

A Comparison of Two Different Methods and Materials Used to Repair Polycarbonate Crowns

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Abstract

Aim: The aim of this study was to evaluate the bond strength and crown-repair material interface of polycarbonate crown repaired using flowable resin composite and hybrid resin composite following two different surface preparations.

Methods and Materials: The facial surfaces of fifty-two polycarbonate crowns were flattened and roughened. Specimens were then divided into four test groups. A bonding agent alone (Groups 1 and 2) or a combination of methylmethacrylate (MMA) + bonding agent (Groups 3 and 4) was applied to the prepared surfaces. Then either a flowable (Groups 1 and 3) or a microfilled hybrid (Groups 2 and 4) resin composite was placed on the surfaces. Forty-eight of the original fifty-two specimens were used for shear bond strength testing. Failure types (adhesive, cohesive, and mixed) were evaluated. The remaining four specimens, one from each group, were used for crown-resin composite interface analysis using a scanning electron microscope (SEM).

Results: There were significant differences in both mean shear bond strength values and failure types ($P < 0.05$). The SEM evaluation revealed a close interface relationship in Groups 3 and 4.

Conclusion: MMA monomer application on a polycarbonate crown prior to application of an adhesive agent improved the shear bond strength of the repair material.

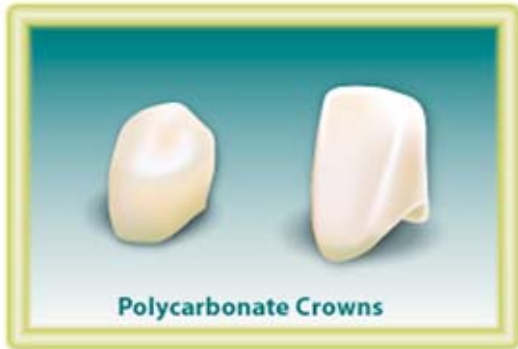
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Introduction

Polycarbonate crowns are used to restore carious primary anterior teeth of preschoolers and to provide temporary coverage for abutment teeth prior to placement of the permanent restoration in adults.¹⁻⁴



These crowns are made of a polycarbonate resin combined with microglass fibers. Lui et al.¹ stated microglass fibers are used to improve the impact strength and flexibility of a crown. Investigators studied the fracture strength of polycarbonate crowns at primary and permanent interincisal angles (1480 and 1350, respectively) and found fracture strengths of the crowns ranged from 470 N to 585 N, respectively.⁵⁻⁷ These crowns have a fracture resistance greater than the average bite force of preschoolers and adults.^{8,9} However, polycarbonate crowns may be fractured or abraded as they have poor abrasion resistance during service.^{10,11} In these cases, if a restoration is functionally adequate, structurally acceptable, and has no extensive carious lesion¹², it can be repaired as an alternative to replacement. The goals of the repair are to preserve tooth hard tissue inexpensively in a less time-consuming manner.¹³

Unfortunately, no study has investigated the repair of polycarbonate crowns. However, Hagge et al.¹⁴ showed a bis-acryl composite provisional crown material may be repaired using a flowable resin composite.

The aim of this study was to evaluate the bond strength and crown-repair material interface of a polycarbonate crown repaired using flowable resin composite and hybrid resin composite following two different surface preparations.

Methods and Materials

Specimen Preparation

Fifty-two central incisor polycarbonate crowns (C-300, 3M Dental Products, St. Paul, MN, USA) were used for this study. The dies for each crown were fabricated using dental stone with high hardness and low expansion (Begostone, Herbst GmbH&Co., Bremen-Germany). The vestibular surfaces of each crown were flattened and roughened using Sof-Lex discs (3M ESPE, Seefeld-Germany). Prepared surfaces were cleaned with a non-fluoride paste, washed, and air-dried. Four experimental groups of 13 specimens were randomly chosen for testing. Test specimens were prepared as follows:

Groups 1 and 2. An adhesive agent (Prime & Bond 2.1, Dentsply, DeTery GmbH D-78467, Konstanz, Germany) was applied to the prepared surface for 30 seconds. Any excessive adhesive agent was gently removed with oil-free compressed air and then light-cured for ten seconds. A clear plastic cylinder with a surface area of 4.4 mm² was placed over the adhesive covered surface and secured with sticky wax (Figure 1).

Groups 3 and 4. Methylmethacrylate (MMA) monomer (RR, DeTrey, Dentsply, Italy) was applied to the prepared vestibular



Figure 1. Assembly for shear bond strength testing.

surface of the polycarbonate crowns for 180 seconds then washed and air-dried. The treated surface had a frosty appearance because the MMA monomer dissolved the surface of the polycarbonate material.¹⁵ Then both adhesive agent application and plastic cylinder placement were performed as described above.

In Groups 1 and 3 Tetric Flow (Vivadent-Ets., FL-9494 Schaan/Lichtenstein) flowable resin composite was injected into the cylinder in two increments. Each increment was cured for 20 seconds with a visible light-curing unit. In Groups 2 and 4 Valux Plus microfilled hybrid resin composite (3M, Malakoff France) was filled into the cylinder in two increments and then each layer was cured using a visible light-curing unit for 40 seconds. As a next step, the plastic cylinder was carefully removed. All specimens were stored in distilled water at room temperature for one week. Of the total fifty-two specimens, 48 were used for the shear bond strength test. The remaining four specimens were used to evaluate the crown-repair material interface under a Scanning Electron Microscope (SEM).

Shear Bond Strength Test

Each specimen was placed into a mechanical testing machine (Hounsfield, Test Equipment, Raydon, England). Shear force was applied using a knife-edged blade, applied parallel to the bonding surface of the polycarbonate crown at a crosshead speed of 1.5 mm min⁻¹ (Figure 2).

Results were recorded in Newtons (N). Shear bond strength values were converted to megapascal (MPa) using the surface area of the

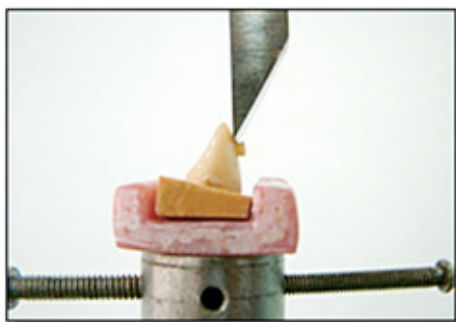


Figure 2. Assembly for shear bond strength testing.

cylinder. The obtained data were compared using one-way analysis of variance (ANOVA) and the post hoc Duncan multiple comparison test at the 95% significance level. In addition, the fractured surface was evaluated under 16X magnification with a microscope (Nikon SMZ-U Multi-point Sensor System, Kanagawa, Japan). In addition, failure modes were scored as an adhesive failure (at the resin/polycarbonate interface), a cohesive failure (within the resin material), or an adhesive/cohesive failure (mixed). The results were statistically analyzed with the Kruskal-Wallis H test for several-independent-samples and a Mann-Whitney U test for two-independent-sample tests at a 95% significance level. All statistical analyses were performed using SPSS 11.0 for Windows software (SPSS Inc., Chicago IL, USA).

SEM Analysis

Four specimens were used to evaluate the polycarbonate crown-resin composite interface using SEM. Each specimen was sectioned longitudinally in bucco-lingual direction through the center of the resin composite for the SEM (Jeol 6500, Jeol USA, Inc. Peabody, MA, USA). All sections were covered using Au-Pd by means of a Polaron Equipment Limited SEM Coating Unit E 500 (Comercial Assens-Llofrin SA, Barcelona, Spain). After the process of covering was completed, the specimens were evaluated under SEM and micrographed.

Results

Shear Bond Strength Analysis

The mean shear bond strength value of each group is presented in Table 1. One way ANOVA indicated a significant difference among test groups ($P < 0.05$). To understand the source of this significant difference, the Duncan multiple comparison test was applied to the data. Although Group 2 (Prime & Bond + Valux Plus) possessed lower shear bond strength than Group 1 (Prime & Bond + Tetric Flow), none of the differences were statistically significant ($P > 0.05$). The Duncan test showed the mean shear bond strength of Groups 3 and 4 (19.69 and 17.78 MPa, respectively) was significantly different from the others ($P < 0.05$). Although Group 3 had a slightly higher shear bond strength than Group 4, there was no significant difference between Groups 3 and 4 ($P > 0.05$).

Table 1. Shear bond strength and failure mode.

Groups	N	Shear Bond Strength		Failure Mode (%)		
		Mean Values (MPa)	±SD	Adhesive	Cohesive	Mixed
Prime & Bond + Tetric Flow ^{a a}	12	13.45	4.04	10 (83.3)	-	2 (16.7)
Prime & Bond + Valux Plus ^{a a}	12	11.76	3.73	11 (91.6)	-	1 (8.4)
MMA + Prime & Bond +Tetric Flow ^{b b}	12	19.69	5.66	1 (8.4)	-	11 (91.6)
MMA + Prime & Bond + Valux Plus ^{b b}	12	17.78	4.41	3 (25)	-	9 (75)

The difference between the groups marked by the same letter or letters is statistically insignificant ($P>0.05$).

a and b letters were used in the Duncan multiple comparison test.

a and b letters were used in the Mann-Whitney U two-independent-samples tests.

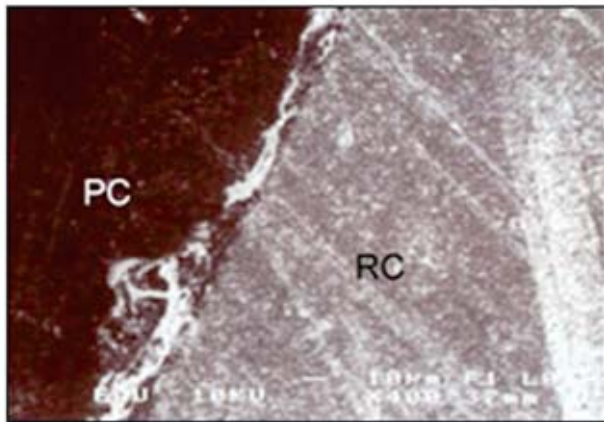


Figure 3. Interface Tetric Flow-polycarbonate crown. There are some separations along the interface (PC, polycarbonate crown; RC, resin composite; Original magnification X400)

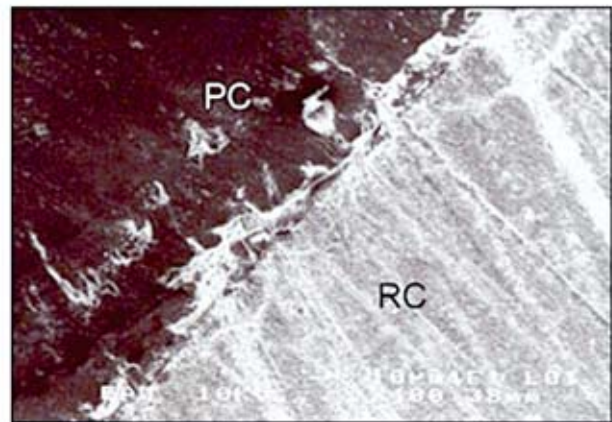


Figure 4. Interface Valux Plus-polycarbonate crown. There are some separations along the interface (PC, polycarbonate crown; RC, resin composite; Original magnification X400)

Failure modes in all specimens (adhesive, cohesive, and mixed) are shown in Table 1. There was a significant difference among groups ($P<0.05$). The Mann-Whitney U test showed there was no significant difference between Groups 1 and 2 and between Groups 3 and 4 ($P>0.05$). However, there were significant differences between both adhesive agent + resin composite groups (Groups 1 and 2) and both MMA monomer + adhesive agent + resin composite groups (Groups 3 and 4) ($P<0.05$). The failures that occurred were either adhesive or mixed; none of the groups had cohesive failure.

SEM Analysis

In Groups 1 and 2, SEM micrographs (Figures 3 and 4) revealed polycarbonate crown-repair material interfaces had some separations.

Grooves between the crown and repair material were not observed in either micrograph. Figure 5 (Group 3) showed an intimate relationship between the polycarbonate crown and the test material. In Figure 6 (Group 4), porosities between the polycarbonate crown treated with MMA monomer and repair material were observed.

Discussion

Polycarbonate crowns may be abraded or perforated rather than fractured in the course of service.^{11,15} In any case, these restorations may be repaired in the mouth as an alternative to replacement.

This study compared the shear bond strength of the repair materials used to repair polycarbonate crowns. Polycarbonate may be dissolved

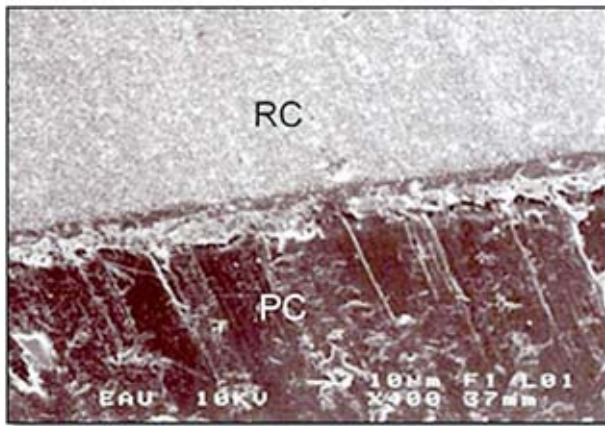


Figure 5. Interface between Teric Flow-polycarbonate crown treated with MMA monomer. There is intimate adaptation between both of those (PC, polycarbonate crown; RC, resin composite; Original magnification X400).

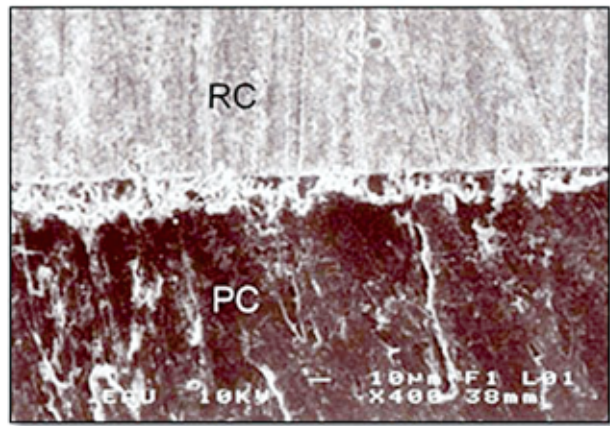


Figure 6. Interface between Valux Plus-polycarbonate crown treated with MMA monomer (PC, polycarbonate crown; RC, resin composite; Original magnification X400).

by means of MMA monomer, eugenol, and phosphoric acid.^{10,15} In the present study the author chose to use the MMA monomer treatment on crown surfaces because eugenol has the ability to inhibit polymerization of resin materials¹⁶ and phosphoric acid works too slowly.¹⁵ No information was obtained regarding the dissolution time of polycarbonate resin by MMA monomer. Therefore, in Groups 3 and 4 the author used a visual criterion, a frosty appearance, on the polycarbonate crown surface 180 seconds after MMA monomer application. MMA monomer creates surface irregularities on the crown. Gross and micro mechanical retention areas provide for the adhesive agent to interlock with the surface irregularities created.¹⁷ This could account for a decrease in adhesive failures and an increase in shear bond strength values in Groups 3 and 4. Nitkin et al.¹⁰ reported when MMA monomer was used to treat the polycarbonate, bonding resin composite to polycarbonate improved. Their results were in agreement with those of the present study. In Groups 1 and 2, the adhesive agent had not penetrated into polycarbonate resin because none of the specimens were treated with MMA monomer. Almost all of the specimens in Groups 1 and 2 (83.3% and 91.6%, respectively) demonstrated adhesive failure. None of the specimens, however, demonstrated cohesive failure. In addition, Groups 1 and 2 had significantly lower shear bond strength than the other groups ($P < 0.05$).

In the present study Tetric Flow (a flowable resin composite) had slightly higher shear

bond strength than Valux Plus (a hybrid resin composite) in all groups. However, no significant difference was found between both Groups 1 and 2 and between Groups 3 and 4 ($P > 0.05$). The probable reasons for this might be flowable resin composite, due to their thixotropic qualities, could better adapt to tiny crevices and voids that are difficult to enter and with fewer air bubbles emerging during the application.¹⁸ SEM micrographs (Figures 3 and 5) supported the explanations. The micrographs shown in Figures 4 and 6 were not a close adaptation between polycarbonate and the repair material.

The author is of the opinion if a polycarbonate crown restoration is still esthetically acceptable, remains functional, and there is an absence of recurrent caries, it is easier and faster to repair the crown using the technique used in this study. Applying MMA monomer on the polycarbonate crown to improve the shear bond strength of resin composite should be done with caution because of the gross softening of the polycarbonate resin.^{10,15}

Conclusion

1. MMA monomer treatment prior to adhesive agent improved the shear bond strength of both Tetric Flow and Valux Plus.
2. Tetric Flow had slightly higher shear bond strength than Valux Plus in groups both with and without MMA monomer.
3. Almost all of the specimens in groups with and without MMA monomer demonstrated mixed and adhesive failures, respectively.



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