Comparative Analysis of Tensile Bond Strength of the Adhesive Luting Agents for a Non-percious Alloy (Ceramo-Metal) to Dentin: An In Vitro Study

Girish Kulkarni

Introduction
Retention of cemented restorations depends on the preparation design and frictional adherence provided by the luting agent and chemical bonding. During last few years, some luting with good bonding characteristics has been developed. For over a century, zinc phosphate cements have been widely used as a luting agent for restorations due to easy handling restorations, irritant quality due to acidic pH has supported the search for suitable alternatives.¹

A continuous search for alternative luting materials has resulted in the development of cements such as reinforced zinc oxide eugenol cements, fluoride containing silicon phosphate, polycarboxylate, glass ionomer, resin-reinforced glass ionomer cement, and resin cements.

These adhesive luting agents allow a more conservative approach to tooth preparation with the reduced removal of sound tooth structure. The increased retention conferred by an adhesive luting agent would be particularly advantageous in the restoration of teeth with short clinical crowns, excessively tapered preparations and other unfavorable geometric configurations.²

These adhesive resin cements have opacity, optimal film thickness, good compressive strength and tensile bond strength to teeth, metal as well as to ceramics. They are insoluble in oral fluids, bond to enamel, dentin porcelain, and surface treated alloys. These properties make adhesive luting cements an attractive alternative to conventional luting agents such as zinc phosphate cement.³ The purpose of this in vitro study is to compare and evaluate the tensile bond strength of different luting agents for a base metal alloy (ceramo-metal) bonded to dentin.

Methods
After cementing metal samples to dentin surfaces with respective luting cements, excess cement was removed from margins after initial setting. Samples were stored in distilled water at 37°C for 24 h. Metal cups were mounted in an Instron universal testing machine. Tensile load was applied at a cross head speed rate of 1 mm/min. The load at which the bond failure occurred was recorded and tabulated.

Results: The results showed that tensile bond strength of All Bond C&B composite luting cement is highest (25.941 MPa) followed by tensile bond strength of resin-modified glass ionomer luting cement (12.25 MPa) and conventional glass ionomer luting cement (4.7 MPa).

Conclusion: The composite resin luting cement (All Bond C&B), because of its higher bond strength to dentin than any other luting cements, can be used in critical clinical situations such as short tooth preparations, tapered preparations, and any other clinical circumstances where retention is compromised.

Key Words: Adhesive luting cements, bonding agent, ceramo-metal, tensile bond strength

Contributor:
Private practitioner & Consulting Endodontist, Banglore, Karnataka, India.

Correspondence:
Dr. Kulkarni G. Private practitioner & Consulting Endodontist, Banglore, Karnataka, India. Email: jaguaramazon@mail.com

How to cite the article:

Abstract:
Background: Dentistry has long sought a cementing medium that would adhere to tooth structure. Such material would eliminate microleakage around restorations and provide better retention for indirect restorations. Bonding of luting cement to enamel, dentin, and restorations is important and is one of the factors that determine the success of indirect restorations. Adhesive luting cements such as glass ionomer, resin-modified glass ionomer, and composite resin luting cements have been shown to reduce microleakage and increase retention. The purpose of this in vitro study is to compare and evaluate the tensile bond strength of different luting agents for a base metal alloy (ceramo-metal) bonded to dentin.

Methods: After cementing metal samples to dentin surfaces with respective luting cements, excess cement was removed from margins after initial setting. Samples were stored in distilled water at 37°C for 24 h. Metal cups were mounted in an Instron universal testing machine. Tensile load was applied at a cross head speed rate of 1 mm/min. The load at which the bond failure occurred was recorded and tabulated.

Results: The results showed that tensile bond strength of All Bond C&B composite luting cement is highest (25.941 MPa) followed by tensile bond strength of resin-modified glass ionomer luting cement (12.25 MPa) and conventional glass ionomer luting cement (4.7 MPa).

Conclusion: The composite resin luting cement (All Bond C&B), because of its higher bond strength to dentin than any other luting cements, can be used in critical clinical situations such as short tooth preparations, tapered preparations, and any other clinical circumstances where retention is compromised.

Key Words: Adhesive luting cements, bonding agent, ceramo-metal, tensile bond strength
Teeth samples were then inserted into metallic cups and fixed with self-curing acrylic resin (Figures 1 and 2).

After cementing metal samples to dentin surfaces with respective luting cements, excess cement was removed from margins after initial setting. Samples were stored in distilled water at 37°C for 24 h.

Metal cups were mounted in an Instron universal testing machine (Figures 3 and 4). Tensile load was applied at a cross head speed rate of 1 mm/min. The load at which the bond failure occurred was recorded and tabulated. The same procedure was repeated for the test sample. The tensile bond strength was calculated using the following formula:

\[ \text{Tensile bond strength} = \frac{\text{Load in kilograms}}{\text{Area in sq mm}} \]

These values were converted to MPa.

The type of bond failure was observed for all samples using a scanning electron microscope (SEM) (Figures 5-8).

Figure 1: Teeth samples in metal cups.

Figure 2: Metal samples on teeth cemented on dentin surface.

Figure 3: Instron testing machine.

Figure 4: Test specimen tensile loading.

Figure 5: Scanning electron microscope picture: Brittle fracture of zinc phosphate cement.

Figure 6: Scanning electron microscope picture: Conditioned dentinal surface with 10% polyacrylic acid partially opened dentinal tubules.
The raw data collected from each specimen were recorded, tabulated, and subjected to statistical analysis utilizing analysis of variance (ANOVA) test.

### Materials

<table>
<thead>
<tr>
<th>Cement</th>
<th>Manufacturer</th>
<th>Lot number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harvard cement</td>
<td>Harved, Berlin-West</td>
<td>2111095019</td>
</tr>
<tr>
<td>Fuji-Type I</td>
<td>G.C. Corporation, Tokyo, Japan</td>
<td>170661</td>
</tr>
<tr>
<td>Fuji-DUET</td>
<td>G.C. Corporation, Tokyo, Japan</td>
<td>131251</td>
</tr>
<tr>
<td>One step universal adhesive system</td>
<td>Bisco Inc., Itsca, USA</td>
<td>129195</td>
</tr>
<tr>
<td>All Bond C&amp;B</td>
<td>Bisco Inc., Itsca, USA</td>
<td>069205</td>
</tr>
<tr>
<td>Remanium - C S Alloy</td>
<td>Dentaurum</td>
<td></td>
</tr>
</tbody>
</table>

### Results

An assessment of in vitro tensile bond strength of adhesive luting agents to dentin using ceramo-metal was conducted. The total number of 60 samples were included in this study.

These were divided into four groups, each consisting of 15 specimens. Composite resin luting cement (All Bond C&B) showed the highest tensile bond strength value 25.941 MPa, followed by resin-modified glass ionomer (Fuji DUET) 12.251 MPa, glass ionomer (Fuji Type 1) 4.709 MPa, and zinc phosphate cement 1.1068 MPa in descending order (Graph 1).

The results obtained showed that mean tensile bond strength of Group D was maximum than rest of the groups. All four groups compared with the ANOVA test. Table 1 indicates that statistically significant difference exists at \( P < 0.05 \) between all four groups.

### Discussion

Good tensile bond strength of luting agents is one of the determinant factors controlling the clinical success of dental restorations that are to be cemented. The tensile bond strength that attributed strength coefficient will give a total estimation of the bonding capacity of the luting agents. The tensile bond strength is preferred because of the ease of obtaining the pure tensile strength of luting agents bonded to various materials.\(^5\)

One of the most expected aspects of restorative dentistry is the firm attachment of indirect restorations to prepared teeth with no or minimum microleakage and with maximum bond strength. Hence, the tensile bond strength should be considered as the most significant mechanical property of luting agents.\(^5\)

When comparing the performance of materials, it is important to standardize as much as possible all variables involved. The use of 5 mm × 5 mm casted ceramo-metal samples proved to be an effective method for obtaining perfectly identical preparations. This made it possible to calculate a total bonding surface and to express bond strength in MPa.

In this study, tensile bond strength for adhesive luting agents namely glass ionomer, resin-modified glass ionomer, composite resin cement to dentin using ceramo-metal was evaluated in vitro using zinc phosphate cement as a control. The results showed the highly significant difference in the

![Figure 7: Scanning electron microscope picture: Resin tags after application of dentin bonding agent to etched enamel surface.](image)

![Figure 8: Scanning electron microscope picture: Hybrid layer formed at resin-dentin interface.](image)

**Table 1: ANOVA - test.**

<table>
<thead>
<tr>
<th>Variation</th>
<th>Sum of squares</th>
<th>Df</th>
<th>Mean square</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between groups</td>
<td>5772.206</td>
<td>3</td>
<td>1924.0686</td>
</tr>
<tr>
<td>Within groups</td>
<td>1152.345</td>
<td>56</td>
<td>20.577</td>
</tr>
</tbody>
</table>

Variance ratio \((F) = 93.505\)

Inference: \(P < 0.05\) highly significant. ANOVA: Analysis of variance

**Graph 1:** Bond strength in MPa.
Table 2: Tensile Bond strength in MPa.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Group A</th>
<th>Group B</th>
<th>Group C</th>
<th>Group D</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.258</td>
<td>4.415</td>
<td>12.275</td>
<td>23.667</td>
</tr>
<tr>
<td>2</td>
<td>1.015</td>
<td>4.919</td>
<td>12.226</td>
<td>25.706</td>
</tr>
<tr>
<td>3</td>
<td>1.097</td>
<td>4.574</td>
<td>12.024</td>
<td>26.392</td>
</tr>
<tr>
<td>4</td>
<td>1.039</td>
<td>4.754</td>
<td>12.715</td>
<td>25.460</td>
</tr>
<tr>
<td>5</td>
<td>1.051</td>
<td>4.755</td>
<td>11.883</td>
<td>26.695</td>
</tr>
<tr>
<td>6</td>
<td>1.098</td>
<td>4.892</td>
<td>12.027</td>
<td>25.803</td>
</tr>
<tr>
<td>7</td>
<td>1.013</td>
<td>4.653</td>
<td>12.376</td>
<td>25.323</td>
</tr>
<tr>
<td>8</td>
<td>1.147</td>
<td>4.559</td>
<td>12.323</td>
<td>26.068</td>
</tr>
<tr>
<td>9</td>
<td>0.980</td>
<td>4.755</td>
<td>12.271</td>
<td>26.401</td>
</tr>
<tr>
<td>10</td>
<td>1.256</td>
<td>4.697</td>
<td>12.437</td>
<td>26.497</td>
</tr>
<tr>
<td>11</td>
<td>1.244</td>
<td>4.793</td>
<td>12.251</td>
<td>25.805</td>
</tr>
<tr>
<td>12</td>
<td>1.165</td>
<td>4.674</td>
<td>12.355</td>
<td>26.988</td>
</tr>
<tr>
<td>13</td>
<td>1.090</td>
<td>4.801</td>
<td>12.421</td>
<td>26.598</td>
</tr>
<tr>
<td>14</td>
<td>1.006</td>
<td>4.532</td>
<td>12.277</td>
<td>26.666</td>
</tr>
<tr>
<td>15</td>
<td>1.144</td>
<td>4.870</td>
<td>12.130</td>
<td>26.408</td>
</tr>
<tr>
<td>Mean</td>
<td>1.1068</td>
<td>4.709</td>
<td>12.251</td>
<td>25.941</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>0.0931</td>
<td>0.1434</td>
<td>0.2007</td>
<td>0.7633</td>
</tr>
</tbody>
</table>

tensile bond of these luting agents claiming their superiority over other.

This study showed that glass ionomer cement has the higher bond strength to dentin than control group zinc phosphate cement (Table 2). Similar findings have been registered by Michelini et al. They stated that glass ionomer cement adheres to dentin with a bond strength of 4 MPa.

Galun et al. reported that diametral tensile bond strength of the glass ionomer is three times more than zinc phosphate, even in immersion in water for 7 days. This study also confirms the same results. Kern et al. explained that, with the cementation method used, the glass ionomer cement was an acceptable alternative to conventional zinc phosphate cement.

Oilo discussed the strength, retention and film thickness, solubility of glass ionomer cement, and zinc phosphate cement. Glass ionomer luting cement has high strength and retentive properties and low solubility compared to zinc phosphate.

Coury et al. confirmed that glass ionomer cements adhere to tooth structure, and more force was needed to dislodge the cements from teeth than zinc phosphate cement.

In the present study, the new generation glass ionomer cement, i.e., resin-modified glass ionomer cement showed higher bond strength 12.25 MPa to dentin, compared to glass ionomer cement and zinc phosphate cement. This improved strength is probably due to the development of new molecules, an unsaturated hydrophilic polymer which cures by chemical means or by photo energy. This higher bond strength is because of removal of smear layer and conditioning of dentin with 10% polyacrylic acid and hydroxyethyl methacrylate (HEMA) component of cement which is a hydrophilic polymer and adheres to conditioned dentin.

This finding is similar to the study of Shane-N - White et al, and Rusz et al, who demonstrated greater compressive and diametral tensile strength of resin-modified glass ionomer cement hybrids than conventional cements.

Fritz et al. has shown that bond strength of four resin-modified glass ionomer cements (13 MPa) is higher than conventional glass ionomer cement (4 MPa).

Mount stated that some of the improved bond strengths could certainly be attributed to the improved cohesive strength of resin-modified glass ionomer cement.

Group D: This group comprising of composite resin cement (All Bond C&B) has potential to bond to enamel and dentin porcelain and alloys. This property makes it a good alternative to cements such as zinc phosphate cement. In this study, All Bond C&B composite resin cement was used for comparison. This cement showed 25.941 MPa mean bond strength which was very high compared to zinc phosphate cement, glass ionomer cement, and resin-modified glass ionomer cement (Table 2). This high bond strength is probably due to acid etching of dentin which eliminates smear layer and smear plugs, opens dentinal tubules, and intertubular dentin is roughened. These changes in dentin help in establishing a strong bond between resin and dentin after application of resin adhesive, i.e., a bonding agent. Microtags of resin that are formed play a definite role in forming hybrid layer.

Michelini et al. compared the tensile bond strength of gold and porcelain inlays to extracted molars using zinc phosphate cement, glass ionomer cement, and resin composite cement. Inlays cemented with resin composite cement are four times more retentive than glass ionomer cement.

Zinc phosphate cement is self-etching cement which partially removes the smear layer and cement can penetrate in dentin to some extent. The main mode of retention is micromechanical.

Glass ionomer cement adheres to enamel and dentin because of polyacrylic acid in the liquid. The compressive and tensile bond strength values after 24 h become more than zinc phosphate cement. Maintaining a dry field is essential to achieve good bond strength.

This study proved the adhesive quality of glass ionomer luting agent by showing higher bond strength to dentin than zinc phosphate cement. The mechanism of adhesion of the glass ionomer cement to the enamel and dentin has been attributed to the ionic forces operating across the interface. An ion exchange layer is responsible for an intensive adhesive bond of glass ionomer cement with tooth substrate and is a chemical one.

Johnson et al. concluded that glass ionomer binds to apatite and fluorapatite chemically and the bond strength was
influenced by the cohesive strength of the ionomers and surface roughness of apatite. Glass ionomer cement bonds to precious and non-precious alloys while zinc phosphate does not.

SEM studies show that resin-modified glass ionomer has the ability to penetrate through smear layer and into the dentinal tubules. There is more mechanical interlocking with the substrate and resin-modified glass ionomer cement resulting in higher tensile bond strength than conventional glass ionomer cement.

Resin-modified glass ionomer cements come close to having the characteristics of ideal cement. This cement bonds to tooth structure, releases fluoride, nearly insoluble, has good strength. Longer working time as HEMA slows the acid-base reaction in cement. Resin-modified glass ionomer cement has retentive characteristics, better than glass ionomer and zinc phosphate cement.

All Bond C&B cement is resin cement and capable of forming bonds not only with tooth structure but also with porcelain, metal. Etching produces micro-retentive surface characteristics. Etching produces opened dentinal tubules and porous intertubular dentin to which a chemically adhesive resin can bond. Adhesion of resin to these etched bonding sites prevents separations of the resin from dentin. It has been shown that dentin can be treated with 10% phosphoric acid gel or as high as 37% for 10-15 s. In the present study, Group D teeth sample’s occlusal surface was treated with 32% phosphoric acid gel.

Acid etching opens the dentinal tubules, creates microporosities on dentin, and exposes collagen that collapses due to loss of inorganic support. Primer application raises the collapsed collagen network keeping the porosities open. Resin bonding agent penetrates the collagen network resulting in a mechanical interlocking with dentin to form a hybrid layer or resin infiltrated layer.

This study shows that All Bond C&B resin luting cement exhibits highest bond strength to dentin compared to other luting cements used here. This strong bond strength is because of conditioning of dentin followed by application of bonding agent which contains HEMA, bisphenol A-glycidyl methacrylate, and urethane dimethacrylate.

The present study within its limits shows that following adhesive luting cements have tensile bond strength in increasing order, glass ionomer, resin-modified glass ionomer, and composite resin luting cement.

Although the results obtained from this study may not be directly extrapolated to the clinical situation, they provide some information with regard to the performance of the new adhesive luting agents. Independent long-term further clinical studies are required to assess the durability, biocompatibility, and intra-oral serviceability of these luting materials.

The choice of adequate luting agents depends on:
1. Restorative materials such as metal, ceramic, and composite
2. Type of tooth preparation
3. Longevity of restoration
4. Biocompatibility
5. Masticatory forces
6. Caries activity.

To obtain optimal performance from any cement, carefully follow the manufacturer’s instructions for dispensing, mixing, and application. Retention of the restoration is a multifactorial or multifaceted challenge. Because of the high retentive strength of adhesive luting agents, they may provide the solution for the cementation of over tapered or short preparations. These cements are responsible for conservation of sound tooth structure which would otherwise be victim to the dental burs.

Summary
The present study was designed to evaluate and compare the tensile bond strength of adhesive luting cements, namely, glass ionomer, resin-modified glass ionomer, and composite resin luting cements for a base metal alloy bonded to dentin with zinc phosphate cement as a control.

All samples were analyzed under SEM to observe the nature of the bond failure. Except zinc phosphate cement, cohesive fracture was observed in luting cements in the majority of sample (Table 3).

The results showed that tensile bond strength of All Bond C&B composite luting cement is highest (25.941 MPa) followed by tensile bond strength of resin-modified glass ionomer luting cement (12.25 MPa) and conventional glass ionomer luting cement (4.7 MPa) (Table 2 and Graph 1).

Conclusion
This study evaluated and compared the tensile bond strength of glass ionomer, resin-modified glass ionomer, and composite resin luting agent with zinc phosphate as control to dentin for a base metal alloy.

The highest tensile bond strength was obtained using the All Bond C&B
1. composite resin luting cement (25.941 MPa). This is because of, (a) removal of smear layer, (b) intertubular

<table>
<thead>
<tr>
<th>Cement</th>
<th>Metal cement</th>
<th>Cement</th>
<th>Tooth cement</th>
<th>Combination</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zinc phosphate</td>
<td>0</td>
<td>13</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Glass ionomer</td>
<td>0</td>
<td>9</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Resin-modified glass ionomer</td>
<td>0</td>
<td>10</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Composite resin cement</td>
<td>0</td>
<td>11</td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

Table 3: Relative frequency distribution of cohesive and adhesive failure interface in cementing medium.
Comparative analysis of tensile bond strength of adhesive luting agents ...

Kulkarni G


