Retentive Force and Microleakage of Stainless Steel Crowns Cemented with Three Different Luting Agents

Yucel YILMAZ, Anya DALMIS, Taskin GURBUZ and Sera SIMSEK
Department of Pedodontics, Faculty of Dentistry, Atatürk University, Erzurum, Turkey
Corresponding author, E-mail: yyilmaz25@atauni.edu.tr

Received June 11, 2004/Accepted October 27, 2004

The aim of this investigation was to compare the tensile strength, microleakage, and Scanning Electron Microscope (SEM) evaluations of SSCs cemented using different adhesive cements on primary molars.

Sixty-three extracted primary first molars were used. Tooth preparations were done. Crowns were altered and adapted for investigation purpose, and then cemented using glass ionomer cement (Aqua Meron), resin modified cement (RelyX Luting), and resin cement (Panavia F) on the prepared teeth. Samples were divided into two groups of 30 samples each for tensile strength and microleakage tests. The remaining three samples were used for SEM evaluation. Data were analyzed with one-way ANOVA and Tukey test.

The statistical analysis of ANOVA revealed significant differences among the groups for both tensile strength and microleakage tests (p<0.05). Tukey test showed statistically significant difference between Panavia F and RelyX Luting (p<0.05), but none between the others (p>0.05).

This study showed that the higher the retentive force a crown possessed, the lower would be the possibility of microleakage.

Key words: Luting cement, Stainless steel crown, Microleakage, Primary tooth restoration

INTRODUCTION

One of the most common reasons for early loss of primary teeth is excessive tooth decay. Since introduced in the early 1950s by Dr Humphrey), stainless steel crowns (SSC) are unique coronal restorative materials that restore primary molars which are grossly broken down.

Although SSCs have a high clinical success rate, a key reason for its clinical failure is loss of crown due to cementation failure). Therefore, choice of cementation material has an important effect on SSC retention.

Both non-adhesive cements (zinc oxide-eugenol cement, zinc phosphate cement, and polycarboxylate cement) and adhesive cements (glass ionomer cement (GIC), resin modified glass ionomer cement (RMGIC), and resin cement) have been used for cementing SSCs for a long time). However, both laboratory and clinical studies have shown that GICs possess higher retention strength — and hence higher success rate — than non-adhesive luting agents. In a study by Karatoprak and Kirzioglu, that compared cementing agents for SSC, they found that GIC was the most retentive cement for retaining crowns on primary molars. Some investigators examined clinically SSCs cemented using GIC. They reported that none of the crowns was lost or loosened during the evaluation period.

GICs, however, have prolonged maturity period and water sensitivity during the early setting reaction. Therefore, RMGICs and resin cements — instead of GICs — are the more popular materials for routine cementation involving crowns. These cements have some advantages such as improved mechanical properties, reduced early sensitivity to moisture, and low solubility in oral fluids.

Guellmann et al. have studied the tensile strength of SSCs luted with RelyX ARC luting cement, an adhesive resin cement system, on plastic typodont primary incisors. However, their study did not include comparison of different cements, and neither were natural, human primary molars employed in the test. As for RMGIC, to date, no studies have been done to investigate the tensile strength of SSC cemented with this luting agent.

For luting cement materials, their requisite properties are good marginal seal ability and retentive strength. Marginal gap formation may allow coronal microleakage because of cement loss at the marginal area resulting from exposure to oral fluids. Although many studies have been conducted to investigate microleakage of cast crowns cemented on permanent teeth, only two studies have been done concerning microleakage of SSCs cemented on primary molars using different luting agents. Berg et al. studied microleakage of SSCs luted using zinc phosphate cement, polycarboxylate cement, and GIC on primary molars. They found that there were no significant differences between GIC and the other luting agents. Shiflett and White also examined the microleakage of SSCs cemented with adhesive and
non-adhesive cements on primary anterior teeth. Their investigation suggested that adhesive cements significantly reduced microleakage.

The aim of this study was to compare the retentive force and microleakage of SSCs cemented on primary molars with three different cements — GIC, RMGIC, and resin cement. In addition, the sealing ability of these cements was examined using a scanning electron microscope (SEM).

MATERIALS AND METHODS

In this study, a total of 63 freshly extracted, human primary first molars — without caries, restoration and developmental defects, and with root structure higher than 2/3 — were used. Tissue remnants on the root surfaces were cleaned with a scaler. The roots of each tooth were embedded in acrylic resin block up to 1 mm below the cementoenamel junction. Then, occlusal surface and occlusal one-third of the buccal and lingual surfaces of the primary first molars were reduced to approximately 1.5 mm with 169 L diamond bur (Dentsply International Inc., USA). All mesial and distal undercuts were removed. SSCs (D2, Ref. ND-96, 3M Dental Products, St. Paul, MN 55144-1000) were fitted and uniformly contoured and crimped (003-139-00 and 003-114-00, Dentaurum, Germany). Samples were randomly divided into two groups of 30 samples each for tensile strength and microleakage tests. The remaining three samples were used for evaluation under SEM.

Tensile strength test

Before the crowns were cemented on the prepared teeth, SSCs were prepared in the same manner as described by Noffsinger et al.7). SSCs were altered by having a hole through the central fossa with #557 carbide bur (Dentsply International Inc., USA) (Fig. 1). An 1-inch nail was inserted through the hole from the undersurface of the crown for subsequent gripping by the test machine7). Samples were randomly divided into three groups. Within each group, the procedure of adapting SSCs for cementation on the primary molars is described as follows.

Group 1: SSCs were cemented using a GIC (Aqua Meron, Table 1). The cement was mixed according

Table 1  Materials used

<table>
<thead>
<tr>
<th>Material Class</th>
<th>Brand Name (Batch No)</th>
<th>Manufacturer</th>
<th>Material Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glass ionomer cement</td>
<td>Aqua Meron (1172)</td>
<td>Voco, Cuxhaven, Germany</td>
<td>Powder: Fluoroaluminosilicate glass</td>
</tr>
<tr>
<td>Resin modified glass ionomer cement</td>
<td>RelyX Luting (3505)</td>
<td>ESPE, Seefeld, Germany</td>
<td>Liquid: Polymethylacrylic acid, Water</td>
</tr>
<tr>
<td>Resin cement</td>
<td>Panavia F (#1083-EU)</td>
<td>Kuraray, Osaka, Japan</td>
<td>Paste: Silanized fillers, Monomers, Initiators, and Filler</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>RD Primer: HEMA, 5-NMSA, 10-MDP, Water, Catalyst</td>
</tr>
</tbody>
</table>

HEMA: 2-hydroxyethyl methacrylate
5-NMSA: N-methacryloyl-5-aminosalicylic acid
10-MDP: 10-methacryloyloxydecyl dihydrogen phosphate
to manufacturer’s recommendations (powder-liquid ratio of 3.3:3.8:1 g/g) and filled on the inner surface of each crown. The crowns were then placed in their correct position on the prepared teeth with finger pressure and sustained under 5-kgf static load for 10 minutes. Excess cement was removed using a dental explorer.

Group 2: SSCs were cemented using a RMGIC (RelyX Luting, Table 1) mixed according to manufacturer’s recommendations (powder-liquid ratio of 1.6:1 g/g). SSCs were cemented in the same way as described for Group 1. After cementation, excess cement was removed using a dental explorer.

Group 3: SSCs were cemented on the prepared teeth using a resin cement (Panavia F, Table 1) according to manufacturer’s instructions. First, the SSCs were cleaned with an ultrasonic cleaner. Then, one drop each of Liquid A and Liquid B (ED PRIMER, Table 1) were mixed in a mixing dish. Mixed ED PRIMER was applied and left to remain on the entire tooth structure for 60 seconds. Panavia F paste was mixed and filled into SSCs. SSCs were then seated on the prepared teeth and cemented in the same way as described for Group 1. Excess Panavia F paste at the margin was removed using a dental explorer. Following which, OXYGUARD II (Kuraray, Osaka, Japan) was used to cure the mixed paste at the margin. Three minutes later, OXYGUARD II was removed with water spray.

Following crown cementation, all specimens were kept in distilled water at room temperature for 24 hours. They were then tested with a mechanical test machine (Hounsfield, Test Equipment, 37 Fullertan Road, Roydan, England) at a cross-head speed of 0.5 mm/min. Testing proceeded for each specimen until the SSC was separated from the tooth. The values obtained were recorded in Newton (N).

**Microleakage test**
For microleakage test, none of the SSCs fitted on the primary molars were altered (such as in the tensile strength test of the present study). They were randomly arranged into three groups to be cemented using different luting agents: GIC (Group 1), RMGIC (Group 2), and resin cement (Group 3). All luting cements were mixed according to manufacturers’ instructions. SSC cementation was performed in the same manner as mentioned above.

All cemented SSCs were kept in distilled water at room temperature for 24 hours. They were then thermo-cycled 200 times in 4°C water and then in 55°C water for 30 seconds respectively. Next, the samples were soaked in 0.5% basic fuchsin dye solution for 24 hours, after they were removed from the dye and embedded in an auto-polymerizing acrylic resin. Specimens were sectioned in a mesial-distal direction along their long axis with a slow-speed diamond saw (Art. No.915S/220, Risa Dental GmbH D-78234 Engen). Microleakage in both the mesial and distal parts of the crown was evaluated and photographed under a stereomicroscope (Nikon SMZ-V multipoint-sensor system, Japan) at ×60 magnification. Microleakage measurements at both the mesial and distal parts were done two times successively, and the mean value of the two measurements computed. To determine measurement error, photographs of all samples were re-measured by the same investigator after two-week interval. Microleakage measurements were recorded in micrometer (µm).

**SEM evaluation**
Three SSCs were each fitted on a primary molar and cemented using GIC, RMGIC, or resin cement. After setting time had elapsed, the samples were stored in distilled water at room temperature for 24 hours. They were then evaluated by SEM (JSM-6400, JEOL, Tokyo, Japan) at three regions: interface between tooth’s hard tissue and cement material, interface between cement and SSC, and within the cement itself. Specimens were sectioned along the longitudinal axis of the tooth in the mesial-distal direction. All sections were ion sputter-coated with Au-Pd by means of an ion coating equipment (SEM Coating Unit E 500, POLARON Equipment Limited, Barcelona, Spain), then evaluated under SEM and micrographed.

**Statistical analysis**
To assess intra-examiner reliability of microleakage measurement, photographs of all specimens were re-measured after two weeks. Houston analysis was used for reliability of microleakage measurements.

Data obtained from both the tensile strength and microleakage tests were statistically compared using one-way ANOVA. When the F ratio was significant, Tukey’s multiple comparison test was used to compare the means. Statistical analyses were performed by means of SPSS 11.0 for Windows software (SPSS Inc., Chicago, IL, USA).

**RESULTS**

**Tensile strength**
Table 2 shows the mean values and standard deviations obtained from the tensile strength test of the SSCs cemented with GIC, RMGIC, and resin cement.

As shown in Table 2, the mean values for the retentive force of Groups 1 through 3 varied from 215 to 248 N. One-way ANOVA revealed significant differences among the groups in terms of tensile strength (p<0.05). According to Tukey’s multiple comparison test, resin cement had significantly higher mean tensile strength than RMGIC (p<0.05). No statistically significant differences (p>0.05) in tensile strength were noted between GIC and RMGIC and between GIC and resin cement (Table 2).
Table 2. Mean values and standard deviations for retentive force (in Newton)

<table>
<thead>
<tr>
<th>Material</th>
<th>Tensile Strength</th>
<th>±SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aqua Meron (Group 1, GIC)</td>
<td>237.0&lt;sup&gt;b&lt;/sup&gt;</td>
<td>27.9</td>
</tr>
<tr>
<td>RelyX Luting (Group 2, RMGIC)</td>
<td>215.0&lt;sup&gt;b&lt;/sup&gt;</td>
<td>32.8</td>
</tr>
<tr>
<td>Panavia F (Group 3, resin cement)</td>
<td>248.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>25.3</td>
</tr>
</tbody>
</table>

If marked by the same letter, the difference between the groups is statistically insignificant (p>0.05)

Table 3. Mean values and standard deviations for microleakage (in μm)

<table>
<thead>
<tr>
<th>Material</th>
<th>Tensile Strength</th>
<th>±SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aqua Meron (Group 1, GIC)</td>
<td>120.4&lt;sup&gt;b&lt;/sup&gt;</td>
<td>86.4</td>
</tr>
<tr>
<td>RelyX Luting (Group 2, RMGIC)</td>
<td>167.7&lt;sup&gt;b&lt;/sup&gt;</td>
<td>92.0</td>
</tr>
<tr>
<td>Panavia F (Group 3, resin cement)</td>
<td>68.6&lt;sup&gt;a&lt;/sup&gt;</td>
<td>89.9</td>
</tr>
</tbody>
</table>

If marked by the same letter, the difference between the groups is statistically insignificant (p>0.05)

Microleakage

Houston analysis value for intra-examiner reliability of microleakage measurement was above 0.95. The mean microleakage value and standard deviation obtained for each cement group are shown in Table 3. The mean values ranged from 68.6 to 167.7 μm. None of the cement materials tested completely eliminated microleakage (Table 3). One-way ANOVA revealed significant differences among SSC groups cemented with three different cementation agents (p<0.05). Results of Tukey’s multiple comparison test showed that resin cement had significantly lower mean value than RMGIC (p<0.05), and the mean values for resin cement-GIC and GIC- RMGIC were not significantly different from each other (p>0.05) (Table 3).

SEM evaluation

All GIC, RMGIC, and resin cement sections were evaluated with SEM at three regions: interface between tooth's hard tissue and cement material, within the cement itself, and interface between the cement and SSC (Figs. 2-4). GIC and RMGIC specimens exhibited gaps between SSC and cement material (Figs. 4(a) and 4(b)). This was not evident in the case between SSC and resin cement (Fig. 4(c)). For GIC and RMGIC materials, microstructural porosity or voids were observed (Figs. 3(a) and 3(b)), but not so

Fig. 2 SEM images of interface between luting cement material and tooth's hard tissue. (a) Aqua Meron-tooth hard tissue (original magnification at ×1500); (b) RelyX Luting-tooth hard tissue (original magnification at ×500); (c) Panavia F-tooth hard tissue (original magnification at ×1500) (T: Tooth; C: Cement).
Fig. 3 SEM images of inner structure of cement material. (a) Aqua Meron (original magnification at ×1500); (b) RelyX Luting (original magnification at ×1500); (c) Panavia F (original magnification at ×1500) (C: Cement).

Fig. 4 SEM images of interface between cement material and SSC. (a) Aqua Meron-SSC (original magnification at ×1500); (b) RelyX Luting-SSC (original magnification at ×1100); (c) Panavia F-SSC (original magnification at ×1100) (C: Cement; SSC: Stainless steel crown).
with resin cement (Fig. 3(c)). Indeed, the interface between resin cement and tooth's hard tissue presented intimate adaptation, but some gaps were seen between GIC-tooth structure and RMGIC-tooth structure interfaces (Figs. 2(a)-2(c)).

**DISCUSSION**

A luting cement material must possess the dual abilities of adhering to tooth structure and crown as well as providing good marginal seal. These qualities are key to retaining the crown and eliminating coronal microleakage. In this study, three adhesive cements were used: GIC, RMGIC, and resin cement. Adhesive luting cements have shown better laboratory and clinical properties than conventional non-adhesive cements such as zinc phosphate cement, polycarboxylate cement, and reinforced zinc oxide-eugenol cement.

In the present study, SSCs cemented with resin cement provided higher retentive capability than the others. There were significant differences between resin cement and RMGIC (p<0.05), but not so between resin cement and GIC (p>0.05). The mean retentive force of GIC was similar to those found by Karatoprak and Kirzioglu, who used a GIC to cement SSCs on primary molars. Yilmaz and Noffsinger et al. compared the SSCs cemented with GIC on primary anterior teeth and permanent third molar teeth, respectively. They obtained cementation values of 150 N and 100-104 lbs (1 lb = 4.448 N) respectively. The mean retentive force of GIC in the present study was not consistent with their data. The difference could be due to variation in the tooth used, because it has been suggested that a larger occlusal area may improve retention.

As for microleakage, GIC had intermediate mean microleakage value and there were no significant differences between GIC and the other luting agents (p>0.05). This result was consistent with a previous study.

In our study, the mean retentive force of RMGIC was lower than those of resin cement and GIC. It could be because we did not use any bonding agent to cement crown with RMGIC — as recommended by the manufacturer. If we had applied a bonding agent on the tooth, it could mean better tensile strength and microleakage results. Some investigations have demonstrated that when a bonding agent was applied to tooth tissues, both the bond strength and microleakage results of RMGIC were improved. Moreover, if RMGIC specimens were kept in extended storage in distilled water, it could improve the bond strength and microleakage results too. It has been reported that water sorption and hygroscopic expansion of RMGIC are useful in improving bonding ability and marginal seal. We are of the opinion that there is a need for more in vitro studies on this subject.

It has been suggested that resin luting cements have higher mechanical properties than both GICs and RMGICs. For the resin cement in our present study, both Panavia F paste and ED PRIMER contained a phosphoric acid ester monomer such as 10-MDP (10-Methacryloyloxydecyl dihydrogen phosphate) and 5-NMSA (N-methacryloyl-5-aminosalicylic acid). When ED PRIMER is applied on tooth structure, phosphate esters in the primer would de-calcify dentin or enamel, thus improving the micromechanical bonding between tooth’s hard tissue and resin cement. In addition, ionic interactions may contribute to bonding between tooth structure and cement. It has been suggested that MDP is one of the best promoters for adhesion to metal.

Based on the results of this study, the cement materials were ranked in the same order for both microleakage and tensile strength. Although resin cement appeared to leak less than the other two groups, statistical analysis only found significant difference between resin cement and RMGIC (p<0.05). When specimens were observed by SEM, the tooth structure-resin cement-SSC interfaces presented intimate adaptation (Figs. 2(c) and 4(c) respectively), which helped to explain the low microleakage result of resin cement. Affirmatively too, the adhesion mechanism between tooth structure and cemented crown (as mentioned above) also contributed to the microleakage value. In addition, 10-MDP is water-resistant and more stable against hydrolysis and thermal stress.

However, resin cement microleakage values in the present study were not consistent with the results reported by Shiflett and White. They showed that Panavia 21 resin cement (chemically similar to Panavia F) had a lower mean microleakage value than GIC, but a higher value than RMGIC. These differences could be due to variations in the teeth used and sampling size, because their study was conducted using only five primary anterior teeth in each test group.

Shiflett and White also claimed that non-parametric scoring technique was more subjective. Therefore, in the present study, microleakage was quantified with direct parametric measurements.

When the inner structure micrographs of all the three cement materials were examined (Figs. 3(a)-3(c)), microstructural porosity or voids were found for GIC and RMGIC (Figs. 3(a) and 3(b)). When SSCs are cemented onto teeth in the mouth, similar
voids may occur within the cement material itself. SSCs are prefabricated crowns, and may be crushed under the chewing forces in the mouth. The forces that crush SSCs may lead to crack propagation due to the collapse of voids within the cement material. As a result, cementation fails after some time due to crack propagation. Xie et al.38) showed that microstructural porosity or voids were typically linked by crack propagation paths. This phenomenon could be the cause for loss of SSC cemented onto tooth.

CONCLUSIONS

The conclusions drawn from this study were:

1. Resin cement significantly improved crown retention when compared against RMGIC. However, the difference was not significant when compared against GIC.
2. Resin cement had lower microleakage than RMGIC, but was not significantly lower than GIC. Also, GIC did not exhibit significantly lower microleakage than RMGIC.
3. The higher the retentive force a crown possessed, the lower the possibility of microleakage.
4. In SEM micrographs, there was intimate adaption between resin cement and tooth structure and between resin cement and SCC.

REFERENCES

9) Karatoprak O, Kirzioglu Z. Comaprison of the microleakage and cementing characteristics of three different cements used to cement stainless steel crowns (English Abstract). Ataturk Univ Dış Hek Fak Derg 1997; 7: 21-27.
28) Cheylan JM, Gonthier S, Degrange M. In vitro push-


36) Roulet JF, Degrange M. Adhesion the silent revolution in dentistry: the key for the indirect technique, Quintessence Publishing Co, Chicago, 2000, pp.92-93.
