

Does Abutment Collar Length Affect Abutment Screw Loosening After Cyclic Loading?

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A significant vertical space that is corrected with vertical ridge augmentation may necessitate selection of longer abutments, which would lead to an increased vertical cantilever. This study investigated the influence of different abutment collar heights on single-unit dental implant screw-loosening after cyclic loading. Fifteen implant-abutment assemblies each consisted of an internal hexagonal implant were randomly assigned to 3 groups: Group1, consisting of 5 abutments with 1.5 mm gingival height (GH); Group2, 5 abutments with 3.5 mm GH; and Group3, 5 abutments with 5.5 mm GH. Each specimen was mounted in transparent auto-polymerizing acrylic resin block, and the abutment screw was tightened to 35 Ncm with an electric torque wrench. After 5 minutes, initial torque loss (ITL) was recorded for all specimens. Metal crowns were fabricated with 45° occlusal surface and were placed on the abutments. A cyclic load of 75 N and frequency of 1 Hz were applied perpendicular to the long axis of each specimen. After 500 000 cycles, secondary torque loss (STL) was recorded. One-way ANOVA analysis was used to evaluate the effects of abutment collar height before and after cyclic loading. One-way ANOVA showed that ITL among the groups was not significantly different ($P = .52$), while STL was significantly different among the groups ($P = .008$). Post-hoc Tukey HSD tests showed that STL values were significantly different between the abutments with 1.5 mm GH (Group1) and with 5.5 mm GH (Group3) ($P = .007$). A paired comparison t-test showed that cyclic loading significantly influenced the STL in comparison with the ITL in each group. Within the limitations of this study, it can be concluded that increase in height of the abutment collar could adversely affect the torque loss of the abutment screw.

Key Words: dental implant, screw loosening, abutment design

INTRODUCTION

Although many successful clinical applications have been reported for osseointegrated dental implants,¹⁻³ the esthetic and mechanical stability of implant-supported restorations are at the center of attention in dentistry today.⁴⁻⁶ Implant supported restorations, including single-implant restorations, are subjected to mechanical and biological complications.⁷⁻¹¹ Some clinical studies have shown that among the common mechanical complications of implant-supported prostheses are the fracture or loosening of abutment or retaining screws.¹²⁻¹⁸ According to Jemt,⁴ the most common practical problems during the first year were related to loosening of abutment screws.

Screw loosening could cause an unpleasant experience for patients.¹⁹ In addition, retightening and securing the prosthesis is a time-consuming experience for clinicians and could become economically troublesome.¹⁹ Cement-retained restorations may be destroyed in this situation, especially if crowns cannot be removed without damage. Frequent presence of this problem may be the sign of future failure of other components,

such as screw fracture. The result of screw loosening is instability and poor fit in the interface of the prosthesis/abutment or abutment/implant.²⁰ Furthermore, patients would experience pain at the interface between soft tissue and the prosthesis, and swelling or fistula formation may develop.³ Upon tightening, the generated axial load between the abutment screws and the mating threads of the implant is called "the preload."^{21,22} When the preload in the screw joint is surpassed, overload can occur.²¹ This overload could result in early implant failure by screw loosening or fracture.^{23,24} Usually, the manufacturers recommend that the most favorable preload should cause a stress in the joint that is 60%–75% of the yield strength of the material from which the abutment screw is manufactured.^{23,24}

To reduce the probability of screw loosening, several techniques have been suggested. These techniques include (1) proper preload in screws, (2) narrowing the occlusal table, (3) centering the occlusal contact, (4) flattening the cuspal inclination, and (5) reducing the cantilever length.²⁴⁻²⁹ The majority of the cantilever designs exhibit length or height that may increase forces on screws due to the lever effect and, therefore, should be avoided.³⁰ Significant vertical space that has not been corrected with vertical ridge augmentation may necessitate selection of longer abutments, which would lead to an increased vertical cantilever. Furthermore, selection of the height of abutment collar would be affected if different distances between the implant platform and the gingival

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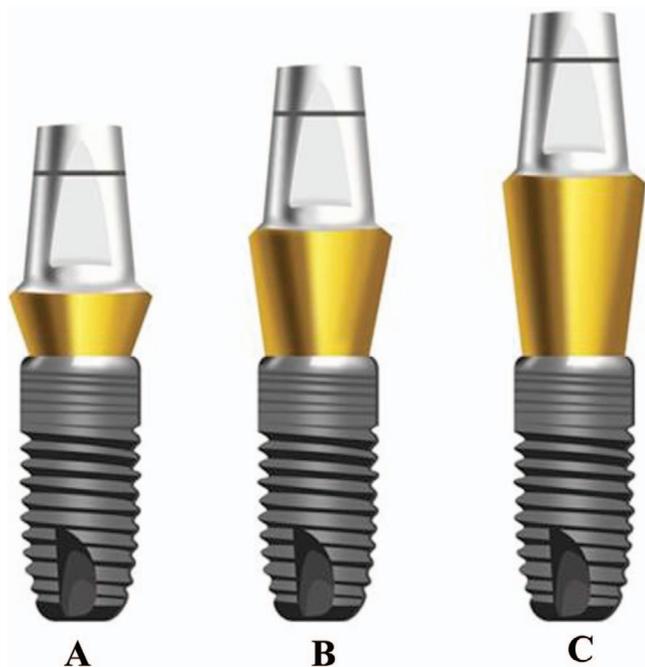


FIGURE 1. Three groups with different collar length. (a) Collar length is 1.5. (b) Collar length is 3.5. (c) Collar length is 5.5 mm.

margin exist, despite consistent occlusogingival dimension. Abutment selection according to gingival height index is a critical factor for achieving esthetic results when placing the crown margin subgingivally, especially on the buccal surface.³¹ By selecting an appropriate abutment collar height, the restoration margin could begin at a more subgingival level. When there is deeper gingival sulcus, the abutment collar may need to be longer. To achieve best esthetic results, the titanium collar should be at least 1 mm below the gingival margin.³¹ Although increased restorative vertical space could play a role in screw loosening,^{32–35} there is no certain evidence that increase in abutment collar height can affect screw loosening. However, considering the abutment height from implant platform to the top of abutment (including abutment collar), an increase in the collar height might result in an increase in the vertical cantilever. Today, the conical, tapered connection of the implant-abutment junction region and use of an abutment that has smaller diameter than that of the implant platform—known as “platform switching”—are prevailing. This concept showed high frictional resistance, and it provides a hermetically sealed implant-abutment junction with a simultaneous lack of micromovement.^{36–41}

No comparative data are available regarding the effect of different abutment collar heights on screw loosening in internal hexagon implant systems under cyclic loading. The purpose of this study was to test the hypothesis that an increased abutment collar height could result in loosening of the abutment screw after cyclic loading in a platform-switching dental implant system. The null hypothesis was that no difference in the screw loosening would be observed among the different heights of abutment collar under cyclic loading.



FIGURE 2. Wax up pattern with 45° inclination of the occlusal surface.

MATERIALS AND METHODS

One cylindrical stainless steel model (20 × 20 mm) was made as a reference. Fifteen transparent auto-polymerizing acrylic resin cylinders (Rapid Repair, Meliodent, HeraeusKulzer GmbH, Germany) were made using this reference model. One hole—4.5 mm in diameter and 12 mm in length—was created in each model. One internal connection implant (Implantium, Dentium, Seoul, South Korea)—10 mm in length with 4.3 mm diameter—was inserted in every sample and secured with auto-polymerizing acrylic resin (Rapid Repair, Meliodent). The fixture adaptor was secured on the vertical rod of a surveyor (J.M. Ney Co, Bloomfield, Conn) and was used to orient implants vertically on the surveyor while inserting in the holes. These 15 samples were divided into 3 groups randomly. Three groups (n = 5 in each group) of implant-abutment assemblies were created with different abutment collars (Figure 1). In Group1, 5 dual abutments (Hex, Ti Abutment Screw, G/H 1.5, Ø 5.5, H 5.5, Dentium) with 1.5 mm gingival height (GH) were fastened into the implants on the resin models (Figure 1a). In Group2, 5 dual abutments (Hex, Ti Abutment Screw, G/H 3.5, Ø 5.5, H 5.5, Dentium) with 3.5 mm GH were fastened into the implants on the resin models (Figure 1b). In Group3, 5 dual abutments (Hex, Ti Abutment Screw, G/H 5.5, Ø 5.5, H 5.5, Dentium) with 5.5 mm GH were fastened into the implants on the resin models (Figure 1c).

A burnout cylinder was seated on 1 abutment and waxed to a thickness of 0.7 mm in all areas. This dimension was evaluated using a digital caliper (Mitutoyo America Corp, Aurora, Ill) that was accurate within 1 µm. A unilateral plane at 45° of inclination was used on the occlusal surface (Figure 2). This inclination was prepared to distribute the forces at 45° angle to the occlusal surface of the prosthesis during cyclic loading.⁴² This pattern was cast and used as a template. A

TABLE					
Descriptive measurements of initial torque loss and secondary torque loss of the three groups*					
Groups	Measurement	Mean	SD	Min	Max
Group1 (GH = 1.5)	ITL, Ncm (percent)	4.80 (13.71%)	1.64 (4.69%)	2 (5.71%)	6 (17.14%)
	STL, Ncm (percent)	10.20 (29.14%)	2.68 (7.67%)	6 (17%)	13 (37%)
Group2 (GH = 3.5)	ITL, Ncm (percent)	4.40 (12.57%)	1.8 (5.19%)	2 (6%)	6 (17%)
	STL, Ncm (percent)	14.40 (41.14%)	1.67 (4.78%)	13 (37%)	17 (48%)
Group3 (GH = 5.5)	ITL, Ncm (percent)	5.80 (16.57%)	2.28 (6.51%)	2 (5%)	8 (23%)
	STL, Ncm (percent)	16.20 (46.29%)	3.03 (8.67%)	12 (34%)	20 (57%)

*ITL indicates initial torque loss; STL, secondary torque loss.

custom mold of this model was made with polyvinyl siloxane impression material (Rapid, Coltene AG, Altstätten, Switzerland) to reproduce the dimensions. This impression was later used as a custom mold for the castings in all groups.

All patterns were invested with a phosphate bonded investment (Cera-Fina, Whip Mix Corp, Louisville, Ky) and were cast in base-metal alloy (Verabond 2, Albadent, Cordelia, Calif). All castings were fabricated by the same technician. These castings were divested with 50 µm aluminum oxide air abrasives. The inner surfaces of the crowns were inspected for surface irregularities under a stereomicroscope (Model BM 38834, Meiji Techno, Tokyo, Japan) at ×10 magnification and adjusted with a carbide bur (#169L-009; Brasseler Inc, Savannah, Ga). Silicone disclosing medium (Fit Checker, GC Corp, Tokyo, Japan) was used to achieve the best possible fit as performed in clinical situation.

Initial torque loss before cyclic loading

Tightening of abutment screws in all the groups was done with an electronic torque meter with an accuracy of 0.1 Ncm (Lutron Electronic Enterprise Co, Taiwan). The samples were placed in a rigid mounting jig to ensure solid fixation without rotation during tightening of the screws. The abutments were tightened to 35 Ncm torque according to the manufacturer’s recommendation. Ten minutes after first torque application, all screws were retightened to the same torque to ensure achieving optimal preload.⁴³⁻⁴⁵ Initial torque loss (ITL) for each specimen was measured after five minutes of screw tightening and ITL% was calculated for each group.

Secondary torque loss after cyclic loading

After the measured ITL, the abutment screws were tightened to the recommended torque value. The implant prostheses were then seated on the abutments without using any cement to ensure easy removal of the crowns after cyclic loading. Acrylic resin blocks were firmly mounted in a holder of a chewing simulator machine (Chewing Simulator, S-D Mechatronic, Germany) for 500 000 cycles of loading. The cycle loading was equivalent to 6 months’ mastication in human adults.^{46,47} A 75 N load was applied perpendicular to occlusal surface of each crown. The contact time between the rod and crown was adjusted to 0.2 seconds with a frequency of 1 Hz, which simulates the tooth contact duration of each masticatory cycle.^{48,49} After loading, the removal torque value of each

abutment was measured with an electric torque wrench, and the percent of secondary torque loss (STL) was calculated for each group (STL%).

Analysis of variance, paired comparison t-test and post-hoc Tukey HSD for repeated measurements were used to evaluate the differences in torque loss among the 3 groups before and after cyclic loading. An agreement for the significance value was defined and set at 0.05.

RESULTS

The mean and standard deviation values for ITL and STL and their percentages of the 3 groups are shown in Table 1. Torque loss percentage varied from 5%–57%. One-way ANOVA showed that ITL among the groups was not significantly different ($P = .52$), while STL was significantly different among three groups ($P = .008$). Post-hoc Tukey HSD Tests showed that STL values were significantly different between the abutments with 1.5 mm GH (Group1) and 5.5 mm GH (Group3) ($P = .007$). In addition, the paired comparison t-test showed that cyclic loading significantly influenced the STL in comparison with the ITL in each group.

DISCUSSION

The present study focused on the influence of increased abutment collar height on abutment screw loosening in single-unit dental implants. According to the results, the research hypothesis was accepted since an increased abutment collar height resulted in loosening of the abutment screw after cyclic loading. Some studies have reported that screw loosening is a well-known complication in implant dentistry.¹²⁻¹⁶ To reduce the possibility of screw loosening, centering the occlusal contact and reducing the cantilever length have been recommended.^{14,29} However, it is not always possible to achieve such ideal conditions in the oral environment. In the present study, a vertical cantilever with cyclic loading was used to evaluate screw stability in platform-switched implants. To eliminate the possibility of deviations from exact torque value, an electronic torque meter was used. The reason for the eccentric cyclic loading was to simulate forces applied in the mouth. This type of loading was accomplished by vertically loading the occlusal surface of crowns with 45° of inclination,⁴² which resembles the cuspal

inclination of the crowns. However, some studies used crowns with 30° inclination¹¹ or applied the cyclic loading at a 30° angle to the long axis.¹⁰

To firmly attach the crowns to the abutments, prostheses might need to be retained by cementation to prevent them from rotating during cyclic loading.¹¹ In this study, the height and diameter of all abutment bodies were similar and adequate; therefore, the frictional retention of crowns on the abutment surfaces was great enough to hold them in place. Since no rotation or displacement was possible, there was no need to cement the crowns for this purpose. Furthermore, it could be difficult to remove the cemented crowns or abutments intact to examine torque loss after cyclic loading, and it could also be laborious and time consuming. Avoiding this step also eliminated complications related to crown cementation.

According to Gibb et al,⁴⁷ approximately 1 million masticatory movements take place every year. In this study, 500 000 cycles of loading—each cycle for 0.2 seconds—were used, which is similar to cycle of loading of 6 months' mastication in human adults.⁴⁶ However, it should be mentioned that there are limitations to any in vitro study that tries to simulate the biomechanics of chewing, and interpretation of the results should be done with that in mind.⁴⁸

The type of implants used in this study was internal hex with platform switching. Clinical, radiographic, and histologic studies have shown that when switched platform implants were used, there has been less peri-implant bone loss versus traditional techniques.^{38,40,41} This might be the result of more uniform stress distribution around this type of implant.³⁹ According to the literature, internal connection implants demonstrate better performance for in vitro studies, anti-rotational stability, and reduction in abutment screw loosening.²³

The result of this study indicated that there is some torque loss after 5 minutes of applying 2 insertion torques with a 10-minute interval. This finding is in agreement with other studies that reported initial torque loss after 2–3 minutes^{14,18,21,29} and after 15 hours.²² There are some factors that can affect initial torque loss, including tightening torque value, implant system, and abutment screw material.^{17,18} This could also be explained by settling or embedment relaxation phenomena that results in loss of 2%–10% of initial preload.^{11,30} It has been reported that after tightening abutment screws to the internal hex implants at 20 Ncm torque, a progressive decrease in reverse torque value was noted.¹¹ This phenomenon is the result of slight flattening of some irregularities at the screw-implant interface, leading to a reduction in the tensile force that is responsible for preload.²⁸ Tsuge et al¹¹ showed that after applying torque of 20 Ncm, ITL was approximately 20% lower for the titanium (Ti) alloy abutment screws. They used both Ti alloy and gold alloy abutment screws and reported that Ti abutment screws were less prone to loosening. In this study, despite tightening the screws to 35 Ncm torque using an electronic torque wrench, the results showed that the ITL values were lower in all groups by an average of approximately 14%. Lower initial reverse torque loss in this study can be the result of using a higher torque value than in the Tsuge et al¹¹ study. Furthermore, all of

abutment screws in this study were made of Ti alloy. Some factors may occur that affect passive fit between prosthesis and implant, such as errors in casting of metallic alloys, repeated tightening/loosening cycles of the screw, and improper insertion torque. These factors can reduce the frictional fit between the screws and internal threads of the implant, which may lead to the screw loosening.³²

In this study, abutment screw loosening or reduction in reverse torque value occurred after cyclic loading, and STL values showed a significant increase after loading. The mean STLs were between 29%–46% within different groups. This could be the result of wear that occurred in the mating surfaces of the components and improved fit,⁴⁹ which led to fewer irregularities and frictional effects that initially helped engagement of the components. These results were not similar to studies by Khraisat et al¹⁶ and Tsuge et al.¹¹ This contradiction in results between the present study and others could be related to the different compositions of the Ti alloy abutment screws used in the studies. It also could have occurred due to unfavorable and excessive component wear, in the mating surface between the abutment screw and the internal threads of the implant.^{16,43}

In addition, an increase in secondary torque loss (SLT) values after cyclic loading was observed, related to the relative magnitude of abutment collar height values in the groups, a result of an increase in abutment collar height. These results support the use of abutments with the least possible collar height, especially for single-unit implant restorations. The thickness of soft tissue around the abutment affects abutment collar height selection. Therefore, in posterior regions where reduction of surrounding soft tissues' thickness does not interfere with esthetic results, this reduction may be beneficial from a biomechanical point of view. Less collar height for the abutment could have possible advantages beyond less cantilever length and screw loosening occurrence: increase in abutment height for retention of restoration, improving strength of connectors, and improving access for impression-making procedures.

Although the crown height itself might affect abutment screw loosening, in the present study, constant crown height was used. Other limitations in this study include the number of implants, type of abutment-implant connections, and the number and direction of cyclic loading. Further studies should be done to evaluate the effect of different abutment heights and abutment collar heights in a consistent vertical cantilever space. Moreover, additional research is needed to compare abutment screw loosening between screw-retained and cement-retained superstructures.

CONCLUSIONS

Within the limitations of this study, it can be concluded that an increase in height of the abutment collar has significant influence on the torque loss of abutment-implant screw after cyclic loading. It should be noted that the results obtained from this in vitro study cannot necessarily be extrapolated to the clinical situation because of the complexity of the oral environment.

ABBREVIATIONS

GH: gingival height
 ITL: initial torque loss
 STL: secondary torque loss

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