Original Research

Evaluation of Tensile Bond Strength between Dentin and Metallic Copings Using Different Resin Cements

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Abstract

Statement of the Problem: For a successful clinical outcome, luting agents should have a high bond strength. Bond failure is still one of the main reasons of restoration failures. **Purpose:** The present study was designed to comparatively evaluate the retention of metallic copings using different resin luting cements. **Materials and Method:** In the present experimental study, 40 intact premolar teeth were included. The teeth were prepared to receive copings with a chamfer bur at high speed, cooled with an air/water spray. The occlusal surface was prepared flat, perpendicular to the long axis of the root at a standardized height of 4 mm from the gingival chamfer finish line with a 20 degree consistent taper of axial walls. The wax patterns were prepared and cast. Teeth with un-cemented casts were randomly divided into 4 groups based on the type of cement used. The tensile load required to dislodge the crowns was measured using Instron universal testing machine with a crosshead speed of 1mm/min. The data were analyzed by SPSS software and Kruskal-wallis test (α=0.05). **Results:** The maximum and minimum amounts of crown retention were in Panavia-F2 and Maxcem cements respectively. Despite this different retention values in cements, Kruskal-wallis disclosed no significant difference between groups in the mean amount of crown retention. (P-Value=0.۰۶۸) **Conclusion:** Regarding the results of the study, it was concluded that there are no mentionable differences between all groups.

Keywords: Cementation, Dental Cements, Retention, tensile strength.

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Introduction

All crowns require acceptable retention and resistance for their clinical success (1). Based on researches, loss of crown retention has been the second leading cause of failure of crowns and fixed partial dentures (2). Factors such as wall parallelism, preparation length, convergence angle and surface texture highly affect retention rate (3). Also, clinical success of fixed restorations is dependent on the type of cement and cementation procedures (4). Dental luting cements influence crown retention but can vary in tensile strength from 5.5 MPa to 45.1 MPa (5). Ideally, luting cements should have physical properties sufficient to resist functional forces, be resistant to degradation in oral environment and adhere to the underlying dentin (1).

Zink phosphate, polycarboxylate, glass ionomer, hybrid glass ionomers and resin cements are five commercially available luting agents for permanent cementation. Zink phosphate cement provides a mechanical interlocking to tooth and casting irregularities (6) and is still the gold standard for many clinicians (7). Glass ionomers are being used with great success and few complications. This cement holds the tooth and restoration together by physicochemical bonding (8, 9).

In recent years, resin cements have gained great reputation among clinicians because of their improved physical properties. Their dislodgement resistance is greater than other cements such as zinc phosphate or conventional glass ionomer (10). Resin cements not only enhance the retention of restorations, but also are less soluble (11) and have less micro leakage compared to zinc phosphate or glass ionomer cements (12, 13). It was found in a study that many non-metallic and non-retentive restorations can only be cemented by resin cements (4). In another study, resin cements were used to attach crowns to teeth with short clinical crowns and the resultant bond strength was approximately 3 times more than the bond gained by zinc phosphate cement (14). This highlights the fact that resin cements are a great choice when the retentive features of the teeth are compromised (15).

Conventional resin luting cements require pretreatment of prepared dentin including separate etching, priming and bonding. In a study, it was shown that Panavia-F2, which is conventional resin cement, shows higher retentive strength, approximately twice that of zinc phosphate cements (16). Despite their high efficacy, different preparation steps make the use of conventional resin cements sensitive and time consuming (17). Also, micro leakage and polymerization shrinkage can lead to cuspal deformation (18, 19). Therefore, self –adhesive resin cements were introduced and found popularity because they do not need pretreatment of dentin (20). The self-etch property of self-adhesive resin cements eliminates the need for separate etching and priming and reduces technique sensitivity of these cements (21). The number of self-adhesive resin cements is increasing due to their high success rate. Among self-adhesive resin cements, Maxcem, G-CEM and Bifix SE found popularity in dental profession.

Currently, conventional resin luting cements provide the greatest bonding capacity for indirect restorations (22). However, self-adhesive resin cements reduce technique sensitivity and working time. Although some studies have investigated the efficacy of different resin cements, there is no published study to have comparatively investigated these cements regarding their bond strength. Therefore, the present study was designed to comparatively evaluate the retention of metallic copings using different resin luting cements. The null hypothesis was that there would be no difference in the retentive strength of complete metal crowns, luted with different resin cements.

Materials and Method

Sampling

In the present experimental study, 40 human maxillary first premolar teeth of comparable crown length and size, extracted for orthodontic reasons, were included ($n=10$, $\alpha=0.05$, $\beta=0.8$, $d=7.51$ Kgf). Teeth with any sign of crack, caries, previous restorations or filled canals were excluded from the study. Teeth were stored in thymol 0.2 % at room temperature for two days and in 4°C distilled water for no more than one week prior to tooth preparation.

Tooth preparation

Shallow notches were prepared on the outer surface of the roots of the teeth which were vertically mounted in self-cure acrylic resin (Meliodent, Heraeus Kulzer, Hanau, Germeny) within 2 mm of cemento-enamel junction (CEJ). A dental surveyor (Degussa-Ney, Yucaipa, CA, USA) was used to vertically align the long axis of each tooth. Mounted teeth were stored in an atmosphere of 100% humidity. Tooth preparation was initiated by vertically reducing occlusal surfaces in order to expose the dentin. Any remaining enamel was removed to expose the dentin. The reduced occlusal surfaces were examined using a ×19 stereomicroscope (SMZ-1; Nicon, Inc, Garden City, NY). A high-speed hand piece (KaVo America, Lake Zurich, IL, USA) and water spray mounted on a milling machine was used to control the tooth-bur angle and standardize axial reduction. The method used to estimate the axial surface area was similar to that of Felton et al (23). By comparing the foil strip for each sample with strips of known surface area, the appropriate axial surface area was obtained. The teeth were prepared to receive complete cast copings with a 1 mm diameter chamfer bur (Henry Schein Rexodent, Southall, UK) at high speed, cooled with an air/water spray. We made the occlusal surface flat, perpendicular to the long axis of the root at a standardized height of 4 mm from the gingival chamfer finish line with a 20 degree consistent taper of axial walls (12). Putty-wash impressions of the finished preparation were made (Panasil; Kettenbach GmbH & Co KG, Eschenburg, Germany) in prefabricated trays. The impressions were then poured in high-strength stone (GC Fujirock EP, GC Corp, Leuven, Belgium) to construct dies.

Wax patterns with 0.5 mm thickness and flat occlusal surface were made using type I blue inlay wax (Kerr/Sybron, Orange, Calif, USA). A ring like wax pattern was added to the occlusal portion to facilitate tensile testing after cementation as described by Tjan and Sarkissian (24).

The wax patterns were poured and invested using a gypsum-bonded investment (Rema-Exakt; Dentaurum, Ispringen, Germany). Each pattern was cast with ADA predominantly base metal, Ni-Cr-Be alloy (Rexillium III, Pentron, Wallingford, CT). A pilot study was done to produce crowns that seated well with minimal force on the stone dies and tooth preparations.

Casting the crowns and cementation

The accuracy of the copings was measured using wash impression materials (Fit Checker, GC Co., Tokyo, Japan). The internal surface of each casting was inspected with a stereomicroscope mentioned above and any minute nodules were removed using a half-round bur in a slow speed straight handpiece. Then, the inner surfaces of the copings were air abraded at 60 psi from a distance of 3 cm using 50 µm alumina powders (Rocatec Pre, 3M ESPE,USA) for 15 seconds and ultrasonically (Tecna3 ,Technogaz, Parma, Italy) cleaned in deionized water for 10 minutes.

Completely seated, uncemented copings were randomly assigned to the four following groups (table 1) each including 10 specimens:

Group 1: copings luted with Panavia-F2 cement (Kuraray, Osaka, Japan)

Group 2: copings luted with Maxcem cement (Kerr, Orange, CA, USA)

Group 3: copings luted with G-CEM cements (GC America, Alsip, IL)

Group 4: copings luted with Bifix SE (Voco GmbH, Cuxhaven, Germany)

Before filling the castings with cement, the castings and teeth were dried with an air syringe. Cements were prepared and applied in accordance with the manufactures' instructions. Then the castings were seated under a 25 Kg compressive load, applied for 10 minutes using a force gauge (Chatillon model DPP; Ametek US Gauge Division, Largo, Fla) through a 100-mm-length × 8-mm-diameter wood stick placed horizontally on the occlusal surface of the crown. Then the excess cement was removed. The cemented copings were stored in an environment of 100% humidity for 24 hours before tensile testing.

Measuring crown retention

The tensile load required to dislodge the copings was measured using Instron Universal Testing Machine (Instron Ltd., High Wycombe, UK) in a path parallel to the axis of withdrawal for each sample with a crosshead speed of 1mm/min.

The data were analyzed with Kruskal-wallis test and SPSS (22.0) software program. (α=0.05)

Table1. Materials used in study

Cement	Type	Manufacturer	Composition of the resin cement	Mixing method and ratio
Panavia-F2	Dual cure	Kuraray Medical Inc., Okayama, Japan	Paste A: MDP, Methacrylate monomer, Filler, Initiator Paste B: Methacrylate monomer, Filler, NaF, Initiator, Pigment	Hand mix, equal length of base and catalyst
Maxcem	Dual cure	Kerr Corporation, Orange, CA	UDMA, Camphorquinone, Fluoroaluminosilicate glass, others Catalyst Paste: Bis-GMA, TEGDMA, Glycerophosphatedimethacrylate, Barium aluminoborosilicate glass, others	cement mixed through a dual barrel syringe, light cured for 20 s from each side
G-CEM	Dual cure	GC America, Alsip, IL	Fluoroaluminosilicate glass, Initiator, Pigment Liquid: 4-MET, Phosphoric acid ester monomer, UDMA, Dimethacrylate, water, Silicon dioxide, Initiator, Inhibitor	cement mixed through a dual barrel syringe, light cured for 20 s from each side
Bifix SE	Dual cure	Voco GmbH, Cuxhaven, Germany	UDMA, Bis-GMA, , benzoyl peroxide(Initiator), acid methacrylate, amines(cat),BHT (stabilizer)	cement mixed through a dual barrel syringe, light cured for 20 s from each side

Results

The means and standard deviations of crown retention in different groups are shown in Table 2. Pavania-F2 cement showed the highest mean retention values among other resin cements (242.30 Kg) and Maxcem cement showed the lowest (148.90 Kg). Also, the maximum and minimum amounts of crown retention in samples were seen in G-CEM (450.00 Kg) and Maxcem (76.00 Kg) cements respectively. Despite this different retention values in cements, Kruskal-wallis disclosed no significant difference between groups in the mean amount of crown retention. (P-Value>0.05)

Table 2. The means and standard deviations of complete metal crown retentive strength (Kgf) in different groups

Groups	Bifix SE	G-CEM	Maxcem	Panavia-F2
number	10	10	10	10
Mean± S.d	168.30 ± 56.00	232.90 ± 98.67	148.9 ± 50.82	242.30 ± 113.86
minimum	100.00	100.00	76.00	110.00
maximum	230.00	450.00	240.00	430.00
median	158.5	223	50.82	113.86
Interquartile range	122.25	136.25	76.25	182.25

Discussion

The data do not support rejection of the null hypothesis of the present study that there would be no difference in retentive strength of complete metal crowns luted with different resin cements.

Numerous factors in tooth preparation affect the success of cast restorations. It has been shown that height and convergence angles of prepared teeth and the luting agents are the most important factors that influence crown dislodgement (25). Lack of retention is a common cause of fixed prosthesis failure (1). This study substantiated the difference in retention of cast copings that can be directly attributed to the effect of luting cements. Currently, conventional resin luting cements provide the greatest bonding capacity for indirect restorations (22, 26). However self-adhesive resin cements simplify cementation procedures. Clinicians need to know these cements' superiority over each other to choose the most appropriate cement in different clinical situations. The present study comparatively evaluated conventional and self-adhesive resin cements.

In the present study, 40 identical human premolars were included. It has been demonstrated that crown retention can be affected by tooth size and configuration (27). Since the sizes of the all involved teeth were the same, any difference in crown retention can be attributed to the properties of the luting cements, not the preparation configurations.

Dislodging forces act upon a tooth restored with a cast crown during mastication and parafunctions. In the present study, tensile forces were directly applied to the crown, although in clinical situations this force rarely acts to dislodge teeth. However, the force which is applied to the crown can be classified as one of the tensile, shear or compressive forces and the occurrence of tensile forces is not an uncommon event (28). Also, in the C. A. Mitchell study, (28) it was shown that specimens subjected to tensile test, failed in a same manner as in clinical situations. Also, it was concluded that metal ceramic crowns rarely fail due to dentin fracture and most of the failures occur at cement-preparation interface. So, it is reasonable to use tensile test to evaluate the efficacy of different cements.

In the present study, Panavia-F2 cement showed the strongest bond compared to other cements. It has been declared that, the conventional resin cement, Panavia-F2, contains MDP (10-Methacryloyloxydecyl dihydrogen phosphate) incorporated into the self-etch primer. This monomer is reported to be effective in improving cement bond strength to enamel and dentin (29). These findings are consistent with other investigations (6, 30).

In the present study, the Maxcem cement showed the weakest bond strength to tooth structure. Maxcem is self-adhesive resin cement. According to the manufacturer, this cement contains Glycerol phosphate dimethacrylate monomer which is responsible for its self-etching and adhesive properties (31). Our results are consistent with a study reporting that, the weakest bond strength and the highest amount of cement failure was seen with the use of Maxcem cement (32). In the present study, the bond strength of the Maxcem was considerably lower than Panavia-F2 cement. This finding is in agreement with T. Nakamura [(33)] and Goracci's (32) studies which showed that Panavia-F2 presented higher bond strength compared to Maxcem. In D. Tonal study, (31) application of polyacrylic acid for pretreatment, significantly increased tensile bond strength of Maxcem cement. Based on the results of Tonal's and our study, it can be theorized that the weak bond strength of Maxcem may be related to inadequate etching of the cement.

G-CEM is a self-adhesive resin cement which contains water and functional monomers (4-MET and phosphoric acid ester) for self-adhesive properties. G-CEM cement powder is fluoro amino silicate glass and it is structurally similar to glass-ionomer cements; so it is better to classify this cement as resin-modified glass-ionomer cements. In the present study, the bond strength of G-CEM cement was strongest among the self-adhesive cements (Maxcem and Bifix SE). However, its bond strength was weaker than Panavia-F2. Due to the presence of functional monomers, G-CEM is capable of forming chemical bond with tooth structure and this can explain the stronger bond strength of G-CEM compared to other self –adhesive cements. The bond strength of G-CEM was shown to be weaker than Panavia-F2. Since the main functional monomers of these cements are different, it can be suggested that 10-MDP is more effective than 4-MET in improving bond strength.

Although there was a clinically considerable difference between different cements, this difference was not statistically significant. This insignificant difference may be explained by the limited number of specimens in each group. So, it is recommended to conduct further studies with adequate sample sizes. In one study, the investigators evaluated microtensile bond strengths (μTBS) produced by different self-adhesive cements such as G-CEM and Maxcem and compared them with conventional luting agents such as Panavia-F2. It was concluded that the bond strengths produced by Panavia-F2 was significantly higher than G-CEM. Also G-CEM showed significantly higher bond strength compared to Maxcem (34). It has been shown that the bond strength of self-etching self-adhesive cements, like Maxcem, G-CEM and Bifix SE, which do not require a separate conditioning or priming step before bonding of the indirect restorations, is less than the earlier generations of resin cements. Therefore, it has been recommended that the results of bond strength tests of other resin cements be evaluated with the use of the cross-linkers that have recently been introduced (35).

Dental restorations generally last for a long period of time in the wet environment of the oral cavity. In a study, it was shown that cements expand as the time of water immersion increases (33). Therefore, it seems necessary to investigate the behavior of these cements for longer spans in conditions similar to oral cavity in future studies.

The question of whether the application of a second cementation procedure (re-cementation) would lead to a significant reduction in retention of castings cemented with these resin cements remains unresolved. Further investigations should be conducted in this area. Although the test method used in the present investigation was designed to simulate clinical conditions, there were some limitations. First, the unidirectional static loading force applied to the crowns was totally different compared to the complex dynamic forces present in the oral environment. Second, we did not make an artificial aging of the crowns via thermal cycling and mechanical loading. Third, sites of failure were not determined in our study. Finally, we suggest further study on other types of resin cements using modern tooth preparation technologies such as CAD-CAM.

Conclusion

Within the constraints of the experimental design of this study, it was concluded that there are no noticeable differences between all groups. Despite the fact that Pavania-F2 cement showed the highest mean retention values among other resin cements and Maxcem cement showed the lowest, there was not any significant difference between all groups.

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