Scientific Article

Microleakage of Adhesive and Nonadhesive Luting Cements for Stainless Steel Crowns

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Abstract: ***Purpose:*** *This study's purpose was to compare the ability of 5 luting cements to reduce microleakage at stainless steel crown (SSC) margins on primary molar teeth.* ***Methods:*** *Standard preparations were performed on 100 extracted primary molar teeth for SSC restoration. After fitting SSCs, samples were randomly divided into 5 groups of 20 teeth each, which were cemented with nonadhesive cement consisting of polycarboxylate (PC) or zinc phosphate (ZP), or with adhesive cement consisting of glass ionomer (GIC), resin-modified glass ionomer cement (RMGIC), or RMGIC with a bonding agent (RMGIC+DBA). After aging and thermocycling, the specimens were placed in 1% methylene blue, sectioned, and evaluated under a digital microscope. The data were compared between groups with the t test, analysis of variance, and the least significant difference test.* ***Results:*** *Microleakage with adhesive cements was significantly lower than with nonadhesive cements (P<.05). Differences between cements were statistically significant at P<.001. RMGIC+DBA showed the lowest microleakage, followed in increasing order by RMGIC, GIC, and ZP. The PC cement showed the greatest microleakage.* ***Conclusions:*** *Adhesive cements were more effective in reducing microleakage in stainless steel crowns than nonadhesive cements. Use of a bonding agent with a resin-modified glass ionomer cement yielded better results than using the latter alone.* *(Pediatr Dent 2011;33:501-4) Received April 16, 2010 | Last Revision June 18, 2010 | Accepted July 7, 2010*

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The stainless steel crown (SSC), first introduced in 1950 by Engel and developed by Humphrey, is an extremely durable, relatively inexpensive treatment that offers the advantage of full coronal coverage. These crowns have been recommended for the restoration of teeth with extensive caries or developmental defects, following pulpotomy or pulpectomy treatments, and after clinical failure of other restorative materials such as amalgam or composite resin. In addition, SSCs have been used to restore primary teeth that will be used as an abutment for a space maintainer.

A number of studies have documented the clinical success of SSCs over other restorative materials.[1] There are some disadvantages to using SSCs, however, such as inadequate peripheral crown marginal adaptation, gingival inflammation around the edges of crown margins,[2] crown loss,[3] and occlusal surface changes such as denting and perforation.[4] To prevent these problems, 3 rules have been suggested: (1) considering the principles of tooth preparation; (2) proper crown selection in addition to marginal adaptation; and (3) using a suitable luting cement.[5] The clinical success of luting cements is based on their high bond strength and ability to reduce microleakage.[6] Poor marginal sealing may allow microleakage along the interface between the tooth and crown as well as plaque accumulation.[5]

This phenomenon is especially important in prefabricated SSCs because achieving optimal marginal adaption is difficult with these crowns.[7] Thus, luting cements play an important role in obtaining a suitable marginal seal and reducing microleakage through the crown margins.[7] Some studies in permanent teeth with cast restorations showed that reducing microleakage may diminish the penetration of bacteria and their products into the tooth, thereby subsequently reducing tooth hypersensitivity, recurrent caries, pulpal problems, and clinical failures.[7-9]

Different kinds of luting cements have been used to cement SSCs. The earliest "conventional" luting cements (also described as nonadhesive luting cements), such as polycarboxylate and zinc phosphate, provided only a mechanical bond to the tooth. Subsequent efforts have focused on improving bond strength, reducing microleakage, technique sensitivity, and simplifying the usage of conventional cements.[10] As a result, a new generation of luting cements achieve both mechanical and chemical bonding to the tooth. These newer products include glass ionomer, resin-modified glass ionomer, and resin cements.[11]

Most studies have investigated microleakage in full cast crowns in permanent teeth, whereas few have evaluated microleakage from SSCs luted to primary teeth. The purpose of this in vitro study was to compare the ability of different new adhesive and conventional nonadhesive luting cements to reduce microleakage around stainless steel crowns in primary molars.

Methods

One hundred primary molars were selected for this study. Included were 28 mandibular first molars, 25 mandibular second molars, 26 maxillary first molars, and 21 maxillary second molars. The teeth were sound or had occlusal restorations, and the

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Table 1. LUTING CEMENT SYSTEMS USED AND THEIR APPLICATION PROCEDURES

Group	Material type	Code	Brand name	Manufacturer	Luting agent mixing
1	Polycarboxylate cement	PC	Durelon	3M ESPE, St. Paul, Minn	Mix powder and liquid (1:1) for 30 s
2	Zinc phosphate cement	ZP	Elite cement	GC Tokyo, Japan	Mix powder and liquid (1:3) for 60 s
3	Glass ionomer cement	GIC	Ketac-Cem	3M ESPE	Mix powder and liquid (1:2) for 30 s
4	Resin-modified glass ionomer cement	RMGIC	Rely X Luting 2	3M ESPE	Mix paste and paste (1:1) for 20 s
5	Resin-modified glass ionomer cement plus dentin bonding agent	RMGIC+DBA	Single Bond and Rely X Luting 2	3M ESPE	Apply etchant gel for 7 s, rinse, air dry, apply 2 layers of bonding; mix paste and paste (1:1) for 20 s

root resorption rate was lower than two thirds. Specimens with proximal, buccal, and lingual caries were excluded from the study.

Initially, all teeth were immersed in 0.1% chloramine T solution for 2 weeks for disinfection, and were then stored in distilled water at 37°C. The apical parts of the roots (from 2-mm below the cementoenamel junction) were mounted in cold-cured acrylic resin blocks. Next, standardized tooth preparation for SSCs was performed by a single operator. The occlusal surfaces and occlusal third of the buccal and lingual surfaces were reduced 1.0 to 1.5 mm with a 169L bur (Teez Kavan Ltd, Tehran, Iran). All mesial and distal undercuts were reduced using a diamond featheredge bur (Teez Kavan). All line angles were rounded under a water spray. For each prepared tooth, a prefabricated SSC (3M ESPE, St. Paul, Minn) was selected, fitted, contoured, and crimped with pliers (no. 114, 3M ESPE, and nos. 800-417, Denovo, Baldwin Park, Calif).

After the crowns were adjusted, the teeth were randomly divided into 5 groups containing 20 teeth each, according to the luting cement used: (1) polycarboxylate (**PC**); (2) zinc phosphate (**ZP**); (3) conventional glass ionomer cement (**GIC**); (4) resin-modified glass ionomer cement (**RMGIC**); and RMGIC with a bonding agent (**RMGIC+DBA**). All cements were used according to the manufacturers' instructions (Table 1). In Group 5 (RMGIC+DBA), the tooth surfaces were:

1. conditioned for 7 seconds with 35% phosphoric acid (Ultra Gel-Etch, Ultradent, South Jordan, Utah);
2. rinsed; and
3. dried gently under a weak air stream according to wet bonding principles.

It should be noted that some studies recommended a shorter application time (approximately 50%) for the dentin conditioner or the use of a weaker concentration of acid in the primary dentin than in permanent dentin.[12,13,14] Accordingly, in Group 5 we used a 7-second conditioning step. A 2-step etch and rinse adhesive system (Single Bond, 3M ESPE, St. Paul, Minn) was placed in the preparation, thinned by applying a weak air stream, and light-cured for 20 seconds with a halogen light curing unit (Coltolux, Coltene, Whaledent Inc, Altstaetten, Switzerland) at 500 mW/cm^2. Next, the paste (Rely X luting2) was mixed in the same way as for Group 4 (RMGIC alone) and used to cement the SSCs.

In all groups, immediately after the luting cement was mixed, the inner two thirds of the SSC was filled, and the crown was positioned on the preparation with finger pressure. Each SSC was loaded axially with 5 kg for 10 minutes with a loading jig to apply equal pressure to all crowns. Excess cement was removed according to the manufacturer's instructions, and the tooth was transferred to distilled water for aging over 4 weeks at 37°C. After this period, all teeth were subjected to 500 thermal cycles in 5°C and 55°C water baths with a dwell time of 30 seconds and a 20-second transit time between baths. The root surfaces, except for a 1-mm-wide zone around the margins of each SSC, were sealed with 2 coats of nail polish and stored in distilled water. All teeth were then immersed in 1% methylene blue dye solution for 24 hours.

Upon removal from the dye, the teeth were rinsed and sectioned faciolingually across the center of the restorations using a diamond saw (Letiz, 1600, Leica, Wetzlar, Germany) with continuous water irrigation. Under blind conditions, 2 observers examined the sectioned teeth under a digital microscope (Dino Lite, Taipei, Taiwan) at 40× magnification and scored linear dye penetration in millimeters from the margin of the SSC through the interfaces between the tooth and the cement. Mean dye penetration was recorded and statistical analyses were done with analysis of variance (**ANOVA**; $P<.001$), multiple comparisons with the least significant difference (**LSD**) test ($P<.001$), and t tests ($P<.05$). To compare the results between adhesive and nonadhesive cements, the t test and ANOVA were used to compare all groups together. To compare each cement to all other cements, separate LSD tests were used.

Results

Comparisons with t tests detected a significant difference between adhesive and nonadhesive cements. Microleakage (mean± standard deviation) was 0.88±0.44 mm with adhesive cements and 2.30±0.43 mm with nonadhesive cements ($P<.001$). According to ANOVA, mean microleakage also differed significantly between groups (Table 2, Figure 1). The LSD test results showed significant differences in mean microleakage with different luting cements. Crowns cemented with PC showed the greatest microleakage. Among nonadhesive cements evaluated in this study,

Table 2. MEAN±(SD) MICROLEAKAGE (MM) WITH DIFFERENT LUTING CEMENTS

Luting cement	Mean±(SD)	P-value
Elite cement (ZP)	1.97±0.30	<.001
Durelon (PC)	2.63±0.24	
Ketac-Cem (GIC)	1.45±0.24	
Rely X Luting 2 (RMGIC)	0.70±0.15	
Single Bond + Rely X Luting 2 (RMGIC+DBA)	0.52±0.12	

ZP, had less microleakage than PC but more microleakage compared to GICs (GIC and RMGIC). Also the RMGIC cement led to less microleakage than the PC, ZP, and GIC cements. The RMGIC+DBA group showed the least microleakage.

Discussion

Clinical failure of SSCs following cement failure has been noted in some studies.[3] One of the reasons is microleakage through the crown margins.[7] Studies that focused on permanent teeth cast restorations revealed microleakage due to marginal gaps, resulting in tooth sensitivity, recurrent caries, or pulp involvement.[7-9] Regarding the consequences of microleakage in permanent teeth, it is assumed that microleakage occurs along the interface between the tooth and crown in primary teeth.[5] This phenomenon is especially important in SSCs, because complete adaptation of the crown could not be achieved in spite of contouring and crimping.[7] Microleakage can be evaluated with nonparametric scoring techniques or with more accurate parametric measurements,[7] which is the approach used in the current study.

A potential limitation lies in the fact that the in vitro experimental conditions used in the present study do not exactly reproduce the in vivo situation in clinical practice. Among the factors that may limit the generalizability of the results are the time between tooth extraction and preparation in the laboratory, thermal cycling, occlusal load produced by the jig, and the use of bonding agents that may be less straightforward to use in primary teeth under clinical conditions. Because this was a laboratory study under carefully controlled conditions, due caution should be used before the results reported here are extrapolated to complex clinical situations.

The type of luting cement is considered an important factor in reducing marginal microleakage and achieving a good marginal seal. Two main types of luting cement—adhesive and nonadhesive—have been used with SSCs.[1] Our results show that microleakage was lower with adhesive cements than nonadhesive cements, as is in agreement with the results obtained by others.[7,9,15] Both cement composition and physical properties determine cement microleakage.[8] Conventional nonadhesive luting cements provide only mechanical bonding between the cement and the tooth surface. In contrast, adhesive cements are able to form both mechanical and chemical bonds to the tooth surface, resulting in the high clinical success rate of these cements.[16-18] Adhesive cements, however, have certain disadvantages. They may be more difficult to manipulate and more technique-sensitive than conventional cements. Moreover, dentin bonding agents need a separate application step.[4,8]

We found significant differences among all experimental groups. Crowns cemented with PC showed the greatest microleakage. Shiflett and White also found that PC bonds had significantly more microleakage than those prepared with ZP or GICs.[7, 9] The relatively poor marginal seal achieved by PC cement might be attributed to particular characteristics of the cement itself. Although it seems that acidic fluid in the cement mixture could provide a chemical bond with calcium in hydroxy apatite, research confirmed that the cement-to-dentin cement-to-enamel bond strength was poor, leading to short duration and loss of adhesion.[19] The finding that the other nonadhesive cement evaluated in this studs, ZP, had less microleakage than PC but more microleakage compared to GICs (GIC and RMGIC), is in agreement with previous studies.[8,9,15] The higher marginal seal ability

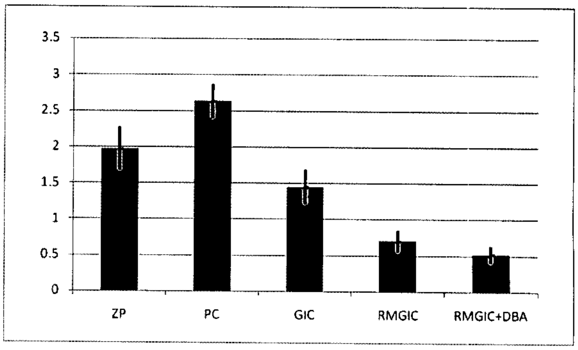

Figure 1. Mean±(SD) microleakage (mm) with different luting cements in 5 experimental groups: Elite cement (ZP); Durelon (PC); Ketac-Cem (GIC); Rely X Luting 2 (RMGIC); Single Bond plus Rely X Luting 2 (RMGIC+DBA).

of ZP compared to PC is related to the physical properties of the former, such as its lower solubility[20] and greater dimensional stability.[7,20] The absence of chemical bonding of ZP with the tooth surface and higher solubility of ZP than GICs, however, are responsible for the greater microleakage seen with the former.[22]

In our study, GICs (GIC and RMGIC) led to significantly less microleakage than PC and ZP. The formulation of glass ionomer adhesives contains calcium ions able to interact with hydroxyapatite in the enamel and dentin.[23] Some studies, however, have demonstrated that the formation of a smear layer results in weak bonding between GIC and the dentin surface, so pretreatment of the surface with acidic solutions before using cement has been recommended.[24] The RMGIC cement led to less microleakage than the PC, ZP, and GIC cements. RMGICs are obtained by adding a resin monomer to a conventional glass ionomer. The resulting RMGIC cements have mechanical advantages over GIC, such as higher bond strength to enamel and dentin, increased flexural strength, and reduced water sensitivity during cement setting.[23, 25] With penetration of the polymer into the demineralized dentin and entrance into the dentinal tubules, stronger micromechanical bonding can be achieved, which in turn results in diminished microleakage compared to GIC.

The RMGIC+DBA group showed the least microleakage. Pretreatment, as used in the RMGIC+DBA group, achieved better micromechanical bonding as well as chemical bonding to the tooth surface, which led to a more stable bond. Application of a dentin bonding agent before using a GIC improves penetration into the matrix of demineralized dentin and establishes a strong hybrid layer and bond, as well as reducing marginal microleakage. In addition, the hydroxyethyl methacrylate in the RMGIC+DBA cements increases bond strength.[7, 9] Adding steps in the application of bonding agents, however, can make the cementation procedures more time-consuming and difficult in pediatric patients.

Conclusions

The results of this study suggest the following conclusions:

1. None of the luting cements investigated in the present study could seal crown margins completely.
2. Resin-modified glass ionomer cement significantly reduced microleakage compared with polycarboxylate, zinc phosphate, and conventional GICs tested with stainless steel crowns and primary molars.

3. The combination of a dentin bonding agent prior to the resin-modified GIC decreased microleakage more than resin-modified GIC alone under in vitro conditions.

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