Effect of different angulation angled abutment on screw loosening of implants under cyclic loading

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Abstract

Objectives: The purpose of this study was to compare the removal torque values (RTVs) of two different angulation (15, 25 degrees) and two different diameters (3.5, 5.0 mm) fixtures after dynamic cyclic loading with the clinical situation of the first maxillary premolar.

Material and methods: Twenty sets of 3.5 mm diameter x 10 mm implants and twenty sets of 5.0 mm diameter x 10 mm implants were divided into four groups: Group I (ϕ3.5 mm, 15°) Group II (ϕ3.5 mm, 25°), Group III (ϕ5.0 mm, 15°) and Group IV (ϕ5.0 mm, 25°). Each implant and abutment assembly was positioned in cylindrical polyvinyl chloride tubes with epoxy resin. Initial analysis was made by abutment screw tightened with 30 Ncm torque twice with 10-minute intervals using a digital torque gauge. After 10 minutes, the Removal torque value before cyclic loading (RTVb) of the abutment screws were measured and calculated to torque maintenance (%TM). The semi-anatomic superstructures were cast with non-precious metal and cemented with non-eugenol temporary cement; each screw was tightened by applying a 30 Ncm. The post-loading removable torque values (RTVa) were measured after 500,000 cycles of mechanical loading along the long axis of superstructure between 20 and 200 N at 14 Hz.

Results: In all groups RTVb was lower than the insertion tightening torque of 30 Ncm, %TM ranged from 50.00 to 93.00%. Group I had the highest %TM (85.53 $\pm$ 8.66) while that of Group III was the lowest (69.93 $\pm$7.54), showed no statistical differences among the groups. The ΔRTVa of Group IV was the highest while that of Group I was the lowest. [The ΔRTVa regarding the angulation showed significant differences by two-way ANOVA (P<0.0001), but without interaction with the angulation of abutment.]

Conclusions: The ΔRTVa of Group IV after cyclic loading was the highest while Group I was the lowest. The ΔRTV showed better results when less angulation (15°) abutment was used. Noticeable mobility at the implant-abutment interface and abutment-crown interface was not observed in any case after cyclic loading.

Keywords: removal torque values, angled abutment, dental implant, cyclic loading, screw loosening,

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Introduction

Ideally, dental implants should be aligned vertically with the axial forces. When the long axis of the implant fixture and the long axis of the planned prosthetic tooth is not aligned, angled abutment is often the abutment of choice for prosthodontic restorations[1]. Kallus et al.[2] demonstrated prototype angled abutments of the Branemark (Nobel Biocare, Göteborg, Sweden). Nowadays angled abutments vary from 15° to 35° angulation.

One of the most frequent complications of implant supported prostheses is screw loosening.[3,4,5,6] The problem is especially common in single implant-supported prostheses. Incidence of screw loosening was up to 12.7% in single crowns and 6.7% in fixed partial dentures[3, 7,8,9]

Screw joints are made up of two parts fastened together by a screw. Screw loosening occurs when the joint separating force acting on the screw joint is greater than the clamping forces holding the screw unit together.[11,12,13] It is not necessary to eliminate the separating force, only to minimize the clamping forces to prevent screw loosening[9,10,14,15]. Misch CE et al.[16] showed that angled abutment developed transverse force under occlusal loads in the direction of angled abutment. Due to micromovement as a result of functional or parafunctional load, angled implant abutment might play a role in screw loosening.

The application of cyclic loads was to simulate the dynamic conditions found in the oral cavity[19]. To date, there are limited publications regarding the investigation of screw loosening according to the angulation of angled abutment and diameter of fixture. Therefore, the objective of this study was to investigate the effect of abutment angulation (15 and 25 degree) and diameter of fixture (3.5 and 5.0 mm) on the removable torque value of dental implant screws under cyclic loading conditions.

Materials and methods

Twenty sets of 3.5 mm diameter x 10 mm implants (Anyridges; MEGAGEN, Seoul, Korea) and twenty sets of 5.0 mm diameter x 10 mm implants (Anyridges; MEGAGEN, Seoul, Korea) were divided into four experimental groups as shown in Table 1. All implants were 3.75 mm platform and 10 mm in length.

Each implant and abutment assembly was position in cylindrical polyvinyl chloride tubes (18 mm. in diameter x 30 mm in height) with epoxy resin by a dental surveyor and customized acrylic jig was used as a holding device. The epoxy resin was poured into the tube, which was level at the second thread from the top of the fixture, to stimulate implants in bone (Fig 1.)

The epoxy resin was left for 72 hr, then the abutment was tightened by a digital torque gauge (MGT 50, MARK-10 Co., Copiague, NY, U.S.A.), the insertion tightening torque was 30 Ncm as recommended by the manufacturer. Abutment screws were retightened to 30 Ncm after 10 minutes.

After 10 minutes, reverse torque value before cyclic loading (RTVb) was recorded by using the same digital torque gauge and calculated as torque maintenance (%TM = RTVb / insertion

Table 1 Abutment angulation and fixture of 4 experimental groups

Group	N	Abutment angulation	Fixture diameter
I	10	15°	3.5 mm
II	10	25°	3.5 mm
III	10	15°	5.0 mm
IV	10	25°	5.0 mm

tightening torque x 100). A semi-anatomic shape for the maxillary first premolar superstructure was fabricated by a lost wax technique. The cast superstructure were fabricated with nickel-chromium (NORITAKE® super alloy EX-3, Nagoya, Japan). All superstructures were finished and polished followed by green stone and white stone (Shofu®, Kyoto, Japan). All superstructures were checked to the desired dimension using callipers (Pittsburgh, Camarillo, Ca, USA). All superstructures were randomly into four groups.

The abutment screw was tightened to 30 Ncm. All abutment screw access were filled with cotton pellets and sealed with Caviton (GC®, Tokyo, Japan). The superstructure was cemented with non-eugenol temporary ment (RelyX™ Temp NE, 3M™ ESPE™, USA), using finger pressure for 1 minute, then placed 2 kg metal cube load for 10 minutes, excess cement was removed. All superstructures were cemented by the same operator. (Fig. 2)

Each specimen was subjected to cyclic load by an electric dynamic testing instrument (ElectroPuls E1000, All-Electric Test Instruments, Instron, Canton, Mass, USA). The cyclic loading was performed under loads between 20 and 200 N at a loading rate of 14 Hz at 90° to longitudinal superstructure axis for 500,000 cycles, which is approximately equivalent of half a year of in vivo mastication[11,17]. A custom-made jig and round-headed cylinder rod with 5 mm radius were used in this experiment. (Fig. 3)

Post-loading reverse torques after cyclic loading (RTVa) were measured by the digital torque gauge. Data was calculated to the difference between removable torque before loading and removal torque value after completing the cyclic loading (RTVb - RTVa = ∆RTVa).

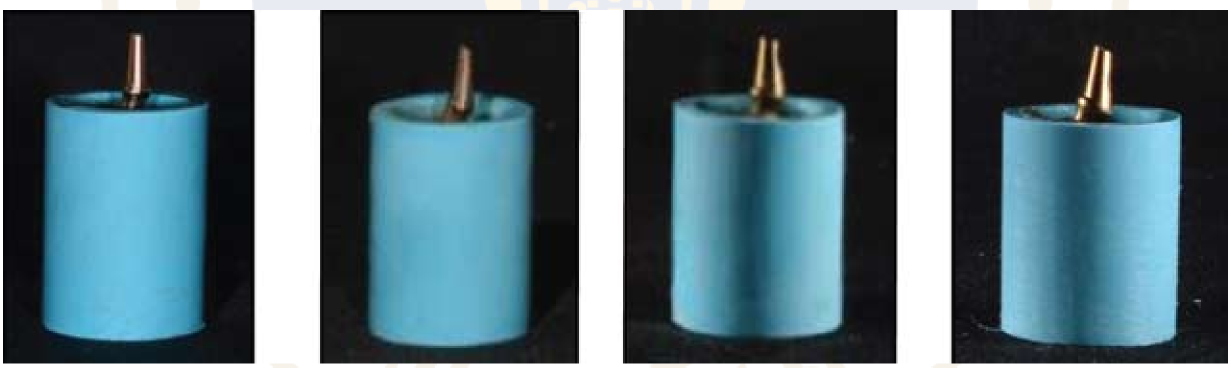

Figure 1 Implant abutment assembly
(a) group I (b) group II (c) group III (d) group IV

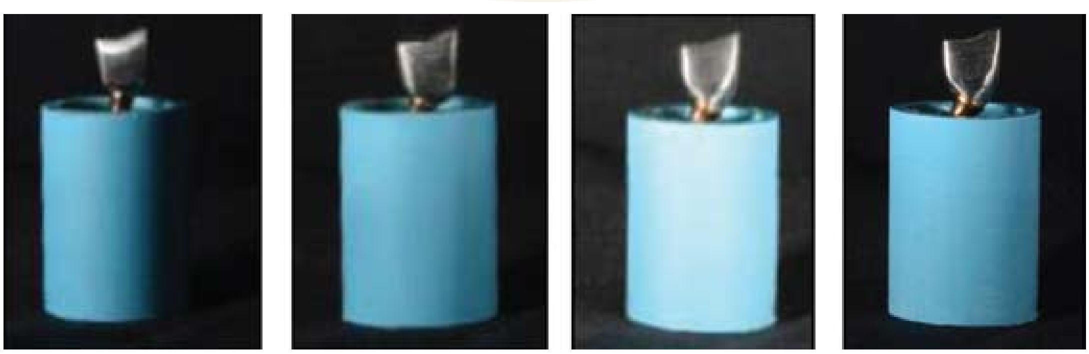

Figure 2 Implant abutment assembly and superstructure cemented before cyclic loading
(a) Group I (b) Group II (c) Group III (d) Group IV

All data were statistically analysed by a Shapiro-Wilk test and Levene's test. These were done to test normality and homogeneity variances of the data. Pairwise comparisons by two-way analysis of variance (ANOVA) compared ΔRTVa between different angulation and diameter of fixture at 95% significant level. A simple effect analysis was used to evaluate interaction effects between these independent variables (SPSS 22.0; SPSS, Chicago, IL).

Results

For all the specimens, no decementation or screw loosening was noticed by tactile or visual inspection during loading or on the completion of loading. The RTVb were ranged from 15.0 Ncm to 28.7 Ncm. Mean and standard deviation of RTVb is shown in Table 2. The mean RTVb values of group I had the highest (25.18 ± 2.737) while group III (20.984 ± 2.272) was the lowest. The %TM ranged from 50.00 to 93.00%. Group I had the highest %TM (85.53 ± 8.66) while that of group III was the lowest (69.93 ± 7.54).

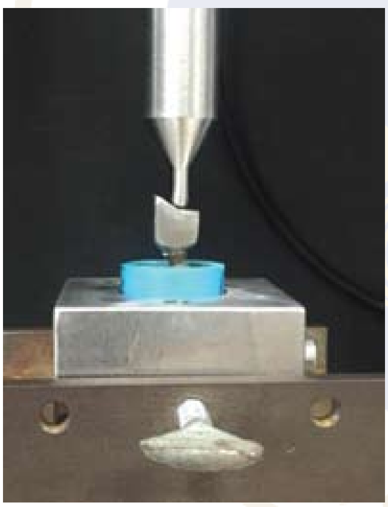

Figure 3 Customized stainless steel cylinder rod and specimen were mounted on a universal testing machine (ElectroPuls E1000, All-Electric Test Instruments, Instron)

The ΔRTVa were analysed. Mean and standard deviation of ΔRTVa after cyclic loading is shown in Table 2. Group IV had the highest mean ΔRTVa while that of Group I was the lowest. The result of two-way ANOVA revealed significant effects for abutment angulation ($P<0.05$) no significance on the interaction between diameter and angulation ($P>0.05$), and no significant effects for implant angulation ($P>0.05$).

Discussion

RTVb and %TM represented the remaining preload in the abutment screw[17]. The mean RTVb was lower than the insertion tightening torque (30 Ncm) in all groups, ranging from 15.0 to 28.70 Ncm in this study. The mean RTVb of Group I had the highest percentage of applied torque (85.53 ± 8.66) while Group III was the lowest (69.93 ± 7.54). The %TM ranged from 50.00 to 93.00%. The reduction of removable torque value in comparison to the insertion tightening torque resulted from Settling effect (embedment relaxation)[19]. It has been reported that 2 to 10% of the initial preload is lost as a result of the settling effect[19,20,21]. The amount of embedment relaxation depends on the number of rough spots on the contacting surface, the surface hardness of the implant and the

Table 2 Mean and standard deviation of RTVb (Ncm) and ΔRTVa (Ncm) of group I to group IV

Group	N	RTVb ± SD	ΔRTVa ± SD
I	10	25.18 ± 2.74	2.67 ± 0.54
II	10	21.02 ± 3.60	3.86 ± 0.45
III	10	20.98 ± 2.27	2.68 ± 0.39
IV	10	21.13 ± 2.07	3.96 ± 0.63

screw and the amount of load applied to the system[22]. By accepting the assumption that the reverse torque value is a measure of the remaining preload in the abutment screw, it can be concluded that the drop of post load reverse torque in the present study conforms to the joint failure mechanism as described by Bickford[25].

The fact the ΔRTVa showed better results when less angulation (15°) abutment was used could be explained by two factors. The first factor could be the distribution of the torque to the system depends on the fitting between the screw head and abutment platform, through friction between screw head and abutment and friction between the threads on the screw and implant and the tension within the screw, defined as the preload. Tightening the screw creates tension in the screw necessary to keep the components together[10, 26]. Thus, the greater the joint preload, the greater the resistance. In this study group I of found that the RTVa values and RTVb had the highest value. The second factor is off axis force, the greater the angulation the greater the off axis force that generates more stress and strain in implant components[22,23,27] There was a statistically significant increase in stress and strain when abutment angulation increased[22]. This supports the concept of eliminating unnecessary occlusal and off-axial forces on implant supported restorations[28,29,30].

Although there was a decrease in the RTVb in every group, loosening of screws could not be detected clinically. This may indicate that the remaining tightening torque would serve clinically for a longer period of time. Further investigations are required to verify the effects of a larger number of cycles on the long-term retention and stability of different abutments with external connections.

Within the limitations of this study, the following conclusions were drawn: The ΔRTVa of Group IV after cyclic loading at 500,000 cycle was the highest while group I was the lowest. The ΔRTVa showed better results when less angulation (15°) abutment was used. Noticeable mobility at the implant-abutment interface and abutment-crown interface was not observed in any case after cyclic loading.

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