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Comparison of microleakage from stainless steel crowns margins used with different restorative materials: An *in vitro* study

Mahtab Memarpour[1], Reza Derafshi[2], Mahshid Razavi[3]

Departments of [1]Pediatric Dentistry, Prevention of Oral and Dental Disease Research Center, [2]Prosthodontics and [3]Pediatric Dentistry, School of Dentistry, Shiraz University of Medical Sciences, Shiraz, Iran

ABSTRACT

Background: Obtaining optimal marginal adaption with prefabricated stainless steel crowns (SSCs) is difficult, especially after removing dental caries or defects in cervical areas. This situation requires the use of an SSC after tooth reconstruction. This study evaluated microleakage and material loss with five restorative materials at SSC margins.
Materials and Methods: One hundred and twenty primary molar teeth were randomly divided into six groups (n = 20). Class V cavities were prepared on the buccal surfaces of the teeth in groups 1-5. Cavities were restored with amalgam, resin-based composite, glass ionomer (GI), zinc phosphate, or reinforced zinc oxide eugenol (Zonalin). Group 6 without cavity preparation was used as a control. Restorations with SSCs were prepared according to standard methods. Then, SSCs were fitted so that the crown margins overlaid the restorative materials and cemented with GI. After thermocycling, the specimens were placed in 0.5% fuchsin and sectioned. The proportions of mircoleakage and material loss were evaluated with a digital microscope. Statistical analysis was performed with Kruskal–Wallis and Mann–Whitney tests.
Results: The groups differed significantly ($P < 0.001$). Amalgam and GI showed the least microleakage. Amalgam restorations had significantly less microleakage than the other materials ($P < 0.05$). Microleakage was greatest with resin-based composite, followed by Zonalin. Material loss was greater in samples restored with Zonalin and zinc phosphate.
Conclusion: When SSC margins overlaid the restoration materials, cavity restoration with amalgam or GI before SSC placement led to less microleakage and material loss. Regarding microleakage and material loss, resin-based composite, zinc phosphate, and Zonalin were not suitable options.

Key Words: Dental restorations, crowns, primary teeth, stainless steel

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Address for correspondence:
Dr. Reza Derafshi,
Department of Prosthodontics, School of Dentistry, Shiraz University of Medical Sciences,
Shiraz, Iran.
E-mail: derafshi@sums.ac.ir

INTRODUCTION

Prefabricated stainless steel crowns (SSCs) are intended to cover the whole coronal surface of the tooth. They are used to restore primary or permanent teeth with extensive or multisurface cavities, cervical decalcification, and/or developmental defects.[1,2]

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Ensuring adequate SSC marginal adaptation reduces microleakage around the tooth-crowns margins; however, this aim can be difficult to achieve with prefabricated crowns.[3] Problems may also be

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associated with the use of SSCs for full crown coverage in teeth with large cavities or cervical decalcification. For example, it may be necessary to reduce tooth size and extend parts of the crown margins beyond the sound tooth after caries or defect removal.[2,3] In permanent teeth, reconstruction with restorative materials as a core may be indicated.[4,5] Also when the crown margin is not supported by a sound permanent tooth, some methods recommend increasing the clinical crown length by orthodontic forces or periodontal surgery,[6,7] both of which are contraindicated for children. In addition, removing part of the tooth structure without replacing it may lead to the accumulation excessive luting cement at the crown margins, which is inconsistent with the rule of low film thickness of the luting cement for crown cementation.[4,8] Lack of due attention to this rule may compromise long-term crown retention.[8] Therefore, a suitable restorative material is needed to replace the tooth structure, especially when the crown margin does not completely cover the whole restoration.

The ideal core material should provide properties similar to dentin as well as adequate mechanical characteristics, that is, biocompatibility, resistance to leakage of oral fluids, minimal water absorption, inhibition of caries and ease of manipulation.[9] Different kinds of materials have been used for core restoration; however, the ideal criteria have yet to be established. The older amalgam cores provide high compressive strength and low solubility; however, they require cavity preparation, additional retention and a long setting time that postpones crown preparation to a subsequent appointment.[4,10,11]

Tooth-colored restorative materials may also be used as core materials. Resin-based composites provide micromechanical bonding to the tooth structure, minimize the need for additional retention and set rapidly. However, the physical properties of composites are less satisfactory than amalgam, and the required techniques are more sensitive.[4,5,12]

Glass ionomers (GIs) provide chemical bonding to the tooth structure and release fluoride; however, their tensile strength and fracture resistance are low.[12] Equia™, a new-generation GI, combines a bulk filled radiopaque GI has been introduced to overcome some of the problems with conventional GI.[13]

Although SSCs have been used mostly after pulp therapy, some clinicians may prefer to reconstruct the coronal surface with nonadhesive cement such as reinforced zinc oxide eugenol (ZOE) or zinc phosphate. These materials provide mechanical retention to the tooth structure, set quickly and are easy to use and inexpensive. However, their mechanical properties are less satisfactory than permanent restorative materials such as amalgam, and some products have shown varying degrees of water absorption and low resistances to oral fluids.[12,14]

The type of restorative material used beneath a full crown influences crown retention and microleakage along the crown margins.[5,15] Few studies have evaluated different types of restorative materials beneath SSCs in primary teeth. The aim of this *in vitro* study was to evaluate microleakage and material loss with five different core restorative materials at the SSC margins in primary molars.

MATERIALS AND METHODS

After obtaining approval by the Human Ethics Review Committee of the Faculty of Dentistry, Shiraz University of Medical Sciences, 120 primary molars were selected. The teeth were sound or had occlusal restoration. The root resorption rate was less than one half. Teeth that did not fulfill these criteria were excluded from the study. All teeth were immersed in 0.1% chloramine T solution for 2 weeks for disinfection and then stored in distilled water at 37°C. The apical parts of the roots (from 3 mm below the cementoenamel junction) were mounted in cold cured acrylic resin blocks. Then the teeth were randomly divided into six groups of 20 teeth each. In groups 1-5, Class V cavities (2.5 mm high, 3.0 mm wide, 1.5 mm deep) were prepared on the buccal surface at the cementoenamel junction with a fissure diamond bur. The incisal margin was prepared on the enamel, and the gingival margin was located about 2 mm below the cementoenamel junction. The SSC margins overlaid the restorative materials after restoration while the materials extended past the margins of the SSC. A group of teeth without cavity preparation was used as a control (n = 20).

All cavity restorations were performed by an operator before tooth preparation for SSC as follows:

Group 1: Amalgam — The cavity rinsed, dried and restored with non-gamma 2 admix alloy amalgam (gs-80, SDI, Dublin, Ireland). Then, the tooth preparation for SSC was postponed for 24 h to ensure that the amalgam had set completely.

Group 2: Resin-based composite — The tooth surfaces were etched with phosphoric acid 35% (3M, ESPE, St. Paul, MN, USA) for 20 s, washed and dried under a weak air stream (wet bonding). Then a two-step etch and rinse adhesive system (Tetric N-Bond, Ivoclar Vivadent, Schaan, Liechtenstein) was applied on the etched surfaces, thinned by applying a weak air stream, and light-cured for 20 s with a halogen light curing unit (Coltolux, Coltene, Whaledent, Altstaetten, Switzerland) at 600 mW/cm^2. The cavity was filled with a nanohybrid resin-based composite (Tetric N-Ceram, Ivoclar Vivadent) with the incremental method. Each increment was light-cured for 40 s with a light-curing unit.

Group 3: GI — Cavity conditioner (GC Conditioner, Alsip, IL, USA) was applied to the tooth walls for 10 s, rinsed, and gently dried under a weak air stream. Then, a GI capsule (EQUIA Fil, GC America, Alsip, IL, USA) was activated according to the manufacturer's instructions and mixed in an amalgamator for 10 s at 4000 rpm. The GI was inserted into the cavity with the GC capsule applier. The material was adapted to the outer tooth surface after the cavity was filled. Excess material was removed by an explorer.

Groups 4: Zinc phosphate cement — The powder and liquid components (1.8:1 for 90 s) of a zinc phosphate cement (Hoffman Harvard, Dental-Gesellschaft, Berlin, Germany) were mixed, and the cavity was dried and filled with a plastic filling instrument. Excess cement was removed after the cement had set.

Group 5: Reinforced ZOE — The powder and liquid components (5:1 for 60 s) of fast-setting ZOE (Zonalin, Kemdent, Purton, Wiltshire, UK) were mixed to a thick putty consistency. The dried cavity was filled with the cement mixture, taking care not to extend the cement to the outer margin of the cavity, and the excess was removed.

Group 6: Sound teeth (control group) — The crowns margins were fitted over the sound tooth.

In all groups, standardized tooth preparation for SSCs was performed by the same operator. The occlusal surface was reduced by about 1-1.5 mm with a football diamond bur. The line angles were rounded along all proximal surfaces with a diamond featheredge bur (858/014, Dia Tessin, Vanetti, Gordevio, Switzerland). An appropriately sized prefabricated SSC (3M, ESPE) was selected through a trial and error procedure and fitted on the tooth. Then the crown was adjusted, contoured and crimped with pliers (No. 114, 3M ESPE, and No. 800-417, Denovo, Baldwin Park, CA, USA).

Before the crowns were cemented, two grooves were made on the buccal and lingual surfaces of the crown to mark the plane through which the crowns were cut through the middle of the restoration. In all groups, the teeth were prepared and the crown was cemented with luting cement after the GI powder and liquid were mixed (1.8:1 for 20 s) (GC, USA). The inner two-thirds of the SSC was filled with cement. First the crown was seated on the tooth with finger pressure. Then, to apply equal pressure to all crowns, each SSC was subjected to a static load force of 5 kg for 10 min with a loading jig. The excess cement was removed. Aging was done by storage in distilled water for 4 weeks at 37°C. Then all specimens underwent thermal cycling for 1000 cycles of 5°C and 55°C in a water bath, with a dwell time of 30 s and a 20 s transit time between baths. The exposed root surfaces, except for 1 mm below the margins of each SSC, were covered with two coats of nail polish and stored in distilled water. To test for microleakage the teeth were immersed in 0.5% basic fuchsin (Merck, Darmstadt, Germany) for 24 h. Each tooth was rinsed and sectioned with a diamond saw (Mecatome, Presi, France) under continuous water irrigation through the grooves on the crown surface.

Under blind conditions, two observers measured dye penetration in millimeters through the interface between the cement and tooth (controls, group 6) or between the cement and restorative materials along the restoration margins. Measurements were made with a digital microscope (Dino Lite, Taipei, Taiwan) at ×50 magnification. The microscope was calibrated before measurement. Consistency between examiners was ensured by measuring microleakage in 10 sectioned teeth. The proportion of microleakage (PM) was calculated by dividing the total length of dye penetration by the total length of the restoration. Loss of restorative materials below the crown margins was also recorded in each group according to remaining sound restorative materials or any degree loss of the materials [Figure 1]. Statistical analyses were done using Kruskal–Wallis test to compare all groups together and the Mann–Whitney test for pair-wise comparisons ($P < 0.05$).

RESULTS

The mean and standard deviation for PM in all groups showed the greatest PM in group 2 (resin-based composite), followed by group 5 (Zonalin), and the lowest PM in group 1 (amalgam) and group 3 (GI). There were significant differences between the groups in PM ($P < 0.001$). Group 1 was significantly different from the other groups ($P < 0.05$) [Table 1]. Table 2 shows the loss of restorative materials below the crown margin. Zonalin led to the greatest loss of material beyond the SSCs margins, whereas cavities prepared with amalgam, resin-based composite and GI were intact.

DISCUSSION

The marginal gap along the interface between the crown margins and the tooth may lead to microleakage, especially with prefabricated SSCs. When the SSC margins are not supported by a sound tooth, the margins overlaid the materials used to fill the cavity. Therefore, some parts of the core will be exposed to oral fluids, and microleakage may occur.[4,5]

All the groups in the current study showed some degree of microleakage along the SSC margins and restorative materials as well as from the tooth walls (control group). This may be related to:

a. Inadequate fitting between the tooth or restorative materials and the SSC, and
b. The mechanical properties of the luting cement, that is, poor adhesion between the cement and core materials.[2]

Table 1: Mean and SD of the proportion of microleakage in all six groups

Group	Mean rank	Mean ± SD	95% CI
Group 1: Amalgam	34.05^A	0.009±0.02	0-0.021
Group 2: Composite resin	99.85^B	0.522±0.23	0.415-0.631
Group 3: Glass ionomer	47.53^C	0.062±0.10	0.010-0.115
Group 4: Zinc phosphate	50.95^C	0.128±0.19	0.040-0.218
Group 5: Zonalin	76.95^B	0.296±0.21	0.195-0.399
Group 6: Control	50.05^C	0.064±0.21	0.007-0.122

Mean rank values with the same letters were not statistically different (Mann–Whitney U-test). CI: Confidence interval; SD: Standard deviation.

Table 2: Frequency and percentage of sound restorative materials below the stainless steel crown margin in each group (*n* = 20)

Group	Sound (%)	Damaged (%)
Group 1: Amalgam	20 (100)	0 (0)
Group 2: Composite resin	19 (95)	1 (5)
Group 3: Glass ionomer	17 (85)	3 (15)
Group 4: Zinc phosphate	16 (80)	4 (20)
Group 5: Zonalin	2 (10)	18 (90)
Group 6: Control	20 (100)	0 (0)

In the present study, we used GI, one of the most common types of luting cement, to cement the SSC. GI cement is effective in reducing microleakage and provides high strength with low solubility.[16,17] However, its adhesiveness varied with different core materials.[14,17]

Our results also showed that PM differed significantly among the groups we compared. This is consistent with previous reports that the type of core material influences microleakage, bond strength and the success of crowns.[4,15] However, Yesil found no significant differences in the degree of microleakage between amalgam and a composite used as the core.[18] The discrepancies between studies may be due to differences in the type of teeth or crowns, core materials, storage time, pH of the medium, luting cement and methods of evaluation.[18]

For many years, amalgam has been the most widely used core material because of its favorable physical properties (e.g., its elastic modulus is equivalent to dentin), high compressive strength, high durability and lower solubility.[4,12] Larson recommended amalgam as a core material when caries removal leads to extensive loss of tooth structure.[4] In the present study, cavity restoration with amalgam (group 1) led to the lowest PM in comparison to the other groups. Earlier studies also found that amalgam led to less microleakage when used as a core.[4,19] This effect may be related to the characteristics of amalgam as well as the good bond strength between GI luting cement and amalgam.[20,21] Corrosion, prolonged setting time and difficulties in restoring large cavities are potential disadvantages with amalgam; however, less corrosion was found with high copper amalgams.[4,12]

Figure 1: Microleakage and loss of material when the restorative material extended past the margin of the stainless steel crowns (Group 3, glass ionomer).

Resin composites, which have also been used as a core material, have the advantages of resistance to lateral occlusal load (shear forces), rapid setting before crown preparation and low solubility.[4,11] However, resistance to shear forces is not an important factor in children because of their low occlusal bite forces.[22] In the present study, PM was greatest in group 2 (resin-based composite), which is in agreement with previous studies. This may be due to the minimal chemical bonding between GI luting cement and resin-based composite after complete composite setting.[23] Some studies showed applying dentin adhesive or sealant material reduced microleakage at the resin-base composite margin.[24,25] The potential disadvantages of this material are polymerization shrinkage, and the appearance of voids during composite buildup.[11] Therefore, some researchers have advised against the use of composite for core buildup when too much of the tooth structure has been lost.[4]

GI cement is also used as a core material in permanent teeth to block out undercuts and improve the preparation design. In comparison to amalgam, GI is not recommended for core buildup in permanent teeth because of its low fracture resistance, low modulus of elasticity (inadequate strength) and poor condensability.[4,11] In the current study, we found more microleakage with GI (group 3) than with amalgam (group 1); however, the results with GI were acceptable as a restorative core material in primary teeth, and there were no significant differences in PM between the GI and the control group. This result may reflect adequate bonding between the GI core and luting cement. In addition, we used a newer GI product, Equia, a bulk-fill GI, is useful for restoring primary teeth. It has advantages over other kinds of GI such as low shrinkage, increased strength, optimal marginal sealing, high fluoride release and moisture tolerance.[13,26] Other researchers, like us, found that GI provided better sealing than other types of cement such as zinc phosphate, and ZOE-based cement.[27]

Zinc phosphate (group 4) and ZOE (group 5) are used mainly as a base or temporary cement, and may be considered as core materials after pulp therapy thanks to their ease of use and low cost. Zinc phosphate composition contains phosphoric acid liquid which is an irritant and pulp protection should be used. We found mean PM in the zinc phosphate group was greater than with GI (group 3) and lower than with Zonalin (group 5). This result may be related to the physical properties of the cement. The compressive strength of ZOE is lower than zinc phosphate or GI.[5,12]

Cavities restored with ZOE in the present study showed a considerable loss of material beneath the SSC margins due to the high solubility of ZOE compared to other materials, especially after thermal changes. Zinc phosphate is less water-soluble than ZOE.[28] As our result some studies showed that GI is more resistant to solubility than zinc phosphate in artificial saliva.[17] Amalgam and resin-based composite are more resistant to water solubility than other materials,[4,11,12] a finding that our results support. However, the current study showed that resin composite was associated with more microleakage than GI and amalgam.

The main limitation of this study is its *in vitro* design, and the experimental conditions we used cannot be assumed to be entirely equivalent to *in vivo* conditions. Additional clinical studies should be designed to compare the performance of different types of core materials beneath SSCs in primary teeth.

CONCLUSION

The results of this experimental study with primary molars lead that none of the restorative materials investigated was able to seal the SSC margins completely. Also, the proportion of microleakage from the margins when the restorative materials extended past the SSC margin, differed significantly between different the materials. The microleakage from the SSC margins was significantly lower with amalgam than with glass ionomer, resin-based composite, zinc phosphate, and zinc oxide eugenol. According to the results for the microleakage and restorative material remaining beneath the SSC margins; glass ionomer may offer an alternative to amalgam for restoring large cavities before SSC placement in primary teeth.

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Conflicts of interest

The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or non-financial in this article.

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