Generation of retentive force by an electroformed telescope crown on a zirconia inner crown

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This study was performed to evaluate the retentive force generated by an electroformed telescope crown on a zirconia inner crown. The inner crowns were made of zirconia with 2° taper and ten outer crowns were made by electroforming on the inner crown. We measured the retentive force generated between the inner and outer crowns when glycerin solutions of different viscosities replaced saliva during removal of the outer crown of the electroformed telescope. The mean value of the peak retentive force was 6.4 N even with no solution, which was an adequate retentive force. The peak retentive force was significantly greater at glycerin concentrations of 40% and 60% when compared with no solution. Significant increases were observed in the distance over which retentive force was generated, especially after peak retentive force, with water and glycerin solutions compared with no solution. The above findings suggest that the viscosity of saliva effectively increased the retentive force in a 2° electroformed telescope using a zirconia inner crown, and that the electroformed telescope crown on the zirconia inner crown combination was as effective as when the inner crown was made of gold. (J Osaka Dent Univ 2011; 45: 199-205)

Key words: Electroforming; Telescope; Retentive force; Zirconia; Attachment

INTRODUCTION

Although electroformed telescope dentures using outer crowns produced by applying electroforming technology are often used clinically,¹-⁵ esthetic problems with gold inner crowns have inhibited the spread of telescope dentures. Recently, the technology for making zirconia copings using CAD/CAM was developed and zirconia copings for natural teeth as well as individual zirconia implant abutments have been fabricated by CAD/CAM and used as primary crowns.⁶-⁸ Electroformed gold copings were used as a secondary telescope. The combination of these techniques and materials results in an esthetic, biocompatible prosthetic reconstruction of high quality and good fit. Because the retentive force characteristics of electroformed telescope dentures using zirconia coping as the inner crown have not been clarified, we investigated this issue and compared the results with a traditional gold inner crown. We investigated the retentive force characteristics of electroformed telescope crowns by analyzing the retentive force-displacement curve during vertical dislodgement using a tensile testing machine.⁹-¹⁴

MATERIALS AND METHODS

Materials

We fabricated telescopic inner crowns for the mandibular second premolar on a dental model with missing molars (E 50-536; Nissin Dental Products, Inc., Kyoto, Japan) as in our previous study.⁹-¹⁴ Inner crowns were made by the Noritake Katana Zirconia Frame System (Noritake Dental Supply Co., Ltd, Miyoshi, Aichi, Japan) with milling taper angles of 2° between the axial surface and the principal axis of the abutment teeth as in our previous study.¹¹-¹⁴ Ten outer crowns were made by electro-
forming each of the inner crowns. The AGC® Galvanux System (Wieland Dental & Technik GmbH & Co. KG, Pforzheim, Germany) was used to make the outer crowns. A U-shaped hook was fixed to the top of the outer crown by laser welding (Fig. 1).

**Methods**
The inner crowns were fixed to an acrylic case with Unifast III dental autopolymerizing resin (GC Corporation, Tokyo, Japan). This system was then fixed to a tensile testing machine (SVF-500 N; Imada Seisakusho, Toyohashi, Aichi, Japan) (Fig. 2), and tensile tests were performed repeatedly by removing the outer crown from the inner crown at a separating speed of 50 mm/min. Tests were performed with no water between the inner and outer crowns (NO), with water (0% glycerin), and with 20%, 40%, and 60% glycerin in water as artificial saliva. Measurements were repeated five times for each of the ten outer crowns.

**Analysis**
Data from the tensile test machine was transferred to a personal computer through a PCI-3178 AD converter (Interface Corporation, Hiroshima, Japan) and analyzed using BPC-0600 wave analyzing display software (Interface Corporation). We measured the onset, peak, and end of the retentive force, and the energy generated between the inner and outer crowns.
and outer crowns (Fig. 3).

Statistics
The average of five measurements was calculated for each sample. Analysis of variance (ANOVA) was performed for the factors of glycerin concentration. Bonferroni tests were performed for multiple comparisons. A probability of less than 0.05 was considered statistically significant. SPSS ver.12.0 J (SPSS Japan, Inc., Tokyo, Japan) was used for statistical analysis.

RESULTS

Peak retentive force
The mean values of peak retentive force were 6.4 N (NO), 7.9 N (0%), 7.9 N (20%), 8.2 N (40%) and 8.7 N (60%) (Fig. 4). The peak retentive force increased with the concentration of the glycerin solution and was significantly greater with glycerin at a concentration of 40% (p<0.05) or 60% (p<0.01) than with no solution (Fig. 4).

Displacement before the generation of peak retentive force
The mean values of displacement before the generation of peak retentive force (DBP) were 0.054 mm (NO), 0.065 mm (0%), 0.068 mm (20%), 0.072 mm (40%), and 0.075 mm (60%) (Fig. 5). The DBP was extended insignificantly despite increasing concentration.

Displacement after the generation of peak retentive force
The mean values of displacement from peak retentive force to disappearance (DAP) were 0.26 mm (NO), 0.50 mm (0%), 0.50 mm (20%), 0.71 mm (40%) and 0.68 mm (60%) (Fig. 6). DAP increased with the concentration of the glycerin solution and was significantly greater with water (0%) (p<0.01) and glycerin solution at a concentration of 20%, 40% or 60% (p<0.001) than with no solution (Fig. 6).

Retentive force generating distance (DBP + DAP)
The amount of displacement with retentive force
was 0.32 mm (NO), 0.57 mm (0%), 0.57 mm (20%), 0.78 mm (40%) and 0.75 mm (60%) (Fig. 7). The amount of displacement increased with the concentration of glycerin solution and was significantly greater with water ($p<0.01$) and glycerin solution at a concentration of 20%, 40% or 60% ($p<0.001$) than with no solution (Fig. 7).

Retentive energy before generation of peak retentive force
The mean values of retentive energy before the peak (EBP) were 0.09 Nmm (NO), 0.14 Nmm (0%), 0.15 Nmm (20%), 0.19 Nmm (40%) and 0.24 Nmm (60%) (Fig. 8). EBP increased with the concentration of glycerin solution and was significantly greater with glycerin solution at a concentration of 20%, 40% or 60% than with no solution ($p<0.05$) (Fig. 8).

Retentive energy after generation of peak retentive force
The mean values of retentive energy after the peak were 0.30 Nmm (NO), 0.66 Nmm (0%), 0.85 Nmm (20%), 1.15 Nmm (40%) and 2.00 Nmm (60%) (Fig. 9). EAP increased with the concentration of glycerin solution and was significantly greater with water ($p$...
\(<0.01\) and with glycerin solution at a concentration of 20\%, 40\% or 60\% (\(p<0.001\)) than with no solution (Fig. 9).

**Retentive energy (EBP + EAP)**

The mean values of retentive energy were 0.39 Nmm (NO), 0.81 Nmm (0\%), 1.00 Nmm (20\%), 1.34 Nmm (40\%) and 2.25 Nmm (60\%). The retentive energy increased with the concentration of glycerin solution and was significantly greater with water (\(p<0.05\)) and with glycerin solution at a concentration of 20\%, 40\% or 60\% (\(p<0.001\)) than with no solution (Fig. 10).

**DISCUSSION**

**Experimental method**

The characteristics of the retentive force of partial denture retainers could be clarified using the retention-displacement curve, measuring displacement before and after peak retentive force, and calculating retentive energy before and after the peak.\(^{5-14}\) We modified the techniques reported by Leung et al.,\(^{15}\) who analyzed the retentive force of stud attachments. The potential clinical application of an electroformed telescope crown on a zirconia inner coping was examined in this study using the same analytic methods as in our previous studies.\(^{3-14}\)

**Peak retentive force**

The mean values of peak retentive force were 6.4 N (NO), 7.9 N (0\%), 7.9 N (20\%), 8.2 N (40\%) and 8.7 N (60\%), which were within the range of desirable retentive force (5–10 N).\(^{16-21}\) According to Körber,\(^{16}\) the telescope crown has a retentive force of 5–9 N at 6° taper. Tabata et al.\(^{9}\) reported a peak retentive force of 5.41 N with Magmax and 5.26 N with Magdome C. The values for the 2° electroformed telescope crown with a gold inner crown were similar to the magnetic attachments.\(^{11}\) The retentive force was reinforced significantly by the interposition of artificial saliva between the inner and outer crowns.\(^{10, 14}\) When the glycerin concentration was varied, no significant increase in retentive force was seen between no solution and 0\% glycerin (water), while significant increases were observed as the concentration or viscosity of the glycerin increased. The viscosity of saliva and the negative pressure generated between the inner and outer crowns increased the retentive force effectively in the 2° taper electroformed telescope.\(^{14}\)

It is speculated that the characteristics of retentive force with the zirconia inner crown were similar to that with the gold inner crown. The retentive force of electroformed telescope crowns was augmented by interposition of the artificial saliva Saliveht (Teijin Pharma Ltd., Tokyo, Japan)\(^{10}\) or glycerin solution.\(^{14}\) Denture retention increased as higher viscosity saliva was interposed in the denture base.\(^{22-24}\) Ogishi\(^{25}\) reported that the presence of saliva caused the retentive force to increase more than without saliva in conic telescopes. We reported in the previous study\(^{14}\) that the interposition of saliva and water increased the retentive force of the telescope crown; a low concentration of glycerin had low viscosity and generated only slight retentive force, while a higher concentration had higher viscosity and produced greater retention.

Negative pressure did not participate in the generation of retentive force directly; it was found that the generation of retentive force was related to friction and the flow resistance of saliva between the inner and outer crowns in the electroformed telescope. Weigl investigated the adhesive strength produced between a ceramic primary crown and a secondary electroformed telescope.\(^{9}\) Van der Waal’s force and the adhesion forces of saliva are primarily active between the inner ceramic crown and the outer gold crown. An extremely thin saliva layer between the ceramic inner crown and the outer gold crown contributes to a clinically desirable adhesive strength. A saliva film between the coping and the patrix generates additional adhesive force. The adhesive mechanism of the saliva film is based on two physical phenomena. When the matrix is separated from the patrix, negative pressure is created. Flow resistance, which depends on the gap width, counteracts the separation of the two components. The adhesion of liquids acts as the second physical phenomenon. The enormous adhesive
force of water between two glass plates is well known. The glass plates can easily be shifted in relation to each other, but can only be separated at right angles to the plane with great difficulty. It is speculated that the integration of these forces enables application of the zirconia inner crown.

**Amount of displacement associated with retention**

The displacement characteristics associated with retention of the electroformed telescope with the zirconia inner crown were similar to the electroformed telescope on the gold inner crown. The DBP was very short and was not extended significantly with increasing concentration. This was effective for retention during the early stages. DBP was also similar to that with a magnetic attachment and with an electroformed telescope with a gold crown. Tabata *et al.* report a DBP of 0.04 mm with Magmax and 0.05 mm with Magdome C. Kawashima *et al.* reported that the value for the 2° electroformed telescope crown (0.06 mm) was similar to that of magnetic attachments.

The DAP was 1.43 mm with Magdome C, 1.47 mm with Magmax, and 1.46 mm with the 2° electroformed telescope crown with a gold crown. DAP in the zirconia inner crown increased with the concentration of glycerin solution and was significantly greater with water and with glycerin solutions at a concentration of 20%, 40% or 60% than with no solution. The retentive characteristics of the displacement associated with retention were also similar to those of magnetic attachments. Van der Waal’s force and the adhesion forces of saliva between inner and outer telescope crowns were the most important. These phenomena are most important during displacement associated with retention after the peak retentive force.

**Retentive energy required to dislodge the retainer**

The retentive energy before the peak retentive force (EBP) at 2° with a zirconia inner crown was very small and similar to that with a gold inner crown. Tabata *et al.* reported an EBP of 0.138 Nmm with Magmax and 0.160 Nmm with Magdome C. We reported that the values for the 2° electroformed telescope crown with a gold inner crown were similar to those of magnetic attachments. It is speculated that stress on the abutment of a 2° electroformed telescope crown with a gold inner crown was small and could be used as an effective retainer to protect abutment teeth. Tabata *et al.* reported an EAP of 0.582 Nmm with Magmax, 0.499 Nmm with Magdome C, and 0.047 Nmm with Konus. The values for the 2° electroformed telescope with gold or zirconia inner crowns were almost the same or a little greater than those of the magnetic attachment. EAP in the zirconia inner crown increased with the concentration of glycerin solution and was significantly greater with water and glycerin at a concentration of 20%, 40% or 60% than with no solution.

The total retentive energy needed to dislodge the retainer of the electroformed telescope crown with a zirconia inner crown increased with the concentration of glycerin solution and was significantly greater with water and glycerin at a concentration of 20%, 40% or 60% than with no solution. It has been reported that the EBP + EAP was 0.720 Nmm with Magmax, 0.659 Nmm with Magdome C, and 0.641 Nmm with Konus. The corresponding values for the electroformed telescope crown with a zirconia inner crown were similar to magnetic attachments.

The above results suggest that the electroformed telescope crown with a taper angle of 2° using a zirconia inner crown exhibits retentive force characteristics similar to those of a gold inner crown, and thus can be used as an effective retainer.

**REFERENCES**


3. Weigl P. Ceramic primary crowns with directly electroformed matrices—an innovative retention element with new proper-