The Effect of Die Spacer on Retention and Fitting of Complete Cast Crowns

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Purpose: This study evaluated the effect of die spacer on the fit and retention of complete cast crowns by using three different cements.

Materials and Methods: Standardized full crown restoration preparations were completed on 99 extracted molar teeth, impressions were made with poly(vinyl siloxane), and stone dies were made. Dies were covered with four layers of die spacer using three techniques: (1) covering the occlusal and 1/3 of the axial surfaces, (2) covering the occlusal and 2/3 of the axial surfaces, and (3) covering the entire preparation except the apical 0.5 mm of the preparation. Complete metal crowns were cast using Pors-on 4 alloy. Crowns were then assigned to one of three luting agent groups: resin modified glass ionomer cement, resin cement, or zinc phosphate cement. The castings were placed on their respective teeth and the marginal opening was recorded by two methods: 72 specimens were examined before and after cementation using optical microscopy with 0.001 mm resolution, and 27 specimens were examined after cementation with scanning electron microscopy. After cementation, the teeth were thermocycled for 700 cycles between 5°C and 55°C. The tensile retentive strength was measured on a universal testing machine with a crosshead speed of 0.5 mm/min. The data obtained for the fitting were recorded in millimeters and the data for the tensile retentive strength were recorded in KgF. The statistical analysis was performed by analysis of variance and post hoc Tukey's test ($p < 0.05$).

Results: Before cementation, better marginal fit was obtained when the die spacer covered all but the area 0.5 mm short of the margin of the preparation; however, after cementation, the resin modified glass ionomer cement group had the best fit with the same application of die spacer. Castings luted with resin cement required the greatest tensile force to produce cement failure.

Conclusions: Increasing the area of the die surface covered with spacer improved the fit of the cast restoration. After cementation, the resin modified glass ionomer showed better adaptation; however, the optical microscopy and scanning microscopy correlate well. Resin cement had the highest resistance to tensile forces.

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INDEX WORDS: cast crowns fitting, dental cements, die spacer

THE INCOMPLETE fit of full cast crown restorations remains a critical problem for dentists, leading many researchers to study this problem.[5,6,9,12,21] Recently, many researchers have agreed that the use of die spacers during fabrication improves the fit of the casting at cementation and may improve retention.[5,6]

In the past, researchers believed that better retention would be achieved with a frictional fit between the coping and the tooth surface.[29] This meant that during the cementation process, a perfect fit could not be obtained because of the lack of space for the luting agent.[1-4]

Die spacers allow increased space for the cement between the tooth surface and the internal surface of the casting, reducing stress areas created during cementation, and thereby resulting in better fit and retention of the final restoration.[5-9]

In fixed prosthetic treatment, luting agents have an important role in the final result. A luting agent that provides adequate marginal seal, without producing great vertical discrepancies in casting fit, makes an important contribution to a successful treatment result.

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Many researchers[6,13,17-19,23,24] have studied the effects of different luting agents (zinc phosphate, glass ionomer, and resin cements) on the retention and fitting of full cast crowns. These studies[13,17,19] show that the best fit is obtained with glass ionomer cements. On the other hand, resin cements provide better retention,[18,22-25] but also show greater vertical discrepancies of marginal fit.[6,13]

These concerns have led to the creation of several techniques that ensure an adequate space for the cementing agent, without losing retention of the final restoration. The objective of this study was to evaluate the effect of the area of the stone die covered by die spacer on the retention and fit of full cast crowns and to compare the effects of three cementing agents.

Materials and Methods

Ninety-nine extracted third molar teeth were selected and stored in distilled water at 37°C until the experiment. The roots of the teeth were notched and stabilized in standardized plastic cylinders 35 mm long and 18 mm in diameter. The teeth were then embedded in acrylic tubes with orthophthalic unsaturated resin (Redefibra, SP, Brazil). Standardized cylindrical preparations for full crowns were obtained by using a milling machine (Sanches Blanes, SA, Brazil) with water spray irrigation. The preparations were 6 mm in diameter at the occlusal surface, with 12° tapered and chamfered cervical margins, and an axial groove 3.5 mm long (Fig 1).

Stone dies (Velmix, Kerr, Romulus, MI) were prepared from poly(vinyl siloxane) impressions (Express, 3M Dental Products, St. Paul, MN) of the preparations and were divided into three groups. A new die spacer kit (Tru-Fit, George Taub Products, Jersey City, NJ) was used to cover each group of dies using four alternating layers of silver and gold die spacer. Individual stainless steel matrices were made for standardizing the application of die spacer in each group. The dies were grouped as follows: Group 1: die spacer covering the occlusal surface and 1/3 of the axial wall surface; Group 2: die spacer covering the occlusal surface and 2/3 of the axial wall surface; and Group 3: die spacer covering the entire preparation down to 0.5 mm short of the preparation margin (Fig 2).

Using standardized laboratory procedures, wax patterns for the cast copings were made on the isolated stone dies (Isolite, Degussa, Hanau, Germany) using a waxing instrument (Sensowaxer, Degussa) at 90°C. The wax patterns were made with standardized dimensions (0.5 mm thick) using a stainless steel matrix. The marginal seal was made with red wax (Plastodent Artline, Degussa), and the remainder of the pattern with green wax (Plastodent Artline). A wax loop was attached to the center of the occlusal surface of the crown, parallel to the long axis of the tooth, to facilitate the tensile strength test.

An identifying number was marked in the wax pattern, ensuring that each cast coping would be returned to the proper tooth. The wax patterns were sprued and invested in a carbon-free, phosphate investment (Deguvest, Degussa), prepared in an electrical evacuating and mixing unit (Multivac 4, Degussa). To ensure standardization, each silicone casting ring contained only one wax pattern. A standardized burn-out and pre-heat procedure was used. The crowns were cast in a palladium-based metal ceramic alloy (Pors-on 4, Degussa) using a centrifugal casting machine (Tiegelschleuder TS3, Degussa).

Each casting was thoroughly cleaned of investment residue with a 50-μm aluminum oxide micro-etcher (Renfert, Hilzingen, Germany). No other adjustment was made to improve restoration fit. Four reference marks on the uncemented specimens were made to

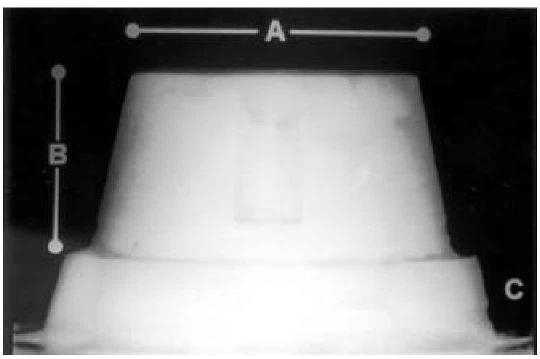

Figure 1. Prepared teeth dimensions (A—upper diameter 6 mm, B—preparation height 4 mm, C—base 2 mm).

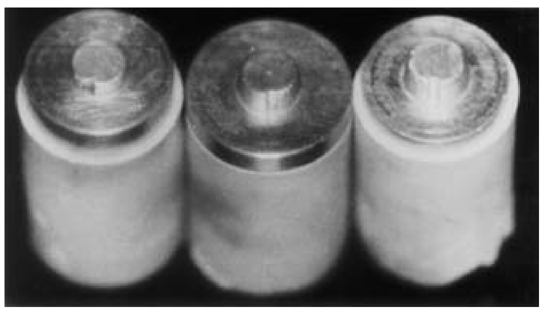

Figure 2. Stone dies covered with four layers of die spacer using three different stainless steel matrices made for each group.

ensure that the marginal opening would be recorded in the same position before and after the cementation procedure. All procedures were carried out by one operator.

The metal crowns were placed on their respective teeth, and the extent of marginal opening was recorded by two methods: 72 specimens had the external marginal discrepancies measured before and after cementation using an optical microscope (Mitutoyo, Kawasaki, Japan), and 27 specimens had the marginal discrepancies measured after cementation using a scanning electron microscope.

For baseline measurements, the crowns were held in position before cementation with two orthodontic elastics according to the methods of Gegauff and Rosenstiel.[20] A static load of 10 Kg was applied to the specimens, before and after cementation.

Prior to cementation, the 72 optical measurement specimen castings, already divided into three groups by die spacer application (24 castings for each group), were randomly sub-divided into three luting agent groups of 8 specimens: Group A—zinc phosphate cement (Harvard Dental-GmbH, Berlin, Germany); Group B—resin cement (Panavia 21, Kuraray, Osaka, Japan); Group C—resin modified glass ionomer cement (Vitremer luting cement, 3M Dental Products, St. Paul, MN).

The 27 electron microscopy analysis specimen castings were also divided into three groups (9 specimens for each group) by die spacer application, and then subdivided into three luting agent groups: Group A—zinc phosphate cement (Harvard Dental-Gmbh); Group B—resin cement (Panavia 21); and Group C—resin modified glass ionomer cement (Vitremer luting cement). After cementation, the teeth were embedded in orthophthalic resin and then sectioned along the long axis with a low-speed, water-cooled, diamond saw (Labcut, Extec, Enfield, CT). The cut surface was finished under running water through 120, 240, 400, 600, and 4000 grit silicon carbide abrasive papers with a revolving polishing machine (Ecomet III, Buehler Limited, Lake Bluff, IL). After this procedure, the specimens were ultrasonically cleaned in water for 5 minutes and then, dehydrated in different grades of ethyl alcohol (25%, 50%, 75%, 90%, and 100%). Finally, they were dried with hexamethildisilazane for 10 minutes. All specimens were fixed in specimen stubs, coated with gold, and observed with a scanning electron microscope (Leo 401, Cambridge, UK).

All luting agents were handled according to the manufacturer's instructions. The cements were applied to the inner surfaces of the castings using a micro brush. And next, the castings were seated on the individual teeth, and cemented using a 10-Kg vertical static load. For each luting agent, the load was maintained according to the manufacturer's instructions. Vertical discrepancies in the optical group were recorded after cementation for all specimens, at the same locations where the measurements were made prior to cementation. After marginal discrepancies were recorded, all specimens were thermocycled by dwelling in 5°C and 55°C baths for 700 alternating 1-minute immersions.

The forces required to dislodge the casting were measured on a constant displacement rate testing machine (Otto Wolper-Werke, Ludwigshafen, Germany) with a crosshead speed of 0.5 mm/min.

Results

The discrepancies in the marginal fitting before and after cementation were recorded in millimeters.

Table 1 summarizes the mean discrepancies of the marginal fit before cementation of the three groups of die spacer application (Group 1: 1/3, Group 2: 2/3, and Group 3: 0.5 mm). The mean values were 0.051 mm for Group 1, 0.039 mm for Group 2, and 0.027 mm for Group 3. One-way analysis of variance (ANOVA) (Table 2) and post hoc Tukey's test (Table 1) were used to determine the differences among means. Statistical analysis revealed significant differences between the three groups ($p < 0.05$). Marginal discrepancies obtained for Group 1 were significantly higher than those for Group 2, and those for Group 2 were significantly higher than those for Group 3.

Table 3 summarizes the marginal discrepancies after cementation for the three different die spacer application groups (Group 1: 1/3, Group 2: 2/3, and Group 3: 0.5 mm) and the three luting agents. The value considered was the marginal opening as measured by light microscopy, attributed to the cement alone; this is the difference between the marginal opening recorded after cementation and the marginal opening recorded before cementation. Two-way ANOVA (Table 4) and post hoc Tukey's test (Table 3) were used

Table 1. Post Hoc Tukey's Test for the Mean of Marginal Discrepancies Before Cementation

Group *Mean (mm)*	*{1}* *0.0506667*	*{2}* *0.0388750*	*{3}* *0.0272083*
1/3 {1}		<0.001*	<0.001*
2/3 {2}	<0.001*		<0.001*
0.5 {3}	<0.001*	<0.001*	

*p value (<0.05) for the Tukey's test.

Table 2. One-Way ANOVA Procedure for the Dependent Variable Marginal Fitting Before Cementation

Source of Variation	*df*	*MS*	*F Value*	*P*
Die spacer	2	0.000055	60.335	<0.01

df = degrees of freedom; MS = mean square; *P* = probabilities.

to determine the differences among means. Statistical analysis revealed significant differences between the nine groups ($p < 0.05$). Post hoc Tukey's test results for the mean marginal discrepancies recorded after cementation for all groups are listed in Table 3.

Figures 3, 4, and 5 represent the results obtained by scanning electron microscopy for the different groups. Figure 3 depicts a typical margin region of a casting cemented with zinc phosphate, with the die spacer applied 0.5 occlusal to the margin (Group 3). Figure 4 depicts a typical margin region of a casting cemented with resin modified glass ionomer, with the die spacer applied 0.5 occlusal to the margin (Group 3). Figure 5 depicts a typical margin region of a casting cemented with resin cement, with the die spacer applied 0.5 occlusal to the margin (Group 3).

Table 5 lists the mean forces (KgF) required to dislodge the casting for all groups. Two-way ANOVA (Table 6) and post hoc Tukey's test (Table 5) were used to determine the differences among means. Statistical analysis revealed significant differences between the nine groups ($p < 0.05$).

Table 3. Post Hoc Tukey's Test of the Marginal Discrepancies Recorded by Light Microscopy for the Three Groups ($p < 0.05$)

Group	*Mean (mm)*
Zinc phosphate 1/3	0.049 a, g, h, i
Zinc phosphate 2/3	0.022 b, e, f
Zinc phosphate 0.5	0.046 a, c, d, e, h, i
Glass ionomer 1/3	0.047 a, c, d, e, g, h, i
Glass ionomer 2/3	0.027 b, c, d, e, f, h
Glass ionomer 0.5	0.012 b, e, f
Resin cement 1/3	0.067 a, d, g, i
Resin cement 2/3	0.044 a, c, d, e, h, i
Resin cement 0.5	0.049 a, c, d, g, h, i

Same letters show no statistical differences between means.

Table 4. Two-Way ANOVA Procedure for the Dependent Variable Marginal Fitting After Cementation

Source of Variation	*df*	*MS*	*F Value*	*P*
Luting agent	2	0.0036	22.973	<0.01
Die spacer	2	0.0035	22.155	<0.01
Luting agent Xversus Die spacer	4	0.0008	5.219	<0.01
Error	71	55.568		

df = degrees of freedom; MS = mean square; *P* = probabilities.

Discussion

Marginal Fitting

The results of this study show that using the die spacer agent with the stone die improves the marginal fitting of the casting. This is clearly shown in the results, where the best marginal fitting was obtained when the die spacer was applied to the entire prepared surface except the region 0.5 mm above the finish line (Group 3).

In 1993, Grajower and Lewinstein[10] stated that "an optimum fit of the casting can be obtained only if relief space allows for the cement film thickness and roughness of the tooth and casting surfaces." They affirm that applying a spacer on the die, including the base of the tapered region but excluding the horizontal part of the shoulder, is the most effective technique. Also, they arbitrarily recommended a relief of 50 μm for the thickness of the spacer to be applied on the die surface. This value includes 30 μm for the cement

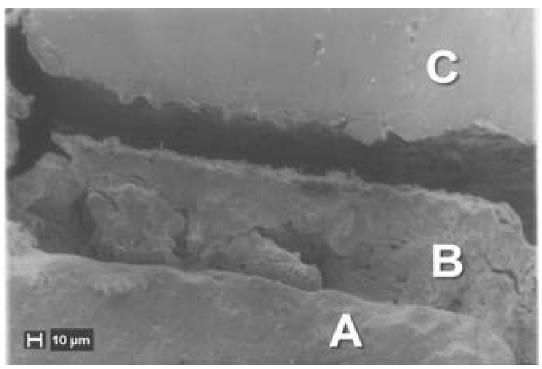

Figure 3. SEM photomicrograph of the cast marginal region cemented with zinc phosphate, with the die spacer applied 0.5 mm before the marginal finish line. (A: tooth, B: cement, C: crown)

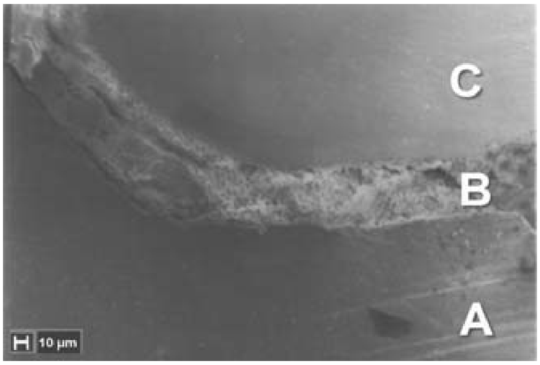

Figure 4. SEM photomicrograph of the cast marginal region cemented with glass ionomer, with the die spacer applied 0.5 mm before the marginal finish line. (A: tooth, B: cement, C: crown)

film and surface roughness, as well as 20 μm for distortion of the wax pattern.

In 1989, Grajower et al[9] asserted that leaving part of axial walls uncovered with the spacer impaired the crown fit considerably. The average elevation of the latter was 653 μm when compared with 49 μm for the application of the spacer to the margin.

In our study, the die spacer agent used (Tru-Fit) was applied in four alternate colored coats as recommended by the manufacturer, providing a 25-μm space. Die spacer was applied over three areas. In all specimens, a casting margin discrepancy was observed at the finish line, including the uncemented specimens. These findings agree with many authors;[6-9,11-16] however, the specific

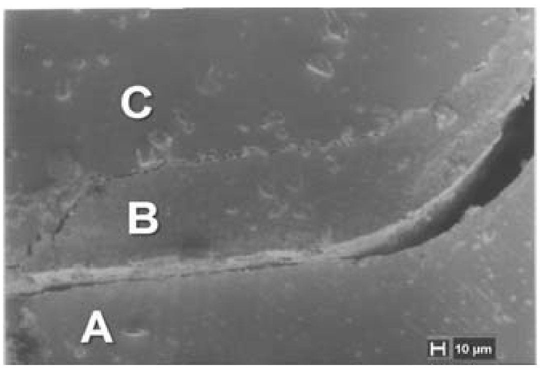

Figure 5. SEM photomicrograph of the cast marginal region cemented with resin cement, with the die spacer applied 0.5 mm before the marginal finish line. (A: tooth, B: cement, C: crown)

Table 5. Post Hoc Tukey's Test for the Mean Forces (KgF) Required to Dislodge the Casting for all Groups ($p < 0.05$)

Group	*Mean (KgF)*
Zinc phosphate 1/3	37.98 a,b,c
Zinc phosphate 2/3	47.32 a,b,c,d,f
Zinc phosphate 0.5	44.52 a,b,c,d
Glass ionomer 1/3	52.07 b,c,d,f
Glass ionomer 2/3	65.17 e,f,g,i
Glass ionomer 0.5	58.02 b,d,e,f,g
Resin cement 1/3	70.17 e,f,g,h,i
Resin cement 2/3	79.20 g,h,i
Resin cement 0.5	74.27 e,g,h,i

Same letter shows no statistical differences between means.

numerical results differed, possibly because of the different methodologies used.

When the marginal discrepancies found in this study were examined, it was apparent that the smallest discrepancy was obtained with the resin modified glass ionomer cement when the die spacer covered the entire preparation except the area 0.5 occlusal to the finish line, with a mean marginal discrepancy of 13 μm.

These results agree with those obtained by Wang et al[17] and White and Kipnis,[13] who obtained best results on the marginal fitting when a glass ionomer cement was used. However, Tjan and Li[18] and Wu and Wilson[15] found that lower marginal discrepancies were observed when a resin cement was used as the luting agent.

Tjan and Li[18] found that a better marginal fitting was obtained by using resin cement, compared with zinc phosphate cement. One possible reason is that the authors applied two layers of copal varnish to the surface of the prepared teeth prior to cementation with zinc phosphate cement; this could influence the marginal fitting of the metal casting.

Table 6. ANOVA Procedure for the Dependent Variable Tensile Strength

Source of Variation	*df*	*MS*	*F Value*	*P*
Luting agent	2	660.5651	129.148	<0.01
Die spacer	2	5869.096	14.535	<0.01
Luting agent Xversus Die spacer	4	15.3295	14.755	>0.01
Error	71	15983.67		

df = degrees of freedom; MS = mean square; P = probabilities.

On the other hand, the results obtained by Gegauff and Rosenstiel[20] and Emtiaz and Goldstein[21] show that the use of die spacer makes no statistically significant difference to the marginal fitting of cemented cast crowns.

In fact, a standardized technique for laboratory or clinical use that can provide a gap-free cast restoration does not exist. Until this is developed, internal surface spacing for cast restorations will remain an important factor in reducing marginal discrepancies of cemented cast restorations, as our work has demonstrated.

Tensile Strength Test

Our results show that resin cement (Panavia 21) exhibits the highest tensile strength when compared with resin modified glass ionomer cement (Vitremer luting cement) and zinc phosphate cement (Harvard, Richter and Hoffmann, Berlin, Germany). The results found in this study agree with the results obtained by Lee and Swartz,[22] Tjan and Li,[18] Pameijer and Jefferies,[23] el-Mowafy et al,[24] and Gorodovsky and Zidan.[25] One possible explanation for these results is that resin cement provides mechanical and chemical adhesion to the metal surface and the tooth surface; also, this material has high cohesive resistance.

Applying die spacer to the occlusal 2/3 of the die produced statistically significant superior tensile strengths for resin modified glass ionomer cement than did applying the die spacer to the occlusal 1/3; this was not observed with the resin or zinc phosphate cement. This suggests that the die spacer can be applied to obtain the best marginal fit without interfering with retention.

As was the case for marginal fitting, several researchers[26,27,28] have affirmed that the application of die spacers increases the tensile strength of the cemented cast restoration. On the other hand, other researchers such as Vermilyea et al[28] and Gegauff and Rosenstiel[20] found that die spacer decreases the resistance to tensile dislodgment for castings cemented with zinc phosphate.

The findings of Vermilyea et al[28] show that when a die spacer is applied 0.5 mm short of the finish line, providing 25 μm of cement space, the cemented castings showed 32% reduction in retention. The same results were also found by Gegauff and Rosenstiel[20] when the die spacer was applied 1 mm short of the finish line.

The results obtained in this study agree with those by Tjan and Sarkissian[19] that the tensile strength presented by the resin modified glass ionomer cement was superior to that obtained with zinc phosphate cement. Gorodovsky and Zidan[25] found no difference between these two cements. The zinc phosphate cement is a non-adhesive cement with limited mechanical properties, but it presents reliable clinical results. The primary retention of cast restorations cemented with zinc phosphate is influenced by the configuration of the tooth preparation, namely the taper, length, and surface area. The luting ability of the cement has a secondary role in retention, which is achieved mainly through mechanical interlocking. Glass ionomer cement attains retentive strength, both through mechanical interlocking and physicochemical bonding. Based on their results, Gorodovsky and Zidan[25] affirm that the adhesive properties of the glass ionomer did not improve the retention of the castings; so it can be inferred that the retentive parameters described for the zinc phosphate were also applicable for the glass ionomer. That is, retention should be seen primarily as a function of the geometric configuration of the preparation.

The major purpose of this study was to create an adequate and standardized laboratory and clinical technique that will improve marginal fitting without losing retention. Additional studies to investigate the optimum relief for specific luting agents and the function of properties such as cement thickness and viscosity in improving the seating of a casting without decreasing retention are needed.

Conclusions

Within the parameters of this study, the following can be concluded:

1. The best marginal adaptation of the uncemented castings was obtained when the die spacer covered all of the preparation down to 0.5 mm short of the marginal finish line.
2. The castings cemented with ionomer-based luting agent provided the best margin adaptation when the die spacer covered all of the preparation down to 0.5 mm short of the marginal finish line.
3. The castings luted with resin cement exhibited the highest retentive strength.

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