Effect of cement washout on loosening of abutment screws and *vice versa* in screw- and cement- retained implant-supported dental prosthesis

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PURPOSE. The purpose of this study was to examine the abutment screw stability of screw- and cement-retained implant-supported dental prosthesis (SCP) after simulated cement washout as well as the stability of SCP cements after complete loosening of abutment screws. **MATERIALS AND METHODS.** Thirty-six titanium CAD/CAM-made implant prostheses were fabricated on two implants placed in the resin models. Each prosthesis is a two-unit SCP: one screw-retained and the other cemented. After evaluating the passive fit of each prosthesis, all implant prostheses were randomly divided into 3 groups: screwed and cemented SCP (Control), screwed and non-cemented SCP (Group 1), unscrewed and cemented SCP (Group 2). Each prosthesis in Control and Group 1 was screwed and/or cemented, and the preloading reverse torque value (RTV) was evaluated. SCP in Group 2 was screwed and cemented, and then unscrewed (RTV=0) after the cement was set. After cyclic loading was applied, the postloading RTV was measured. RTV loss and decementation ratios were calculated for statistical analysis. **RESULTS.** There was no significant difference in RTV loss ratio between Control and Group 1 (*P*=.16). No decemented prosthesis was found among Control and Group 2. **CONCLUSION.** Within the limits of this *in vitro* study, the stabilities of SCP abutment screws and cement were not significantly changed after simulated cement washout or screw loosening. ***[J Adv Prosthodont 2015;7:207-13]***

KEY WORDS: Implant-supported dental prosthesis; Torque; Dental cement

INTRODUCTION

The topic of screw–retained versus cemented implant restorations has been debated by many authors.[1-10] Screw-retained implant prostheses have the advantage of predictable retrievability compared to cemented ones.[2,4,5,9,11,12] Retrievability of implant restorations can provide easy solutions to problems, such as food packing from opened proximal contact, unstable occlusion from porcelain fracture, discomfort in chewing from loosened abutment screws, and so on. On the other hand, cement-retained implant prostheses, if luted with weak temporary cements for retrievability, may be accidentally dislodged. After years of masticatory loading, the cemented implant crowns may not be even retrieved when needed. The disadvantage of screwed implant prostheses includes higher laboratory cost, esthetic and structural screw hole issues,[1,2,5,13,14] and relative lack of passive fit. However, predictable retrievability of screwed implant crowns seems to outweigh initial high fabrication cost by decreasing the repair cost when biological and technical complications occur.

The screw- and cement-retained implant-supported dental prosthesis (SCP) is a combined multiunit implant prosthesis with both screwed and cemented units.[15-18] The screwed unit of SCP allows prosthetic retrievability while

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preventing accidental dislodgement.[16-18] The cemented unit of SCP provides relatively more passive fit than the purely screw-retained implant prosthesis.[19-21] Possibly from its passive fit, SCP was found to have the screw stability as much as the purely cemented implant prosthesis.[18] In spite of its structural stability, SCP may have the chance of having the temporary cement washed out after years of masticatory loading. There is no sufficient data regarding the stability of SCP abutment or prosthetic screws after its temporary cement washout.

Screw loosening of implant prostheses occurs through three major mechanisms: embedment relaxation,[22-26] lack of passive fit among components,[27,28] and overload on screw joints.[23,29-31] The preload of the screw is the force holding two components, such as the implant and the prosthesis framework. External functional loading such as chewing foods erodes the preload. The greater the joint preload, the greater the resistance to loosening, and the more stable the joint. Eventually, the critical load exceeds the screw joint preload and it becomes unstable. In this stage, the external load rapidly erodes the remaining preload and results in vibration and micromovement that lead to the screw backing out. The components misfit of the implant framework also affects preload and screw joint stability. When incorrect fit exists, the achievable preload is significantly reduced.[27] Embedment relaxation occurs as two irregular opposing surfaces of screws are pressed and abraded together upon loading.[22] If the multi-unit implant framework has, when loaded, more movement due to the partial loss of retainability, the opposing surfaces of screws may be more abraded, leading to loss of screw stability. SCP framework may have more movement upon masticatory loading after losing cemented retention. As a result, the screws holding SCP may lose its stability.

The purpose of the present study was to compare the screw stability of SCP before and after cement washout. This study also evaluated the cement stability of SCP before and after complete screw loosening. The null hypothesis was there is no significant difference in the reverse torque value (RTV) loss ratio between cemented and non-cemented SCPs. The second null hypothesis was there is no significant difference in decementation ratio between screwed and unscrewed SCPs.

MATERIALS AND METHODS

This *in vitro* experimental study examined the reverse torque values of titanium abutment screws and the breakage of temporary cement in custom-made titanium implant prostheses (E-Master Dental Hub, Seoul, Korea) fabricated by CAD/CAM technology. Each implant prosthesis was fabricated as SCP type. Their screw-retained part (UCLA abutment type) was directly connected to external type cylindrical implants (Sola RP Ø 4.0 × 10.0 mm, Shinhung, Seoul, Korea). Their cement-retained part was made on the prefabricated titanium abutment (Esthetic abutment - hexed, Shinhung, Seoul, Korea; RP Ø 5.0 × 5.5 mm, G/H 2.0 mm).

A cylinder-shape model(L 30.0 mm× Ø 30.0 mm) was made of orthodontic acrylic resin (Ortho-Jet, Lang Dental, Wheeling, IL, USA) of which mechanical properties (Young's Modulus = 3000 MPa) were similar to those of cortical bone.[32,33] Two implants, A and B (Sola RP Ø 4.0 × 10.0 mm, Shinhung, Seoul, Korea), were placed in the resin models with 5.0 mm-interval by drilling in the resin models and fixed with the same acrylic resin (Ortho-Jet, Lang Dental, Wheeling, IL, USA). Implant level impression copings (Impression Coping Pick-up, Hex, Shinhung, Seoul, Korea) were connected to the implants A and B. In order to make a space for the impression material, two sheets of pink baseplate wax were placed over the impression copings in the model. The dough stage of acrylic resin (Lightplast-Platten, Dreve-Dentamid GmbH, Unna, Germany) was applied to the model to fabricate open-type custom trays. Pick-up impressions of two implants A and B on the model were made by using hydrophilic vinyl polysiloxane impression materials (Examixfine, GC, Tokyo, Japan) and the custom trays. Seventy two dental implants (Sola RP Ø 4.0 × 10.0 mm, Shinhung, Seoul, Korea) were connected to impression copings in the custom trays, where orthodontic acrylic resin (Ortho-Jet, Lang Dental, Wheeling, IL, USA) was poured and set. Thus, total 36 implant- resin models were trimmed and prepared.

On the implant-resin model, Esthetic abutment (hexed, Shinhung, Seoul, Korea: RP Ø 5.0 × 5.5 mm, G/H 2.0 mm) was connected to the implant A (Fig. 1). This specimen was scanned by CAD/CAM machine (Ultrasonic 20, DMG/Mori Seiki, Dubendorf, Germany) after the abutment library for Sola implant system (Shinhung, Seoul, Korea) was set-up. SCP type implant prosthesis was made of titanium block (Starbond Ti4, S&S Scheftner, Mainz, Germany) through CAM data in the CAD/CAM machine (Fig. 2). The screw-retained part of SCP on implant B was an UCLA type crown without hex, and was connected to

Fig. 1. Esthetic abutment connected to implant A in the implant-resin block.

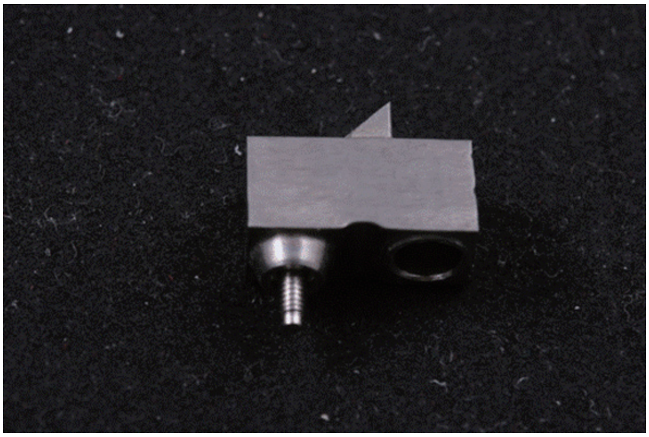

Fig. 2. Screw- and cement-retained implant prosthesis (SCP).

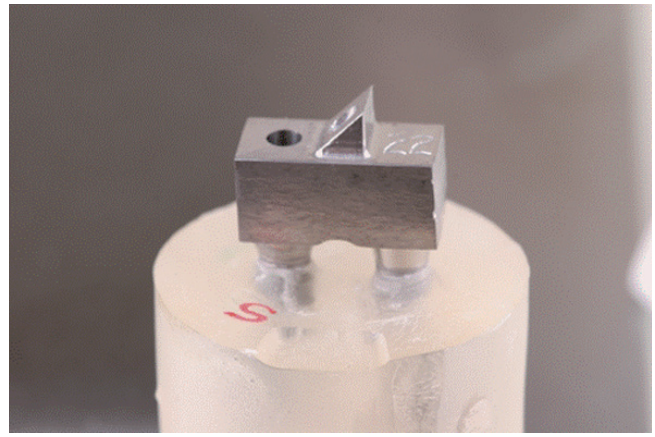

Fig. 3. SCP with a loading dimple on 45° slope.

the cement-retained crown on Esthetic abutment (Shinhung, Seoul, Korea). The thickness for spacing cements was set as 20 μm. For standardizing the specimen prostheses, thirty six SCP's were duplicated from the same computer-assisted designed model. The implant B was, then, removed from each implant-resin model by using a water-irrigated high speed handpiece and diamond burs. After trimming its surrounding resin by the high speed handpiece, the implant B was connected to the screw-type crown of SCP. The hole for placing the implant B was prepared in the implant-resin model. Temporary cement (Temp Pack, Kerr, Orange, CA, USA) was placed by 2 mm width around the margin of the SCP cement-retained crown. The SCP crown was luted to the Esthetic abutment on implant A with a firm finger pressure of the same laboratory technician. After 5 minute-setting of the temporary cement, the implant B connected to the SCP was fixed in the resin model with orthodontic acrylic resin (Ortho-Jet, Lang Dental, Wheeling, IL, USA). After completion of the resin polymerization, the abutment screws of the SCP screw type crowns were fully unscrewed and the SCPs were retrieved. Temporary cement inside the crowns was removed by an explorer and sandblasting (alumina dioxide, 150 μ, 2 atm).

The misfit of each SCP on the implant-resin model was examined. One laboratory technician performed a screw resistance test for the abutment screws of the SCP screw-type crown. If the fit was found to be inadequate (more than a quarter turn), Fit Checker II (GC, Tokyo, Japan) was placed inside the cement-type crown to assess the interferences. The fit was adjusted by grinding the internal surfaces of the crown until the passive fit (less than a quarter turn) of the SCP was achieved. The cement-retained crown margin of each SCP was assessed for any gap, as detected by an explorer. If there was a detectable gap, the interferences inside the crown was identified by Fit Checker II (GC, Tokyo, Japan) and eliminated until clinically acceptable crown margins were obtained.

The SCP had a loading dimple made on the 45° slope in the center of occlusal surface. Each implant crown had its dimension standardized (5.0 × 7.0 × 5.0 mm) (Fig. 3). Thirty six SCP specimens were randomly divided into 3 groups: Control had its cement-type crown cemented with polycarboxylate cement (Durelon, 3M ESPE, St. Paul, MN, USA) and its screw-type crown tightened to 30 Ncm with a digital torque wrench (Torqueworld, Seoul, Korea). Group 1 had its screw type crown tightened to 30 Ncm while having its cement type crown placed without any cement, which simulated the complete cement breakage after the long-term mastication. Group 2 had its cement type crown cemented with Durelon (3M ESPE, St. Paul, MN, USA), but did not have its screw type crown tightened (RTV=0). Polycarboxylate cement was used as a semi-permanent cement which was stronger than temporary cement used in clinic, because the presence of cement was the only variable when comparing Control with Group 1.

The SCP specimens were placed in the aluminum jig for consistent measurement of RTV. The cement type crowns of SCPs in Control and Group 2 were luted with polycarboxylate cement (Durelon, 3M ESPE, St. Paul, MN, USA). The abutment screws of SCPs (screw type crown) were subsequently tightened while the cement was set. Group 1 had the abutment screws of the screw type crowns tightened while having its cement type crowns placed without any cementation. The abutment screws were tightened twice every 10 second with Mini Digital Torque Wrench (Torqueworld, Seoul, Korea) according to the manufacturer's recommendations (30 Ncm).[22] One hour after the cement was set, Group 2 had their abutment screws loosened (RTV=0). The initial preloading reverse torque values in Control and Group 1 were measured with the same torque wrench. Then, the abutment screws were tightened to 30 Ncm as described previously.

Through the aluminum loading jig mounted in Instron machine (ElectroPuls E3000, Instron, Grove City, PA, USA), 30 - 120 N sinusoidal compressive cyclic loading (14 Hz, 5,000,000 cycles) was applied on the loading dimple of each SCP (Fig. 4). The special aluminum loading jig was prepared for placing the long axis of loading stylus at 45 degrees to the occlusal surface of the implant prosthesis, which simulated a chewing force delivered at 45 degrees. Each loading stylus in the jig was positioned and equally tightened to 1.0 Ncm so that tips of all loading styli had even contact with loading dimples of the implant prostheses. First five specimens from each group were placed in the jig with fifteen loading sites, and then second five ones and last two ones were placed for loading. Five million cycles of loading was considered to be equivalent to more than 6 years' mastication in human adults.[34,35] The 30 - 120 N compressive force was within the range of mean values (35 to 330 N) for maximum masticatory force exerted in the molar area by implant prosthesis.[36] After cyclic loading was completed, postloading reverse torque values of Control and Group 1 were measured by the digital torque wrench (Torqueworld, Seoul, Korea). Control and Group 2 had their cement loss evaluated. After the screw-type crowns were fully unscrewed, the SCPs were tried for retrieval by one hand of the operator. If they were retrieved without any resistance or with minimum resistance, the SCPs were categorized as a decemented case. If they were not retrieved after 10 times of trial, they were not categorized as a decemented case.

RTV loss ratio (Control vs Group 1) and decementation ratio (Control vs Group 2) were calculated by the following equations and statistically analyzed with two-independent sample *t*-test for any significant difference (*P*=.05).

RTV loss ratio = (postloading RTV- preloading RTV)/ preloading RTV

Decementation ratio = No. of decemented case/12

SAS Program (Ver 9.3, SAS Institute, Cary, NC, USA) was used for statistical analysis.

RESULTS

The mean preloading and postloading RTVs and their mean differences are shown in Table 1. The preloading RTVs in Control and Group 1 showed some variations from 20.6 to 29.5 Ncm as well as different mean values (26.35, 24.82) possibly due to minute differences in screw finish and amount of embedment.[18] Thus, RTV loss ratio was evaluated for each group. The RTV loss ratio values were 0.2 ± 0.07 and 0.16 ± 0.07 for Control and Group 1. Group 1 had lower values with no statistical significance (*P*=.16) (Table 2). There was no decemented specimen in Control and Group 2 after cyclic loading.

DISCUSSION

Retrievability of a fixed implant-supported prosthesis is an important consideration in delivering quality- and patient-based treatment outcomes.[37] Fit discrepancy of a framework is a major factor causing screw loosening of the implant prostheses.[27,28,38,39] SCP with predictable retrievability was designed for achieving adequate fit of a framework so that it could show stability of abutment screws from the *in vitro* study as well as clinical experiences.[17,18] In the present study, the stabilities of SCP abutment screws with and without temporary cement were compared, and unexpectedly the RTV loss ratio did not show any significant difference in Group 1 with non-cemented specimens compared to Control.

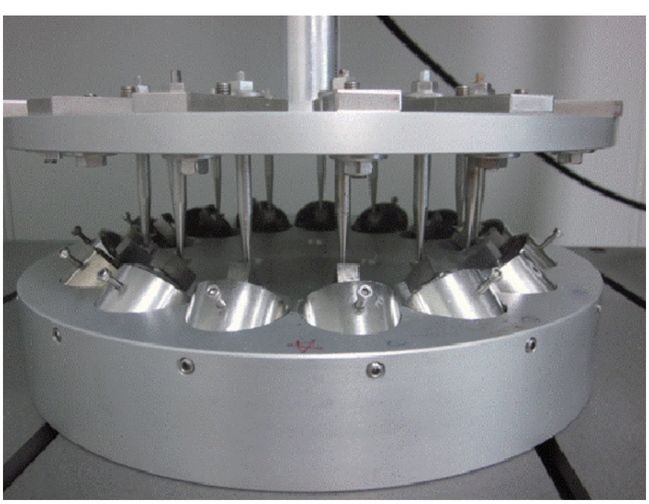

Fig. 4. SCP specimens on the cyclic loading assembly connected to Instron machine.

Table 1. Mean preloading and postloading RTVs (Ncm) and their differences

Group	N	Mean preloading RTV	Mean postloading RTV	Mean difference
Control	12	26.35 ± 2.07	21.06 ± 1.89	-5.29 ± 2.25
Group 1	12	24.82 ± 2.76	20.89 ± 2.26	-3.93 ± 1.88

*RTV: reverse torque value.

Table 2. Results of t-test for RTV loss ratio between Control and Group 1

Group	N	Mean	F	*P*
Control	12	0.20 ± 0.07	22	.16
Group 1	12	0.16 ± 0.07		

The torque applied to a screw forces the mating screw threads together until the shaft of the screw begins to elongate and produce a clamping force, which is also known as preload, within a system.[22,24,25,37,40,41] The screws become loosened when the clamping force is overcome by the forces acting to separate the fastened components.[12,23,41,42] The greater the misfit and frictional resistance, the less clamping force a given torque is able to generate, and the lower the joint-separating forces necessary to induce screw loosening.[37,40,43-45] In the present study, Control and Group 1 had similar passivity in the framework fit since the specimens of both groups were fabricated from the same digital model. On the other hand, the given torque, 30 Ncm might be able to generate the less clamping force in Control than Group 1 possibly due to their difference in frictional resistance from cement. Group 1 showed lower RTV loss ratio than Control without any statistical significance. Group 1, even without cemented retention, presented good stability of abutment screws after 5 years' simulated chewing (5 million cycles, 14 Hz), and this result could be postulated from one *in vitro* study. Lindström and Preiskel found in their strain gauge analysis of SCP that placing the cement in SCP, while in a buffered situation, could reduce the bending moment affecting the screw-retained part (implant) by half.[16] However, in a non-buffered configuration, no differences in the bending moment were found to be seen with the addition of cement. From the results of the present study, the SCP specimens must have non-buffered configurations. The indentation mark or lack of cement seen around the margin areas of Esthetic abutments in Group 1 and Control after cyclic loading proved this speculation (Fig. 5).

Fit discrepancies of the screw-retained implant framework may cause strain of prosthetic components upon loading and eventually lead to screw loosening or fracture.[27,28,38,39,46] Inherent errors in laboratory procedures make complete passivity of the implant framework impossible.[4,6,28,38] The purely screw-retained implant framework elicited more strains while tightening the screws than the cement-retained one when cemented. The screw type showed less marginal opening on tightening than the cemented one.[20] The SCP closed marginal gaps of the cemented part by tightening the screw,[18] which might cause more strains on the prosthetic components than the purely cement-retained implant prosthesis. The SCPs in the present study were, however, fabricated by the CAD/CAM technology, which might make the prosthesis framework more consistent and passive than the casting method. The RTV loss ratio of SCP made by casting in the previous study of our research team was 0.122 ± 0.171.[18] The present one revealed lower standard deviation value, 0.074 possibly due to more consistent quality of CAD/CAM products than the cast ones.

No cement loss of SCP was found in Group 2 as well as Control. In spite of lack of screwed retention, Group 2 seemed to have cemented retention enough to support the whole prosthesis. The use of stronger polycarboxylate cement rather than zinc oxide eugenol cement, often used in clinical application of SCP, might have affected the result.[47,48] The polycarboxylate cement was chosen to make the only variable in Control and Group 1 without cement breakage during heavy cyclic loading.

The purely cement-retained implant prostheses were reported to have cement washout in cases of 3.7% to 9.8% after many cycles of chewing.[15,49] As the cement on one abutment of the multi-unit cement-retained framework becomes washed out, the cements on adjacent abutments begin to be broken, leading to accidental dislodgement of the whole prosthesis. When weaker cements are used for predictable retrievability of the cement-retained implant prosthesis, the cement washout will be expedited. While so-called 'semi-permanent' cements,[48] such as zinc phosphate or glass ionomer cement can be used to decrease the dislodgement rate, the retrievability of the prosthesis may not be as predictable as expected.

In SCP, it was postulated by Preiskel and Tsolka[17] that the screw would assure secure retention, and weak provisional cement would be used to ensure retrievability of the restoration. In addition, he mentioned the cement might act

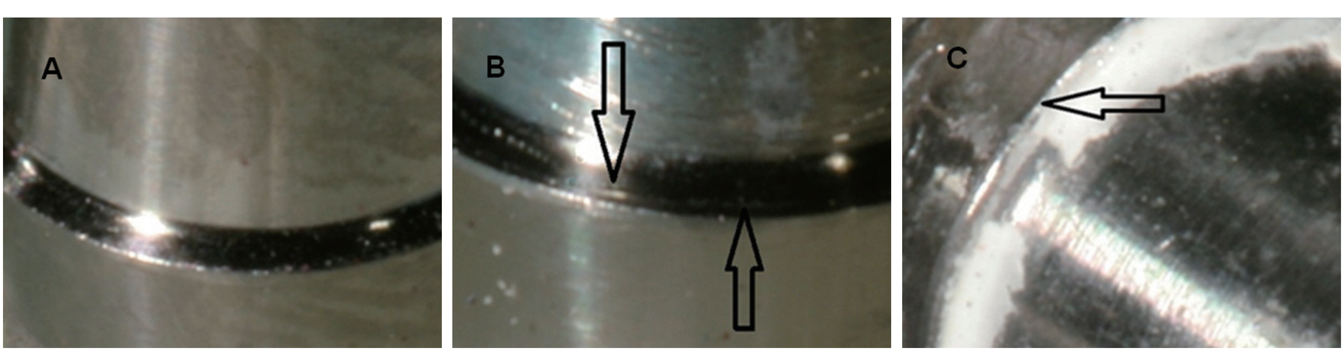

Fig. 5. Views of the margin area of Esthetic abutments after cyclic loading (Not magnified: (A) Group 1 before loading, (B) Group 1 after loading, and (C) Control after loading). The arrows in (B) indicate an indentation mark and in (C) lack of cement around the margin areas of Esthetic abutments.

as compensation for small discrepancies that inevitably occur with the production of casting. After SCP was loaded for several years, weak cement may first break before screw loosening. Group 1 in the present study presumed this hypothetical situation. After complete cement washout, SCP has screwed retention and telescopic crown without cement. Even though Group 1 showed high screw stability from the present results, the non-cemented marginal gap of the restoration could be collecting food debris or harboring bacteria in the intraoral condition. Keller *et al.*[50] mentioned that this bacterial colonization had a role in the growth of bacteria within the internal aspect of the implant. The regular follow-up about screw stability and cement loss will be needed for SCP.

The present study had some limitations as an *in vitro* study. This *in vitro* cyclic loading provided one simple chewing pattern, such as one-directional occlusal loading. Thermal cycling and water storage were excluded from the present study method as intraoral simulating conditions. The test results comparing Control and Group 2 luted with PCA cements might have been affected by those simulating conditions. The small number of specimens could be limiting the test power of the present study (30%).

The present study revealed the structural stability of SCP after screw loosening or cement washout through the *in vitro* study. The clinical situations may provide multi-directional chewing forces as well as abrupt thermal changes to the implant prosthesis. Long-term controlled clinical evaluation of the structural stability of SCP will be needed in the near future.

CONCLUSION

Within the limitations in this study, the stability of SCP abutment screws was not significantly changed after simulated cement washout. There was no change in the stability of SCP cements after the abutment screws were fully loosened (RTV=0).

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