EFFECT OF CASTING PROCEDURE ON SCREW LOOSENING OF UCLA ABUTMENT IN TWO IMPLANT-ABUTMENT CONNECTION SYSTEMS

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INTRODUCTION

Since Brånemark et al[1] published the results of a 10-year study on osseointegration in 1977, dental implants have increasingly been used to replace missing teeth. The use of osseointegrated implants had become a successful procedure for the treatment of complete,[2] partial[3] edentulism, and single-tooth replacements in both the anterior and posterior regions of the mouth. Although improvements in material and protocol have decreased the incidence of screw loosening, and a recent literature review reported that the incidence of screw loosening appears to be decreasing, one of the most common mechanical problems associated with dental implants is loosening of the screws.[4-6]

The use of screw in dental implants has some unique features. McGlumphy et al[7] defined the screw joint as 2 parts tightened together by a screw, such as an abutment and implant being held together by a screw. A screw is tightened by applying torque. Applied torque develops a force within the screw called preload. Preload is the initial load in tension on the screw. This tensile force on the screw develops a compressive clamping force between the parts. The preload is determined by the applied torque and other factors, such as screw alloy, screw head design, manufacturer quality control, screw joint design, surface roughness, and fatigue testing. Opposing the clamping force is a joint-separating force, which attempts to separate the screw joint. Screw loosening occurs when the joint-separating forces acting on the screw joint are greater than the clamping forces holding the screw unit together.[7] Excessive forces cause slippage between threads of the screw and threads of the bore, resulting in a loss of preload.[8] It is not necessary to eliminate separating forces, only to minimize them. Minimizing clamping forces will act to prevent screw loosening.

In single-tooth restorations, a widely used solution is the UCLA abutment. This abutment is designed to directly engage the implant and undergoes casting procedure. The cast abutment has advantages of overcoming angulation problem[9] and esthetic problem.[10] However, when a gold-premachined UCLA abutment undergoes casting, the abutment is exposed to the range and levels of temperatures required in the burnout and casting procedure. These manipulation may alter the abutment surfaces in contact with the implant and may lead to changes at the implant-UCLA cast abutment interface. A less than optimal fit may result in bacterial aggregation, which leads to peri-

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implant inflammation.[11] Also, a poor fit of abutment to implant with resultant lack of frictional resistance to rotation may be possible cause of screw loosening.

To date there have been few studies of effect of casting procedure on screw loosening of gold-premachined UCLA abutments in internal implant-abutment connection systems.

The purpose of this study was to compare the detorque values of prefabricated machined abutments with gold-premachined cast-on UCLA abutments before and after casting in two types of internal implant-abutment connection systems: (1) internal 11-degree taper hexagonal joint, (2) internal 8-degree morse taper octagonal joint. Furthermore, the detorque values of two implant-abutment connection systems were compared.

MATERIALS AND METHODS

Four groups of implants were used: Twenty 4.0 mm (diameter) × 10.0 mm (length) internal 11-degree hexagonal implants (GS Ⅱ, OSSTEM Implant Co., Ltd., Seoul, Korea) and twenty 4.1 mm (diameter) × 11.5 mm (length) internal 8-degree Morse taper octagonal implants (SS Ⅱ, OSSTEM Implant Co., Ltd., Seoul, Korea) were acquired. Group 1 was composed of ten internal hexagonal implants and ten prefabricated titanium abutments; Group 2 was composed of ten internal hexagonal implants and ten gold-premachined UCLA abutments; Group 3 was composed of ten internal octagonal implants and ten prefabricated titanium abutments; Group 4 was composed of ten internal octagonal implants and ten gold-premachined UCLA abutments (Figs. 1 and 2). EbonyGold® abutment screws (OSSTEM Implant Co., Ltd., Seoul, Korea) were used for all sample groups. For each combination of implant and abutment, one abutment screw was used. Table Ⅰ shows the components used and their article numbers as listed in the manufacturer' s catalogue.

Fig. 1. Internal hexagonal implants, abutments and abutment screws (group 1: Titanium abutment, group 2: UCLA-type abutment)

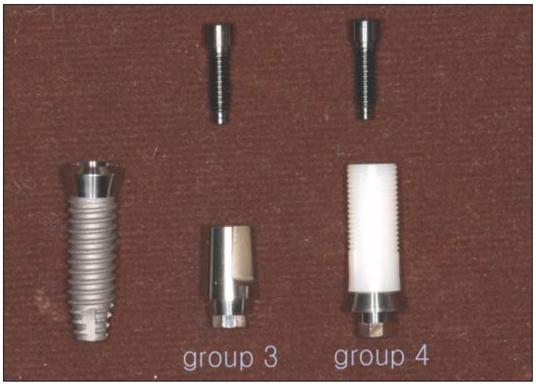

Fig. 2. Internal octagonal implants, abutments and abutment screws (group 3: Titanium abutment, group 4: UCLA-type abutment)

Table I. Components and dimensions of tested specimens

	Implant fixtures	Article number	Types of abutments	Article number
Internal hexa				
Group 1 (Titanium abutment)	GS Ⅱ (4.0×10.0 mm)	GS2R4010R01	Transfer abutment (hex)	GSTA5620
Group 2 (UCLA-type abutment)			GoldCast abutment (hex)	GSGA4510S
Internal octa				
Group 3 (Titanium abutment)	SS Ⅱ (4.1×11.5 mm)	SS2R1811	SS ComOcta abutment (octa)	SSCA485
Group 4 (UCLA-type abutment)			ComOcta Gold abutment (octa)	COG480S

Initial detorque analysis

Each implant and abutment assembly was positioned in a specially designed holding device and the abutment screw was tightened to 30 Ncm according to the manufacturer's instructions using digital torque gauge (MGT 50, MARK-10 Co., Copiague, NY, U.S.A.) (Fig. 3). After 10 minutes, the screw was loosened and the maximum torque required to loosen the screw was recorded. The torque required to loosen the screw was recorded as a percentage of the applied torque.

Abutment preparation and casting procedures

For groups 1 and 3, titanium abutments were connected to the analog in the model with laboratory screws and prepared for the maxillary anterior incisors (Fig. 4). For groups 2 and 4, UCLA-type abutments were screwed on top of the analog in the model using laboratory screws, waxed to the identical abutment shape for the maxillary anterior incisors. The wax patterns were individually invested using carbon-free, phosphate-bonded investment (Ceramvest, Protechno, Girona, Spain) and cast with low-fusing type Ⅲ high-gold casting alloy (AIGIS PLUS56, Sungbotech, Uijungbu, Korea) (Table Ⅱ). All waxing and casting were completed by one individual for consistency. After casting, specimens were allowed to bench-cool and were then divested and cleaned carefully using aluminum oxide (50 ㎛) with 2.8 bar pressure. No further polishing or finishing was performed (Fig. 5).

Second detorque analysis

After preparation and casting procedures, each implant and abutment assembly was positioned in a holding device and the abutment screw was tightened to 30 Ncm according to the manufacturer's instructions using digital torque gauge. After 10 minutes, the screw was loosened and the maximum torque required to loosen the screw was recorded. The torque required to loosen the screw was recorded as a percentage of the applied torque.

Statistical analysis

SPSS statistical software for Windows (release 15.0, SPSS Inc., Chicago, IL, U.S.A.) was used for statistical analysis. Group means were calculated and compared by independent t-test and paired t-test with α=0.05.

Fig. 3. Digital torque gauge.

Table II. Composition and properties of casting alloy (AIGIS PLUS56)

Composition		Au: 56.4% Ag: 27.1% Pd: 4.1% Ir, Cu, Zn
Physical properties	Melting temperature (℃)	910-940
	Casting temperature (℃)	1000-1050
	Tensile strength (MPa)	450
	Yield strength (MPa)	300
	Vickers Hardness (VHN)	155
	Density (g/cm^3)	13.7
	Elongation (%)	15

Fig. 4. Titanium abutments after preparation (group 1: internal hexagonal implant, group 3: internal octagonal implant).

Fig. 5. UCLA-type abutments after casting procedure (group 2: internal hexagonal implant, group 4: internal octagonal implant).

RESULTS

The measured raw data, mean values, standard deviations and loosening torque rate were presented in tables Ⅲ and Ⅳ. All abutments of Group 1, 2 and 3 could not be separated by hand pressure from their counterparts and remained firm after screws were loosened on initial detorque value measurement. Only abutments of Group 3 could not be separated by hand pressure from their counterparts on second analysis after screws were loosened, however, such phenomenon did not occurred on the second detorque analysis for abutments of Group 1 and 2.

Initial detorque values of sample groups were presented in table Ⅲ. Mean initial detorque values of internal hexagonal implants were evaluated for titanium abutments (22.6 ± 0.77 Ncm) and for UCLA-type abutments (23.5 ± 1.35 Ncm) after tightened to 30 Ncm. An independent t-test showed no statistically significant differences between two types of abutments ($P>0.05$) (Table Ⅴ). Mean initial detorque values of internal octagonal implants were evaluated for titanium abutments (21.50 ± 0.97 Ncm) and for UCLA-type abutments (23.10 ± 1.15 Ncm) after tightened to 30 Ncm. An independent t-test showed statistically significant differences between two types of abutments ($P<0.05$) (Table Ⅴ). On comparison of the initial detorque values of two connection systems, an independent t-test indicated significant differences between titanium abutments ($P<0.05$) and no significant differences between UCLA-type abutments ($P>0.05$) (Table V).

Detorque values after preparation and casting procedures were presented in table Ⅳ. Mean detorque value of internal hexagonal implants were evaluated for titanium abutments (20.35 ± 1.49 Ncm) and for UCLA-type abutments (21.2 ± 2.00 Ncm) after tightened to 30 Ncm. An independent t-test showed no statistically significant differences between two types of abutments ($P>0.05$) (Table VI). Mean detorque values of internal octagonal implants were evaluated for titanium abutments (21.05 ± 0.8 Ncm) and for UCLA-type abutments

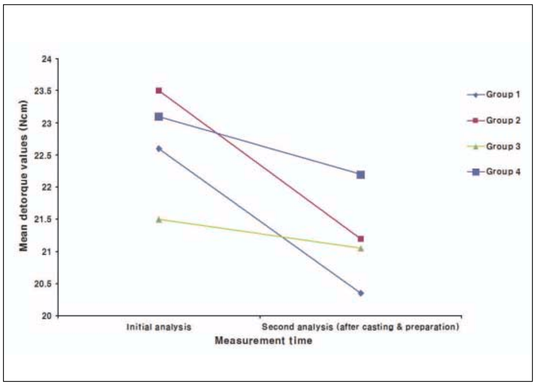

Fig. 6. Comparison of mean detorque values according to the measurement time.

Mean detorque values of internal hexagonal implants (group 1: titanium abutment, group 2: UCLA-type abutment) decreased significantly according to the measurement time ($P<0.05$). Mean detorque values of UCLA-type abutments (group 4) were significantly higher than titanium abutments (group 3) in internal octagonal implants ($P<0.05$).

Table III. Results of initial detorque analysis

		Raw scale (Ncm)				Ratio scale (%)	
	n	Mean	SD	Maxium	Minimum	Mean	SD
Internal hexa							
Group 1	10	22.60	0.77	24.00	21.50	75.33	2.58
Group 2	10	23.50	1.35	25.50	20.50	78.33	4.51
Internal octa							
Group 3	10	21.50	0.97	22.50	20.00	71.67	3.24
Group 4	10	23.10	1.15	24.50	21.50	77.00	3.83

Raw scale: measured raw data

Ratio scale: measured raw data / tightening torque (30 Ncm) × 100

Table IV. Results of detorque values after casting

		Raw scale (Ncm)				Ratio scale (%)	
	n	Mean	SD	Maxium	Minimum	Mean	SD
Internal hexa							
Group 1	10	20.35	1.49	22.50	18.00	67.83	4.97
Group 2	10	21.20	2.00	24.50	18.50	70.67	6.68
Internal octa							
Group 3	10	21.05	0.80	22.50	20.00	70.17	2.66
Group 4	10	22.20	1.01	24.00	21.00	74.00	3.35

Raw scale: measured raw data

Ratio scale: measured raw data / tightening torque (30 Ncm) × 100

Table V. Independent t-test for initial detorque values

According to the types of abutments				
		t	df	*P* value
Internal hexa	Group 1-Group 2	-1.824	18	0.085
Internal octa	Group 3-Group 4	-3.361	18	0.003*
According to the connection systems				
		t	df	*P* value
Titanium abutment	Group 1-Group 3	2.799	18	0.012*
UCLA-type abutment	Group 2-Group 4	0.712	18	0.486

**P*<0.05: statistically significant

Table VI. Independent t-test for second detorque values

According to the types of abutments				
		t	df	*P* value
Internal hexa	Group 1-Group 2	-1.076	18	0.296
Internal octa	Group 3-Group 4	-2.833	18	0.011*
According to the connection systems				
		t	df	*P* value
Titanium abutment	Group 1-Group 3	-1.309	13.757	0.212
UCLA-type abutment	Group 2-Group 4	-1.411	18	0.175

**P*<0.05: statistically significant

Table VII. Paired t-test for comparison of two measurement times

	t	df	*P* value
Internal hexa			
Group 1	5.582	9	0.000*
Group 2	3.343	9	0.009*
Internal octa			
Group 3	1.132	9	0.287
Group 4	1.646	9	0.134

*$P<0.05$: statistically significant

(22.20 ± 1.01 Ncm) after tightened to 30 Ncm. An independent t-test showed statistically significant differences between two types of abutments ($P<0.05$) (Table VI). On comparison of the second detorque values of two connection systems, mean detorque values of two abutments showed no significant differences ($P>0.05$) (Table VI).

Mean detorque values of all abutment groups were compared between two measurement times (Fig. 6). A paired t-test indicated that the mean detorque values of two types of abutments for internal hexagonal implants decreased significantly after preparation and casting procedures ($P<0.05$). However detorque values of abutments for internal octagonal implants showed no significant differences between two measurement times ($P>0.05$) (Table VII).

DISCUSSION

Several mechanisms cause screw loosening and loss of preload. Screw loosening occurs when the clamping force developed within the assembly is less than the forces which pull the assembly apart. If this happens, for example due to occlusal forces, then the screw will back off and loosen.[12] Screws are usually placed under sufficient tension-termed preload-to resist the separating forces in function.[7] Friction on screw threads can result in lower preloads generated in screws for any given insertion torque. To minimize friction, dry lubricant coatings have been developed such as pure gold (Gold-Tite®, 3i Implant Innovations, Inc.,West Palm Beach, FL) and amorphous carbon (TorqTite®, Nobel Biocare UK, Ltd., County Wicklow, Ireland). EbonyGold abutment screw used in this study was a tungsten carbide coated titanium-alloy screw to reduce frictional resistance.

Screw loosening is also associated with embedment relaxation of mating thread surfaces. When torque is applied to new screws and bolts with rough-textured thread surfaces, energy is applied partially toward smoothing mating surfaces and less toward elongation of the screw. After engaging the threads, the surface asperities are flattened so more input torque is applied toward elongation of the screw and production of preload. Ten percent of initial preload can be lost because of embedment relaxation.[13]

In a previous study,[14] ITI (Straumann AG, Waldenberg, Switzerland), (8-degree internal cones), and Astra (Astra Tech AB, Molndal, Sweden), (11-degree internal cones) implant systems were evaluated for loosening torques. The authors reported that the loosening torque was approximately 80% to 85% for all units tested, for clinically relevant levels of tightening torque (20 to 40 Ncm). In their study, 1-piece abutments were used. In a taper connection, form lock and friction are the basic principles.[15] Friction play a decisive role in the maintenance of preload in a taper integrated screwed in abutments (1-piece, solid abutment) which used simultaneously a screw and a tapered fit.[16] Unlike solid abutments, 2-piece abutments are retained mostly by the torque applied on the abutment screw. It seems that the precise mating of the notched region of the 2-piece abutment with its counterpart in the implant provides resistance to loosening.[16] In a previous study of dynamic fatigue resistance,[16] the removable torque values of solid abutments (1-piece) were significantly higher than synOcta abutments (2-piece) in ITI implants. In this study, initial loosening torque values of abutment groups of internal hexagonal and internal octagonal implants were less than the initial tightening torque and ranged from 71.67 to 78.33% of initial tightening torque. In this study, we used 2-piece abutments and it may be related lower initial detorque values than the results of previous study with 1-piece abutments. Also, the differences of initial loosening torque values are in accordance with previous studies demonstrating that components from different manufacturers may produce different detorque values.[17] Even if 2-piece abutments were used in this study, titanium abutments of internal hexagonal and internal octagonal implants and UCLA-type abutments of internal hexagonal implants could not be separated by hand pressure from their counterparts and remained firm after screws were loosened on the initial detorque analysis, and titanium abutments of internal octagonal implants could not be separated on second detorque analysis, too. Clinically it would be recommended that final tightening torque should be applied once at the delivery of prosthesis to achieve most stable joint.

In this study, initial loosening torque values of UCLA-type abutments were higher than titanium abutments in both implant-abutment connection systems, and significantly different in internal octagonal implants ($P<0.05$). Byrne *et al.*[18] reported that the cast-on UCLA abutment consistently was associated with higher preloads than the prefabricated abutment and this variation was thought to be due to an increased tendency of some abutments to cause screw settling or because of variation in the friction between a screw and an implant abutment.

In a previous study,[19] premachined palladium UCLA abutments of external hexagonal implants showed decreased detorque values after casting procedures and presented roughness and some irregularities of the contact surface in SEM pictures. In other study,[20] metal cylinders exhibited a reduction in hardness ranged from 11% to 43% following the casting process. However, other previous studies have reported that premachined metal abutments were not altered by casting procedures when evaluated for marginal fit[21] and rotational misfit,[22] and component integrity was therefore maintained throughout the laboratory procedures. In our study, detorque values of UCLA-type abutments were rather higher than titanium abutments in both internal implant-abutment connection systems after casting procedure and preparation, and significantly different in internal octagonal implants ($P<0.05$). Also, detorque values of all abutment groups decreased on the second detorque analysis than the initial analysis, and, statistically significant only in internal hexagonal implants ($P<0.05$). Results obtained in this study showed that casting procedures of UCLA-type abutments had no significant effect on screw loosening in internal implant-abutment joint designs, and UCLA-type abutments would be related with more stable screw joint than titanium abutments in internal octagonal implants.

Wear of coated/ plated screws after a few tightening sequences is another consideration. Byrne *et al.*[18] studied the effect of repeated opening and closure of titanium and gold-coated Gold-Tite abutment screws. For all insertion torques, the gold-coated screw lost more preload on the second and third tightening than uncoated screws. It would seem that the gold coating on the Gold-Tite screw may be damaged during insertion, and so the coating was less effective on subsequent insertions, though it still provided some lubrication compared with the uncoated screws. Tungsten carbide coating of EbonyGold abutment screw used in this study may be damaged during repeated insertion, and that would be related with the decreased detorque values of all abutment groups on the second analysis in this study.

In comparison of two connection systems, titanium abutments of internal hexagonal implants showed higher initial detorque values than internal octagonal implants ($P<0.05$), not on the second detorque analysis. This difference is thought to be due to manufacturing tolerance and variation of surface contact area and values of the friction coefficient. The detorque values of UCLA-type abutments were not significantly different between two connection systems ($P>0.05$). However, abutments of internal hexagonal implants showed more torque loss after retightening, therefore, consideration would be needed when retightening of abutment screws in internal hexagonal implants.

We examined the effects of casting procedures on screw loosening in an unloaded condition. Further investigation is needed to clarify possible effects of casting procedures on loosening torque of UCLA-type abutments after cyclic loading both in the internal hexagonal implants and internal octagonal implants.

CONCLUSION

Effects of casting procedures of UCLA-type abutments on screw loosening were compared in internal hexagonal implants and internal octagonal implants. Within the limitations of this study, the followings may be concluded:

1. The detorque values between titanium abutments and UCLA-type abutments of internal hexagonal implants showed no significant differences ($P>0.05$).

2. The detorque values between titanium abutments and UCLA-type abutments of internal octagonal implants showed significant differences both on the initial and the second detorque analysis ($P<0.05$).
3. In comparison of internal hexagonal and octagonal implants, the detorque values of titanium abutments had significant differences between two connection systems on the initial analysis ($P<0.05$), not on the second analysis ($P>0.05$) and the detorque values of UCLA-type abutments were not significantly different between two connection systems ($P>0.05$).
4. The detorque values of titanium abutments and UCLA-type abutments of internal hexagonal implants decreased significantly on the second analysis than the initial analysis ($P<0.05$).
5. The detorque values of titanium abutments and UCLA-type abutments of internal octagonal implants showed no statistically significant differences between two analysis times ($P>0.05$).

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STATEMENT OF PROBLEM: The cast abutment has advantages of overcoming angulation problem and esthetic problem. However, when a gold-machined UCLA abutment undergoes casting, the abutment surfaces in contact with the implant may change. **PURPOSE:** The purpose of this study was to compare the detorque values of prefabricated machined abutments with gold-premachined cast-on UCLA abutments before and after casting in two types of internal implant-abutment connection systems: (1) internal hexagonal joint, (2) internal octagonal joint. Furthermore, the detorque values of two implant-abutment connection systems were compared. **MATERIALS AND METHODS:** Twenty internal hexagonal implants with an 11-degree taper and twenty internal octagonal implants with an 8-degree taper were acquired. Ten prefabricated titanium abutments and ten gold-premachined UCLA abutments were used for each systems. Each abutment was torqued to 30 N㎝ according to the manufacturer’ s instructions and detorque value was recorded. The detorque values were measured once more, after casting with gold alloy for UCLA abutment, and preparation for titanium abutments. Group means were calculated and compared using independent t-test and paired t-test (α=0.05). **RESULTS:** The results were as follows: 1. The detorque values between titanium abutments and UCLA-type abutments showed significant differences in internal octagonal implants (P〈0.05), not in internal hexagonal implants (P〉0.05). 2. In comparison of internal hexagonal and octagonal implants, the detorque values of titanium abutments had significant differences between two connection systems on the initial analysis (P〈0.05), not on the second analysis (P〉0.05) and the detorque values of UCLA-type abutments were not significantly different between two connection systems (P〉0.05). 3. The detorque values of titanium abutments and UCLA-type abutments decreased significantly on the second analysis than the initial analysis in internal hexagonal implants (P〈0.05), not in internal octagonal implants (P〉0.05). **CONCLUSION:** Casting procedures of UCLA-type abutments had no significant effect on screw loosening in internal implant-abutment connection systems, and UCLA-type abutments showed higher detorque values than titanium abutments in internal octagonal implants.

KEY WORDS: Screw loosening, UCLA-type abutment, Internal hexagonal implant, Internal octagonal implant, Casting, Detorque value

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