Supplementing retention through crown/preparation modification: An in vitro study

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Statement of problem. The best treatment for a crown that has come loose but has appropriate marginal fit and form is not clear.

Purpose. This study was designed to determine whether the retention of such crowns can be increased without remaking the crown or by extensively modifying the tooth preparation.

Material and methods. Ninety cast metal complete crowns, divided into 9 groups of 10, were fabricated to be slightly loose in their internal adaptation to metal dies with an optimal tooth preparation. Horizontal grooves were formed around the circumference of the internal crown surface and the external surface of the metal die, the control being the unaltered crown and die. The crowns were cemented with resin-modified glass ionomer cement and then subjected to a tensile force until they were dislodged. The data were subjected to a 2-way ANOVA to determine the significance of the differences between crowns and dies, and 2 *t* tests were then used to compare each crown/die combination to the control (α=.05).

Results. The mean retention was significantly higher when 1 horizontal groove was placed inside the crowns (P<.001) and was even higher when 2 grooves were placed inside the crowns (P<.001). Placing 1 or 2 grooves in the metal die or in both the crown and die was not significantly more retentive than placing grooves only in the crown.

Conclusions. Placing 1 or 2 horizontal circumferential grooves into the internal surface increased the retention of metal complete crowns made for optimal tooth preparations. Grooves placed into the crown were as effective as or more effective than grooves placed into the tooth / die. (J Prosthet Dent 2012;107:186-190)

Clinical Implications

Cast metal complete crowns that come loose from properly prepared teeth will have greater retention when 1 or 2 horizontal grooves are placed circumferentially around the entire internal crown surface. The formation of these grooves may make crown recementation a more successful treatment.

Heintze[1] compared the adhesive strengths of many types of dental cement and 12 other parameters of cemented complete metal crowns by using pull-off tests. He concluded that the most important factors influencing in vitro crown retention were the convergence angle and the surface area of the preparation. He also showed that dental cements can influence crown retention but can vary in compressive strength from 62 MPa to 153 MPa, and that tensile strengths vary from 5.5 MPa to 45.1 MPa.[2] Shillingburg et al[3] stated that no biocompatible cements can maintain a restoration in place by adhesion alone. The shape of the preparation must place the cement in compression to provide the necessary retention and resistance. Ching and Wilson[4] showed that changing the surface of the tooth preparation by adding vertical grooves increased the surface area and resistance form. The authors demonstrated that 2 vertical grooves placed in the tooth preparation significantly increased the resistance to a rotational dislodgement. Other authors demonstrated that augmenting

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tooth preparations with 20 degrees of total convergence by the addition of grooves, boxes, and occlusal isthmuses did little to increase resistance to dislodgement when they were placed into the teeth at the same 20-degree angulations as the axial walls. However, recontouring the axial walls and decreasing the cervical convergence did increase the resistance to rotational dislodgement.[5] It has also been shown by Eames et al[6] that random specimens taken from commercial laboratories have an average occlusal convergence of 20 degrees. Ayad et al[7] demonstrated that taper and cement type are instrumental in recementing complete metal crowns and that increasing the occlusal convergence angle decreased the retention. Chan et al[8] found in an in vitro study that placing cement keys, grooves opposing each other in a crown and tooth, could increase the resistance of a crown cemented on even a 30-degree tapered extracted tooth preparation. More significantly, a single groove placed internally in a wax pattern, fabricated on an ungrooved tooth preparation with 7-degrees of convergence, increased the resistance to removal after casting and cementation. It is generally understood, therefore, that the surface area, length of the opposing walls, total occlusal convergence, and resistance form along with the adhesive qualities of the cement provide the resistance to dislodgement for crowns placed intraorally. Occasionally, a crown with clinically acceptable margins, preparation design, and occlusion becomes loose. Providers often debate whether such a crown can be successfully recemented with any degree of confidence that it will not be dislodged under normal masticatory function. Traditional causes for premature crown dislodgment include loss of core structure,[9] adhesive and cohesive failure of the luting agents, inadequate clinical crown preparation, failure to follow the manufacturer's directions for use of the luting agent, and contamination of the luting agent and/or tooth preparation interface. In this study, cast metal complete crowns that had horizontal circumferential grooves placed on their internal aspect were vertically dislodged from metal dies, with and without grooves, reproduced from an ideal shoulder with a bevel ivorine typodont tooth preparation. The purpose of this in vitro study was to determine whether adding horizontal grooves to the internal surface of the crown and/or tooth preparation would improve retention of a metal complete crown. The null hypothesis was that adding horizontal grooves inside the crown and/or on the die surface would not increase crown retention.

MATERIAL AND METHODS

Ninety identical cast metal complete crowns were produced by a commercial dental laboratory (Olson Dental Laboratory, Clinton Township, Mich). To standardize the crowns, the laboratory used a scanner (Dental Wings 5 series 3-D scanner; Dental Wings, Montreal, Canada) and component printer (Envisiontech Perfactory Digital Dental printer; Envisiontech Inc, Gladbeck, Germany), which uses digital light projection technology developed (Texas Instruments Inc, Dallas, Texas), to clone all the crown patterns. The crowns were cast to fit an ideal cast metal complete crown preparation made on an ivorine plastic typodont mandibular right first molar (Columbia Dentoform Corp, Long Island City, NY) (Fig. 1). The crown preparation had a 12-degree total buccal-lingual convergence angle, as measured by the angle between the taper of a medium flame shaped diamond rotary cutting instrument (#6862; Brasseler USA, Savannah, Ga), and the long axis of the tooth, and a buccal 1.0 mm shoulder with a bevel. The lingual, mesial, and distal surfaces had a chamfer finish line made with the same diamond rotary cutting instrument, and the occlusal surface was reduced by 1.0 mm over the nonfunctional surfaces and by 1.5 mm over the functional surface as measured by the interocclusal distance from the opposing tooth at the intercuspal position of the typodont. The ivorine tooth was duplicated by using a silicone mold (Rema Sil; Dentaurum, Ispringen, Germany) and filling it with molten green inlay wax (Maves Co, Cleveland, Ohio). Ten duplicate cobalt-chromium alloy dies (Orion; Indenco Dental Product Inc, Corona, Calif), were fabricated by the lost wax technique at a commercial dental laboratory (Olson Dental Laboratory) (Fig. 2). The reproduction process of the metal dies created dies that did not fit the complete crowns as well as the original ivorine model. The margins were closed but slight movement could be noticed before cementation. The reason for

1 Ivorine teeth, shoulder with bevel, mandibular right first molar preparation.

2 Cobalt-chromium alloy die with 2 grooves.

3 Cast metal complete crown with single internal groove.

4 Device/cable aligned to pull in line with crown.

fabrication of the metal dies was twofold: the metal dies were designed not to abrade with repeated trials, and the ivorine dies were not strong enough to resist fracturing during tensile testing.

The 90 crowns were divided into 9 groups of possible combinations of a crown "C" and die "D" with either no alterations or 1 or 2 grooves. The control was the combination of unaltered crown cemented on an unaltered die. The crowns that had 1 horizontal circumferential groove (C1) were prepared freehand on the internal side with the edge of a #37 inverted cone high speed carbide bur (Sybron Dental Specialties, Orange, Calif) approximately 3 mm from the margin (Fig. 3). The groove was approximately 0.5 mm deep. Crowns which had 2 horizontal circumferential (C2) grooves had grooves parallel to each other and which were several millimeters apart. The dies were prepared in a similar manner. Unaltered dies were designated as D. The grooves on the dies were cut with flat carborundum separating discs (EC Moore Co Inc, Dearborn, Mich), approximately 1 mm deep. Dies had 1 horizontal groove (D1) or 2 horizontal grooves (D2).

Grooves on the crowns and the dies were placed approximately in the same positions to be opposite each other after cementation. This was not a precise technique but was meant to simulate what a dentist could easily do chairside. Ten specimens (convenience sample size) were tested for each of the 9 combinations of dies and crowns with a universal testing machine (Instron Corp, Norwood, Mass). Before cementation, all of the crowns and dies were subjected to airborne-particle abrasion with 50 μm silicon dioxide particles (Emco Inc, Burbank, Calif). The crowns were cemented to the dies with resin modified glass ionomer cement (Fuji Plus; GC America Inc, Alsip, Ill), following the manufacturer's instructions and by using finger force for 60 seconds to seat the crown. The cement was allowed to set in a dry field for 10 minutes, and then the crown/die combinations were placed in water for at least 24 hours. The control specimens consisted of unaltered airborne-particle abraded crowns cemented to the unaltered airborne-particle abraded dies.

The crowns were removed from the dies with a cobalt-chromium alloy device (Orion; Indenco Dental Product Inc) (Fig. 4) designed to create an in-line tensile force on the cement junction. The device was designed in wax to fit around the crowns so that it was below the height of contour and then cast by using the lost wax technique. A 6.35 mm twisted steel cable was connected to the end of the device to allow for adjustment and an equal pull. The cable of the device was held firm by the lower jaw clamp of the tensile testing machine, while the die and crown, inserted in the device, were attached to the chuck of the upper mobile member of the machine. The tensile force (N) needed to remove the crowns was measured with a universal testing machine (Instron 5565; Instron Corp, Norwood, Mass) drawn at a rate of 0.5 mm/min. Software (Merlin 5.03; Instron Corporation) was used to analyze data. Averages and standard deviations were computed. The data were subjected to a 2-way ANOVA to determine significant differences between crowns and dies, and *t* tests were then used to compare each crown/die combination to the control (α=.05). No adjustment was made for multiple comparisons because the differences were statistically significant before the correction and the correction would have no impact. All computations were performed with statistical software (v2.7.2; R Foundation for Statistical Computing, Vienna, Austria).

RESULTS

Table I displays the means and standard deviations of force to fracture for all 9 crown/die combinations. Table II presents the ANOVA summarizing the significance difference due to crown and die modification and their interaction. The significance of the interaction in Table II motivated the comparison of specific combinations to each other. The control specimen acquired an average of 1006 N of force to dislodge the crowns. A mean force of 1626 N was necessary to dislodge crowns that had 1 horizontal internal groove cemented on an unaltered die, or 62% more retention. A mean force of 2039 N was needed to remove crowns with 2 grooves from an unaltered die, more than double that of the control. The mean force needed to dislodge an unaltered crown from a die with a single groove was 1156 N, which was not significantly different from the control (*P*=.38). The assembly with 2 grooves placed in the die with none in the crown required a mean force of 1571 N to dislodge, which was 56% higher than the control, but it was not as retentive as a single groove in the crown. Additionally, placing 2 grooves in a tooth may be difficult to achieve clinically. Retention gained by placing grooves in both the crown and die, for the most part, was comparable to placing a single groove in the crown alone. A minor exception was noted with the combination of 2 grooves in the crown and 1 groove on the die. This combination required a mean force of 1810 N to dislodge the crowns, which was less than when no groove had been placed on the die. This reinforced the idea that the grooves in the crowns were more important for retention than the grooves in the dies in this study.

Table I. Mean (standard deviation) of force, in newtons, to separate crown from die

	D	D1	D2
C	1006 (349)	1156 (319)	1571 (526)
C1	1626 (209)	1586 (407)	1595 (518)
C2	2039 (296)	1810 (203)	1660 (343)

Table II. Two-way ANOVA table assessing effects of crown and die on force to fracture

Source	*df*	Sum of Squares	Mean Squares	F	*P*
Crown	2	5 338 418	2 669 209	19.64	<.001
Die	2	125 764	62 882	0.46	.63
Interaction	4	2 324 279	581 070	4.28	.003
Error	81	11 007 220	135 892		

DISCUSSION

This experiment tested the tensile force required to dislodge a crown from a die. The data support the rejection of the null hypothesis that altering the crown and die would not increase retention. Since all the dies were identical, as were all the crowns and the cement, the results compare the vertical force required to dislodge the crown only. There was a slight shrinkage in the dies upon fabrication and the crowns fit adequately but not tightly. The looser fit was considered to represent most clinical situations where a crown has been dislodged from an ideal preparation. These tests demonstrated a cohesive failure of the cement since cement components were found on both the crown and tooth preparation surfaces.

Mastication is not a process that places forces purely along the long axis of a prepared tooth. If that were the case, mechanically, the cement interface would be placed primarily under compression during the mastication process. It is known that this is not the case particularly when the occlusion is not 3-dimensionally stable, but rather a combination of compression as well as tensile/shear influences. The cement (Fuji Plus) used in this experiment had a compressive strength of 150 MPa and 25 MPa tensile (data from GC America Inc, Alsip, Ill).

A power analysis was not performed for this study because of the fixed number of replicated gold crowns available. A sample size of 10 that demonstrated significant statistical differences in mean retentive strengths was selected. The number was based on other studies[4,5,7,8] where 10 or fewer specimens were tested. It should also be noted that the ideal tooth preparation described in this study is not necessarily observed clinically. Shorter clinical preparations, poor tooth foundation, and preparations with convergence angles of 20 degrees or greater, shift the cement interface from compression to shear, resulting in a greater possibility of failure of the cement interface through cohesive fracture. Also, clinically, many other factors such as bruxism, types of food masticated, amount of saliva in the mouth, and number of teeth remaining may be involved in dislodging a crown. In this study, a single groove in the die did not increase retention significantly and further testing may yield an explanation. It was not until 2 grooves were placed in the die that retention came close to matching a single groove placed in the crown. As previously mentioned, grooves on the crowns and the dies were placed approximately in the same positions so as to be opposite each other when cemented together. The theory behind this procedure was that the alignment of the 2 grooves would place some of the cement interface under compression. Fabricating opposing grooves in the mouth is possible; however, creating 2 pairs of opposing grooves is difficult. Clinical experience has shown that most dislodged crowns do not have enough tooth surface area to accommodate 2 grooves. This research shows that a single groove in the crown is as effective in increasing retention as single opposing grooves and that grooving the internal surface of the crown may be the most efficient method of obtaining additional retention if all other parameters stay the same. Follow-up studies changing the height of the axial walls and/or the total occlusal convergence of the preparation could confirm the benefit of adding grooves. This experiment did not consider bonding or using stronger cements. Therefore, the findings of this study may not apply to crowns with decreased occlusocervical dimension or increased total occlusal convergence.

CONCLUSIONS

Under in vitro conditions, with an ideal tooth preparation, grooving the internal surface of a cast metal complete crown significantly increased the force necessary to dislodge the crown. In contrast, placing a single groove on the die increased the retention less and was not statistically significant (*P*=.38). Since the cements, crowns, and dies were all identical and the process used to seat the crowns and dislodge the crowns consistent, it may be that the grooving of the crowns and/or dies made a difference by increasing retention.

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