (Fig. 1).

(4) Loading machine (Fig. 2)

Mini Bionix II Test System (MTS; MTS systems corp., Eden Prairie, Minnesota, U.S.A.) was used under constant temperature (18℃) and constant humidity (38%) condition.

(5) Customized jig

The jig was customized by the ISO standard[20] so that the force could be applied to the abutment at 30 degrees to the long axis (Fig. 3).

(6) Torque gauge

Detorque values were measured by digital torque gauge (MGT50, MARK-10 corp., U.S.A., Fig. 4), of which details were as follows; maximum measurement was 580 kgmm, scale was 0.5 kgmm, measurement error was 0.5%. Measured

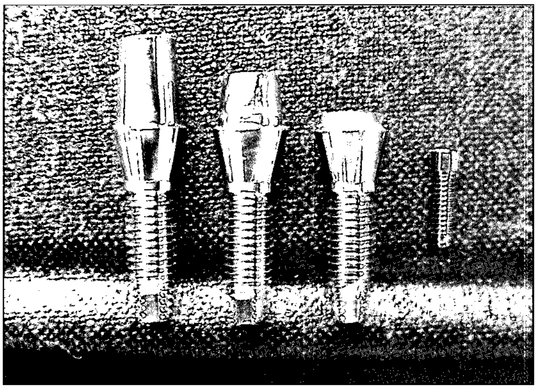

Fig. 1. Implant, abutment screw and abutment (11.0mm, 8.0mm, 5.0mm).

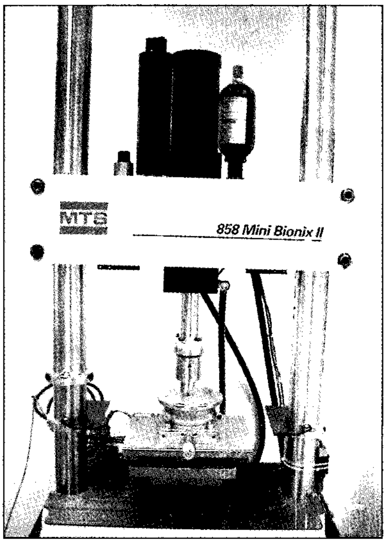

Fig. 2. Loading machine.

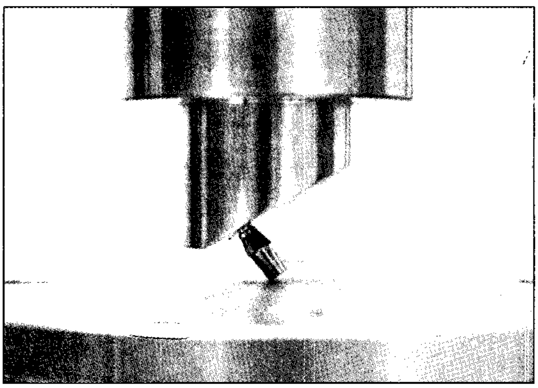

Fig. 3. Mold for cyclic loading test.

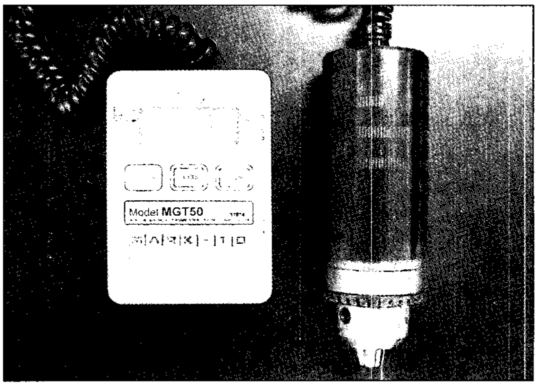

Fig. 4. Digital torque gauge.

values were converted to Ncm, if necessary, on the basis of 1.0 kgmm = 0.98 Ncm.

2. METHODS

(1) Tightening torque

Abutments were retained with titanium abutment screws tightened to 30 Ncm (30.5 kgmm) with digital torque gauge as recommended by the manufacturer.

(2) Initial detorque value

Initial detorque values were measured six times by digital torque gauge, replacing implant, abutment screw, and abutment with new ones each time.

(3) Detorque value after cyclic loading

The each test assembly (abutment, abutment screw, implant) was mounted on the customized jig in MTS loading machine. A testing device delivered dynamic sine curved loading forces between 20 and 320 N at 14 Hz for 2 million cycles (Fig. 5), or the approximate equivalent of 2 years in vivo mastication.

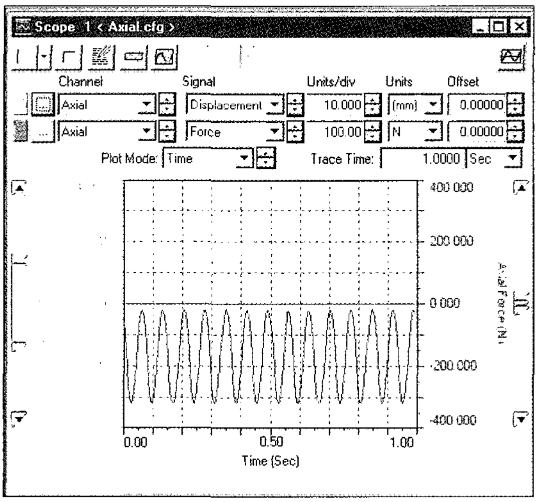

Fig. 5. Loading pattern.

Identical experiments were repeated for each abutment group for six times with new implant and abutment screw each time. Abutments were replaced when necessary.

(4) Statistical Analysis

SPSS statistical Software for Windows (release 10.0, SPSS Inc., Chicago, U.S.A.) was used for statistics analysis. One-way ANOVA was employed to see if there was any influence from different abutment heights ($p<0.05$).

RESULTS

1. Initial detorque value

The average initial detorque values was 27.8 ± 0.93 kgmm (Fig. 6), and the ratio of the initial detorque value to the tightening torque was 0.91(27.8/30.5).

2. Detorque value after cyclic loading

Measured detorque values were declined as the height of the abutment increased, that was, 5.0 mm ; 22.3 ± 0.82 kgmm, 8.0 mm was 21.8 ± 0.93 kgmm, 11.0 mm was 21.3 ± 0.94 kgmm (Fig. 6).

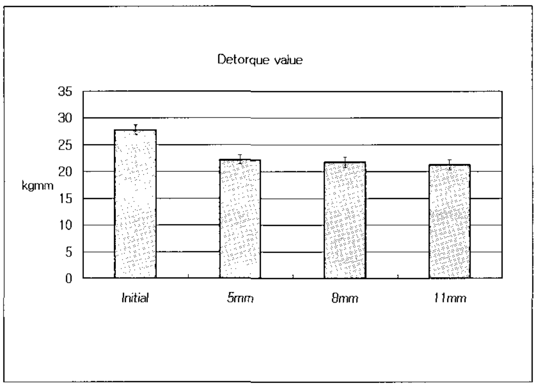

Fig. 6. Initial detorque value and detorque value after cyclic loading.

Detorque value ratios to the tightening torque after cyclic loading were 0.73(22.3/30.5), 0.71(21.8/30.5), and 0.70(21.3/30.5) for 5.0 mm, 8.0 mm, and 11.0 mm, respectively.

One-way ANOVA showed no statistically significant differences among different abutment heights ($p>0.05$). Noticeable mobility at the implant-abutment interface was not observed in any case after cyclic loading at all.

DISCUSSION

Becker et al[14)] presented the results of a retrospective analysis, which represented the first report of replacing single molars with implant-supported prostheses. Loosening of the screws was the main complication. And screw loosening may be an early warning sign of biomechanical design problems or occlusal overload.[21]

Rangert et al[22)] described the implant as a system with compensating forces and a lever arm, with the axial forces and bending moments being the main types of loads acting on the implant-supported prosthesis. Axial forces are more favorable, and a bending moment tends to produce rotation of a rigid body. Geometric load factors as risk factors for implants in the posterior partially edentulous segment are (1) number of implants less than support value, (2) fewer than three implants, (3) implants connected to natural teeth, (4) implant in a line, (5) cantilever extension, (6) occlusal plane aside implant heads, and (7) excessive height of crown-abutment complex.

Screw loosening in single tooth replacement with external connection can be overcome by modification of the implant-abutment interface.[18,23-25] However, because screw loosening in all systems can be occurred, screw hole can be prepared on the occlusal surface against screw loosening even in case of cementation type crown. Also, anti-rotational features, gold screws, torque-controlling mechanisms, and screw cements are recommended.[7,18,26]

Especially in external connection, the operator must minimize the buccolingual and mesiodistal dimensions to reduce the cantilever,[27] shorten the non-functional cusps, and minimize cusp angle, choose a wide implant to reduce the lever arm. And the operator must select an abutment with zero-degree rotation between implant hex and abutment to resist the rotational forces exerted on the crown. In the case of a single anterior implant, occlusal adjustments should be carried out in such a way that the shim stock is lightly in contact during maximum intercuspation and no contact during lateral excursions. Despite these efforts, loosening of screws can still be a problem.

Bickford[28] described the process of screw loosening in 2 stages. Initially, external forces, such as mastication, applied to the screw joint caused thread slippage, contributing to release of the stretch, or preload, of the screw. The second stage of loosening involved continual preload reduction below a critical level, allowing threads to turn and loss of intended screw joint function. If the screw loosens and the preload falls below a critical level, joint stability may be compromised and potentiate clinical failure. On the other hand, Lee et al[29] reported that the wave mode was divided into 4 stages for loosened screws: initial displacement, initial vibration, elastic deformation, and recovery stage and that the initial displacement and initial vibration stages were not discernible for stable screws.

According to Gibb et al,[30] about 1 million masticatory movement occurs a year. In this study, two million cyclic loading was equivalent to the mastication of two years, and 300 N force in this study was the amount of masticatory force generated at premolar.

When initial tightening torques were applied, torque controller or torque wrench could generate some deviations from the exact target value. Therefore, digital torque gauge was used for tightening to minimize these tightening torque errors in this study. Because repetitive use of implant and abutment screw can change the screw surface affecting the detorque values, new components were used for each experiment.

Clinically, crowns for cementation tend to be dislocated more easily as abutment height lowers. However, the authors mounted loading on abutment itself without crown cementation, without considering cementation effects.

The initial and after-loading detorque values of all the screw joints were less than the tightening torque and the ratio of the initial detorque value to the tightening torque was 0.91. These results are consistent with the finding of Schulte et al.[31]

According to Weinberg et al,[32] a comparative evaluation of torque at the gold screw, abutment screw, and implant was calculated for cuspal inclination, implant inclination, and horizontal and vertical implant offset. The results facilitated rational clinical conclusions that cuspal inclination produces the most torque, followed by maxillary horizontal implant offset, while implant inclination and apical implant offset produce minimal torque. But these datas are not intended as a quantitative analysis.

In this study, there were no statistically significant differences between different abutment heights, which implied that crown height did not have any significant impact on abutment screw loosening for clinically popular crown heights (5.0 mm, 8.0 mm, 11.0 mm). However, since abutment screw loosening tended to grow as crown height increased, additional studies might be focused on the cases of extraordinary crown heights in the near future.

CONCLUSION

Initial detorque values were measured and detorque values after cyclic loading were measured for three different abutment heights (5.0 mm, 8.0 mm, 11.0 mm) to see the effects of abutment heights in single implant-supported prostheses with external connection and the results were as follows.

1. The initial detorque value was 27.8 ± 0.93 kgmm, and the ratio of the initial detorque value to the tightening torque was 0.91.
2. Detorque values after cyclic loading were 22.3 ± 0.82 kgmm (5.0 mm height of abutment), 21.8 ± 0.93 kgmm (8.0 mm), and 21.3 ± 0.94 kgmm (11.0 mm). The ratios of the detorque value after cyclic loading to the tightening torque were 0.73, 0.71, and 0.70 for 5.0, 8.0 and 11.0 mm respectively, with no statistically significant differences ($p>0.05$).
3. Noticeable mobility at the implant-abutment interface was not observed in any case after cyclic loading at all.

It can be concluded that abutment screw loosening did not occur at commonly used single implant-supported prostheses heights (5.0 mm, 8.0 mm, 11.0 mm) with external connection for two years' masticatory movements. However, it is considered that studies with more various loading conditions are necessary in the future.

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