A Comparative Study of the Retentive Strengths of Commercial and Indigenously Developed Luting Cements using Both Lathe-cut and Clinically Simulated Specimens

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ABSTRACT

Introduction: Superior adhesive strength in luting agents is of paramount significance in fixed partial denture success. In this in vitro study five cements were tested for retentive qualities, using both lathe-cut and hand-prepared specimens.

Materials and methods: A total of 104 freshly extracted tooth specimens were prepared. Seventy of them were lathe-cut and 30 specimens were hand-prepared to simulate clinical conditions. Five different cements were tested, which included a compomer, a composite, a zinc phosphate, and 2 glass-ionomer luting cements. Of the 5, 2 trial cements were indigenously developed by Sree Chitra Tirunal Institute for Medical Sciences and Technology (SCTIMST), Trivandrum, India – a glass-ionomer cement (Chitra GIC) and a chemical-cure composite (Chitra CCC). All cements were compared within each group and between groups (lathe-prepared and hand-prepared).

Results: GC Fuji 1 (GC America) exhibited superior retentive strengths in both lathe-cut and hand-prepared specimens, whereas the compomer cement displayed the lowest values when tested. In lathe-cut specimens, statistical analysis showed no significant difference between GC Fuji 1 and indigenously developed Chitra CCC.

Conclusion: Both Chitra CCC and GC Fuji 1 have comparable strengths in lathe-cut samples, making Chitra CCC a potential luting agent. Statistical analysis reveals that all cements, except GC Fuji 1, exhibited a significant decrease in strength due to the change in design uniformity. The chemical bonding of GC Fuji 1 proves to be quite strong irrespective of shape and precision of the tooth crown.

Clinical significance: The indigenously developed Chitra GIC and Chitra CCC showed promising results to be used as a potential luting agent.

Keywords: Compomer, Glass-ionomer cement, Luting cement, Retention.

INTRODUCTION

It is well documented that the use of adhesive cements has a great bearing on the long-term clinical outcome of fixed prosthodontic treatments. Given the anatomy and the composition of dentin, it is imperative that any luting cement used must provide an impervious seal between the restoration and the tooth and exhibit impeccable retentive qualities. With the principles of tooth preparation being established as of primary importance in the retention of cemented castings, the retentive qualities of the cementing media, though secondary, have gained crucial importance. New cements are often introduced with claims of superior characteristics, among which claim of superior adhesive strength is of paramount significance in fixed partial denture success.
In this study a newer adhesive system (compomer) was tested against 2 popular luting cements that are chemically different from it. Two indigenously developed trial cements by Sree Chitra Tirunal Institute for Medical Science and Technology (SCTIMST), Thiruvananthapuram, India, were also part of the test. All of them were tested to determine their retentive qualities under standardized conditions. Most in vitro studies report on lathe-cut preparations where uniformity of shape and precision are high, so these luting cements were then re-tested using clinically simulated, hand-cut specimens under the same parameters to determine if they showed variance and to ascertain their clinical implications.

**MATERIALS AND METHODS**

Five luting cements were tested in all (Figs 1A to E). Two indigenously developed cements by SCTIMST, Thiruvananthapuram, India, henceforth referred to as Chitra glass-ionomer cement (acronym – Chitra GIC) and Chitra chemical-cure composite (acronym – Chitra CCC) were also tested to compare their retentive qualities. Other cements tested were, two popular, imported cements, GC Fuji 1™ Glass Ionomer Cement (GC America) and De Trey Zinc™ (Dentsply/Caulk); and a compomer cement, Principle™ (Dentsply/Caulk).

**Sample Collection and Storage**

Specimens were prepared using 104 freshly extracted non-caries human premolar teeth. These were cleansed of debris by placing in 1% hydrogen peroxide solution for 24 hours. Grooves were prepared horizontally in the radicular portions of the teeth (to improve retention in the resin).

**Specimen Preparation by Lathe (70 Specimens)**

Cylindrical, one-side open molds were made using polyvinyl siloxane, Reprosil™ (Dentsply/Caulk) putty material. These molds were filled with autopolymerizing resin, DPI-RR Cold Cure™ (Dental Products of India). While the resin was still soft the teeth were embedded vertically so that the resin was 1 to 2 mm short of their cementoenamel junction (Figs 2A and B) and allowed to polymerize. The acrylic bases thus formed had a diameter and height of 25 mm. These bases were developed to provide a stable base for crown preparation and testing.

By gripping the teeth crowns in the collets of a conventional lathe (model LZ300G, Gedee Weiler Pvt. Ltd., India), the teeth were centered at the base, by removing excess acrylic resin from the base (Fig. 2C). The long axis of each tooth was considered as the long axis of the specimen, and all excess acrylic was removed in a concentric fashion till the diameter of the base was reduced to 20 mm.
A Comparative Study of the Retentive Strengths of Commercial and Indigenously Developed Luting Cements

The acrylic bases of the specimens (whose diameters were now 20 mm) were fixed into the work head collets of the HMT Universal Cutter Grinder machine (model GTC-28). The working head of this machine was a 180 mm diameter, 13 mm thick diamond wheel head rotating at a speed of 2800 rpm, which is tiltable across 360° on both the horizontal and vertical axes. A taper of 2° was set in the horizontal plane to achieve an overall 4° taper in the preparation (Fig. 2D). Using the vertical plane, rotation was done in 360° by hand after tooth to wheel contact. Required feed was given depending on the size of the individual tooth so that a definite margin could be achieved on the tooth. The occlusal aspect was ground flat for ease of study (Fig. 3A).

**Specimen Preparation by Hand (Clinical Simulation – 30 Specimens)**

Square, one-side open molds were made using polyvinyl siloxane, Reprosil™ (Dentsply/Caulk) putty material. These molds were filled with autopolymerizing resin DPI-RR Cold Cure™ (Dental Products of India). Teeth were embedded vertically into the soft resin so that their cemen
toenamel junction was 1 to 2 mm above the resin and allowed to polymerize. Hand-prepared specimens were prepared using conventional diamond chamfer burs (Mani bur No. TR19). Diamond finishing (Mani bur No. TR13 F) and polishing burs (Mani bur No. TR26 EF) were used. These were prepared to simulate clinically prepared crowns. No attempt was made to standardize the preparation or control the convergence angle. All specimens possibly had a taper between 14 and 19°, with a definite chamfer margin and with the occlusal surface prepared flat to aid in the study.

**Base Reduction to Facilitate Testing (Both Lathe-Cut and Hand-Prepared Specimens)**

After completing both the lathe-cut and the hand-prepared crown preparations, the acrylic bases were then reduced to less than 6 mm. This was reduced using conventional stone disks (Lathe wheel white) [3”x1½” (Unident)] by hand to obtain two flat surfaces which would provide stability during the crown preparation by hand. This also helped the specimens to be held by the Universal Testing Machine (Instron model 1011) during testing.
Preparation of Ni-Cr Crowns (Both Lathe- and Hand-Prepared Specimens)

All the specimens were numbered and sorted. Impressions of the teeth were made individually, and poured using Type IV dental stone, Kalrock (Kalabhai Dental) to obtain the dies. Each wax pattern was correspondingly numbered with a pointed instrument. Crowns with loops on the flat occlusal aspect were cast in nickel–chromium alloy, Vera Soft™ (Aalba Dent) using the lost-wax technique. The crowns were retrieved, matched, fit adjustments performed, and sandblasted with aluminum oxide (110 μm).7 The crowns were then finished and polished (Fig. 3B). The cast crowns were not less than 1 mm in thickness on any location.

Cementing and Testing of Specimens

The lathe-prepared specimens were sorted into five groups of 14 each. The luting agents were manipulated according to the manufacturer’s instructions within the working time parameters and loaded onto the crowns using appropriate instruments. Finger pressure was applied by the same operator to seat the crowns and the excess removed. After 10 minutes the specimens were stored in distilled water at 37°C for 24 hours (to mimic the effect of water contamination8), at the end of which they were tested for retentive strengths.

The hand-prepared specimens (Fig. 3C) were sorted into five groups of 6 each. As before, the manufacturer’s instructions were followed for manipulation, the cements were loaded using appropriate instruments, and crowns cemented by finger pressure by the same operator till complete seating was achieved (Fig. 3D). All samples were stored after 10 minutes, in distilled water at 37°C for 24 hours and tested using the same parameters of temperature and humidity as above. Load-at-break was tested for using the same technique and instruments.

All luting agents were manipulated, cemented, and tested at 23 ± 2°C. The thinned out part of the specimen bases was gripped by the lower jaw of the testing machine. A stainless steel wire was passed through the crown loop and held by the upper jaw. Using the Universal Testing Machine; at a cross head speed of
Curing characteristics of all five luting agents were determined using a computer interfaced (286DX, Turbo 2000, DCM, India) cycloviscograph (Model Cyclo-Visco E, Germany) to determine the working and setting times and the curing patterns. The rheograms thus obtained indicate that setting was complete well within 5 minutes (Rheogram of GC Fuji 1™) (Fig. 4B). (Mathematical formulations for the calculation were derived using standard geometrical procedures, which are described in the Sketch diagrams, Figs 4C and D.)

Using a computer (AT Turbo 2000, DCM India), interfaced with the Universal Testing Machine, load-at-break was noted and recorded as a graph (Fig. 4E). Eight samples were tested in each case – a minimum of 6 best samples were taken, and the mean and standard deviation were calculated.

RESULTS
The study yielded significant results, and probability values calculated for the retentive strengths of both lathe-prepared and hand-prepared were considered significant only if they were < 0.05.

On the lathe-prepared specimens, all cements showed significant probability values except zinc phosphate (De Trey Zinc™ Dentsply/Caulk) with Chitra CCC (SCTIMST); GC Fuji 1 (GC America) with Chitra CCC (SCTIMST); and compomer (Principle™ – Dentsply/Caulk) with Chitra GIC (SCTIMST).

In the case of hand-prepared specimen, less probability values were significant (Graphs 1 and 2).

In both groups GC Fuji 1 (GC America) and Chitra CCC (SCTIMST) showed maximum strengths (MPa), although there was a significant overall fall in the retentive strengths measured on the hand-prepared specimens (Graph 3).

DISCUSSION
Statistical analysis done using analysis of variance (ANOVA) (p <0.05) revealed that there was no significant difference between GC Fuji 1 (=5.32 MPa) and Chitra CCC (=4.34 MPa). But GC Fuji 1 (=5.32 MPa) exhibited significant retentive strength compared to De Trey Zinc™ (=3.92 MPa), Chitra GIC (=2.49 MPa), and Principle™ (=2.06 MPa).

Chitra CCC (=4.34 MPa) exhibited significant improvements over Chitra GIC (=2.49 MPa) and was found comparable to De Trey Zinc™ (=3.92 MPa).
Tables 1 and 2 show the tabulated results. However, in the hand-prepared specimens, the retentive strengths showed a significant change. Statistical analysis revealed GC Fuji 1 to be highly superior in strength to all other cements used (≈4.20 MPa). Here Chitra CCC (≈2.09 MPa) was found comparable to Chitra GIC (≈1.63 MPa) and De Trey Zinc™ (≈1.28 MPa). All were superior to Principle™ (≈0.77 MPa).

A statistical analysis between hand-prepared and lathe-prepared groups for each cement used revealed that, except for GC Fuji 1, there is a significant difference in strength occurring due to the method of preparation. This clearly indicates that the chemical bonding of the Fuji 1 GIC is extremely strong and relatively independent of the shape and precision of the tooth crown. This ratifies the observation of Oilo9 that GIC is a viable alternative to zinc phosphate where normal retention was impossible.

Whether the bonding of the cementing media is weaker between the metal–cement interface, the

<table>
<thead>
<tr>
<th>Cement system</th>
<th>Mean retentive strengths (MPa)</th>
<th>Standard deviation</th>
<th>ZnPO₄ (De Trey Zinc)</th>
<th>Fuji 1 GIC</th>
<th>Compomer (principle)</th>
<th>Chitra CCC</th>
<th>Chitra GIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>De trey zinc™</td>
<td>3.92</td>
<td>0.794</td>
<td>N/A</td>
<td>0.0099</td>
<td>0.0006</td>
<td>0.5084</td>
<td>0.005</td>
</tr>
<tr>
<td>GC Fuji 1™</td>
<td>5.32</td>
<td>0.728</td>
<td>0.0099</td>
<td>N/A</td>
<td>3.59 × 10⁻⁶</td>
<td>0.1277</td>
<td>2.2 × 10⁻⁵</td>
</tr>
<tr>
<td>Principle™</td>
<td>2.06</td>
<td>0.478</td>
<td>0.0006</td>
<td>3.59 × 10⁻⁶</td>
<td>N/A</td>
<td>0.0019</td>
<td>0.20</td>
</tr>
<tr>
<td>Chitra CCC</td>
<td>4.34</td>
<td>1.251</td>
<td>0.5084</td>
<td>0.1277</td>
<td>0.0019</td>
<td>N/A</td>
<td>0.0082</td>
</tr>
<tr>
<td>Chitra GIC</td>
<td>2.49</td>
<td>0.581</td>
<td>0.005</td>
<td>2.2 × 10⁻⁵</td>
<td>0.20</td>
<td>0.0082</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Surprisingly, the compomer cement, Principle™ failed to impress, exhibiting the lowest mean strength (≈2.06 MPa), although it is comparable to Chitra GIC (≈2.49 MPa).

Graph 1: Comparison of adhesive strengths of Ni-Cr crowns on lathe-prepared tooth surfaces

Graph 2: Comparison of adhesive strengths of Ni-Cr crowns on hand-prepared tooth surfaces

Graph 3: Comparison of adhesive strengths of Ni-Cr crowns on both lathe and hand-prepared tooth surfaces

Table 2: Mean strengths, standard deviation, and probability values for crown luting cements on hand-prepared specimen

<table>
<thead>
<tr>
<th>Cement system</th>
<th>Mean retentive strengths (MPa)</th>
<th>Standard deviation</th>
<th>ZnPO₄ (De Trey Zinc)</th>
<th>Fuji 1 GIC</th>
<th>Compomer (principle)</th>
<th>Chitra CCC</th>
<th>Chitra GIC</th>
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<tbody>
<tr>
<td>De trey zinc™</td>
<td>1.28</td>
<td>0.685</td>
<td>N/A</td>
<td>0.00017</td>
<td>0.2294</td>
<td>0.0868</td>
<td>0.294</td>
</tr>
<tr>
<td>GC Fuji 1™</td>
<td>4.20</td>
<td>1.017</td>
<td>0.00017</td>
<td>N/A</td>
<td>4.9 × 10⁻⁵</td>
<td>0.0024</td>
<td>0.00015</td>
</tr>
<tr>
<td>Principle™</td>
<td>0.77</td>
<td>0.712</td>
<td>0.2294</td>
<td>4.9 × 10⁻⁵</td>
<td>N/A</td>
<td>0.012</td>
<td>0.0226</td>
</tr>
<tr>
<td>Chitra CCC</td>
<td>2.09</td>
<td>0.785</td>
<td>0.0868</td>
<td>0.0024</td>
<td>0.012</td>
<td>N/A</td>
<td>0.20</td>
</tr>
<tr>
<td>Chitra GIC</td>
<td>1.63</td>
<td>0.319</td>
<td>0.294</td>
<td>0.00015</td>
<td>0.0226</td>
<td>0.20</td>
<td>N/A</td>
</tr>
</tbody>
</table>
cement–tooth interface, or if the bond rupture is prone to take place within the cementing media itself is still not conclusive and may be an avenue for further research.

CONCLUSION

Nickel–chromium crowns cemented with GC Fuji 1 and Chitra CCC showed the maximum strength values compared to the rest of the cements in both lathe-prepared and hand-prepared specimens.

The trend in retentive strength values for lathe-prepared samples can be expressed in short as: GC Fuji 1 ≥ Chitra CCC ≥ De Trey Zinc™ ≥ Chitra GIC ≥ Principle™.

The significantly lower values in hand-prepared specimens point to a correlation between uniform precise preparations and higher retentive values.

The trend in retentive strength values for hand-prepared samples can be expressed in short as: GC Fuji 1 > Chitra CCC ≥ Chitra GIC ≥ De Trey Zinc™ > Principle™.

Statistical analysis reveals the following:
- GC Fuji 1 (GIC) has significantly higher retentive values than De Trey Zinc™ (zinc phosphate cement).
- Chitra CCC has significantly higher retentive values than Chitra GIC in lathe-prepared specimens.
- Chitra CCC has comparable retentive values to that of GC Fuji 1 (glass ionomer) in lathe-prepared specimens.

The test results and analysis point to Chitra CCC (SCTIMST) as being a potential luting agent.

The compomer cement (Principle™ Dentsply/Caulk) tested showed the least retentive strength among the five cements used in this study.

REFERENCES