Effect of Luting Cements on the Compressive Strength of Turkom-Cera™ All-ceramic Copings

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Abstract

Aim: The objective of this study is to investigate the effect of different luting agents on the fracture strength of Turkom-Cera™ all-ceramic copings.

Methods and Materials: Standardized metal dies were duplicated from a prepared maxillary first premolar tooth using non-precious metal alloy (Wiron 99). Thirty Turkom-Cera™ copings of 0.6 mm thickness were then fabricated. Three types of luting agents were used: zinc phosphate cement (Elite™), glass-ionomer cement (Fuji I™), and a dual-cured composite resin cement (Panavia F™). Ten copings were cemented with each type. All copings were cemented to their respective dies according to manufacturer’s instructions and received a static load of 5 kg for ten minutes. After 24 hours of storage in distilled water at 37ºC, the copings were vertically loaded until fracture using an Instron Universal Testing Machine at a crosshead speed of 1 mm/minute. The mode of fracture was then determined.

Results: Statistical analysis carried out using analysis of variance (ANOVA) revealed significant differences in the compressive strength between the three groups (P<0.001). The mean fracture strength (in Newtons) of Turkom-Cera™ copings cemented with Elite™, Fuji I™, and Panavia F™ were 1537.4 N, 1294.4 N, and 2183.6 N, respectively.

Conclusions: Luting agents have an influence on the fracture resistance of Turkom-Cera™ copings.

Keywords: Turkom-Cera™, compressive strength, luting cements, modes of fracture, Makramani Load

**Introduction**

Many alternatives have been suggested for restoring lost tooth structure in the posterior region of the oral cavity. In the 20th century porcelain-fused-to-metal (PFM) restorations have accounted for a significant portion of posterior tooth restorations. 

Patient and clinician alike have an interest in esthetic restorations that are not limited to just the anterior teeth. Aside from poor esthetics, metal-based crowns have some other disadvantages such as galvanic and corrosive side effects as well as causing gingival discoloration. As a result, posterior tooth-colored adhesive restorative techniques have grown considerably over the last decade. All-ceramic crowns are routinely placed not only in the anterior esthetic zone, but also in the posterior region where they are subjected to greater occlusal forces and stress from cyclic loading.

Resin bonding of ceramic restorations to the supporting tooth structure increases retention, marginal adaptation, and the fracture resistance of the restored tooth and the restoration itself. Therefore, adhesive cementation may be beneficial for high-strength ceramic full coverage restorations especially in situations of compromised retention, or high occlusal load.

A new, all-ceramic material, Turkom-Cera™ (Turkom-Ceramic [M] Sdn. Bhd., Kuala Lumpur Malaysia) with aluminum oxide (99.98%), has been introduced in an attempt to provide high-quality, cost effective copings and to improve clinical success with all ceramic restorations. Laboratory studies are useful tools to identify preferred cementation methods and luting materials before they are used clinically. Therefore, the present study was conducted to evaluate the effect of different luting cements on the strength of Turkom-Cera™ all-ceramic material.

**Methods and Materials**

**Materials**

As shown in Table 1, three different types of luting media (Elite™ zinc-phosphate cement, Fuji I™ glass-ionomer cement, and Panavia F™ dual-cured composite resin cement with its silane coupling agent in a Clearfil Silane Kit) were used in this study.

**Die Preparation**

A sound and crack-free human maxillary first premolar was selected and prepared for a full coverage, all-ceramic crown with a 4 to 6 degree angle of convergence, a 1.0 mm hamler cervical margin, and a total preparation height of 4.0 mm using a Nouvag AF 30 surveyor-milling machine (Nouvag AG, Goldach, Switzerland).

Six impressions were taken of the prepared tooth using a sectional tray and Impregum Penta™ polyether impression material (3M ESPE Ag, Seefeld, Germany). The six impressions were then poured in self-curing acrylic resin (Pattern Resin, GC Corporation, Tokyo, Japan) to produce six acrylic patterns of the prepared tooth. The six acrylic patterns were embedded in a base of wax (College Wax, Metrodent Limited, Huddersfield, England) in order to be fitted in a jig constructed to facilitate testing with an Instron Testing Machine (Instron, Norwood, MA, USA). Then the six acrylic patterns, with their wax bases, were sprued, invested, and cast with a non-precious alloy (Wiron99®, Bego AG, Bego, Germany) and finished to be the master dies (Figure 1).

**Specimen Preparation**

Five impressions were made of each master die and poured in die stone (Densite, Shofu Inc., Kyoto, Japan). The preparation of Turkom-Cera™ all-ceramic copings in the dental laboratory requires only a standard laboratory furnace, a propane gas flame, standard laboratory
Table 1. Luting cements used in this study.

<table>
<thead>
<tr>
<th>Material</th>
<th>Manufacturer</th>
<th>Type</th>
<th>Batch Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elite™ cement</td>
<td>GC Corporation, Tokyo, Japan</td>
<td>Zinc phosphate cement</td>
<td>Liquid: 0407071</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Powder: 0407061</td>
</tr>
<tr>
<td>Fuji I™ cement</td>
<td>GC Corporation, Tokyo, Japan</td>
<td>Glass ionomer cement</td>
<td>Liquid: 0511041</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Powder: 0511041</td>
</tr>
<tr>
<td>Panavia F™ cement</td>
<td>Kuraray Medical Inc., Okayama, Japan</td>
<td>Resin luting cement</td>
<td>A paste: 00245D</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>B paste: 00140B</td>
</tr>
<tr>
<td>Clearfil Silane™ Kit</td>
<td>Kuraray Medical Inc., Okayama, Japan</td>
<td>Silane coupling agent</td>
<td>SE bond primer: 00589A</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Porcelain bond activator: 00184A</td>
</tr>
</tbody>
</table>

Figure 1. The six metal dies used in this study.

micromotor, and a Turkom-Cera™ all-ceramic kit. Using the Turkom-Cera™ technique, the stone die was covered by a red plastic foil 0.1 mm thick and dipped in the Turkom-Cera™ Alumina Gel following the manufacturer’s instructions.

After drying of the alumina gel, the coping with the red plastic foil was removed from the stone die and fired in the furnace (Ivoclar Vivadent, Programat p300, Ivoclar Vivadent AG, Schaan, Liechtenstein) for five minutes at 1150°C. The sintered coping was crystal hardened, using Turkom-Cera™ Crystal Powder, in a second firing process in the same furnace for 30 minutes at 1150°C. The excess crystals were removed with a diamond bur. The all Turkom-Cera™ copings were fabricated using the manufacturer’s specifications and materials. A total of 30 copings with a thickness of 0.6 mm were fabricated by one master dental technician.

The specimens were divided into three groups according to the luting cements used. Ten copings were cemented with each type of the previously mentioned luting agents. Two master dies were used for each group, and each of them was used to lute five copings. All copings were cemented onto their corresponding dies according to the manufacturer’s instructions.

Before cementation, all copings were internally sandblasted with 50 μm aluminum oxide (Al₂O₃) particles at an air pressure of 2.5 bars for 13 seconds from a distance of 10 mm. The copings were then steam cleaned and air dried. After the impressions were completed, the dies were
cleaned with acetone then steam cleaned and air dried before cementation of the first coping. After cementation and testing of the first coping, the cement on the dies was removed ultrasonically without damage or alteration of the metal surfaces. Then the dies were steam cleaned and air dried before cementation of the next coping. Five Turkom-Cera™ copings for each master die were cemented in this manner.

Manual finger pressure was used to initially seat each crown on its die. During zinc phosphate and glass ionomer cementations, each crown was held in place while excess cement was removed before the luting agent set completely. Any excess resin luting cement paste remaining at the margins was removed with a disposable brush and a layer of Oxyguard II (Kuraray) was applied for three minutes around the margins of each specimen. The specimens were then placed in a custom-made vertical loading apparatus (Makramani Load) for ten minutes under a 5 kg load (Figure 2). Following cementation, all specimens were placed in a sealed container of distilled water and left in an incubator at a constant temperature of 37°C for 24 hours.

**Compressive Strength Testing**

The master die with cemented coping was removed from the storage container and mounted in a specially designed jig and subjected to testing on the Instron Testing Machine. A 1.6 mm stainless steel bar mounted on the crosshead of the testing machine was used. A compressive load was applied at the center of the occlusal surface along the long axis of the cemented copings at a crosshead speed of 1 mm/min until failure (Figure 3).

The maximum force to produce fracture was recorded in Newtons. The fractured crowns were removed, and the master die was ultrasonically cleaned before a new coping was cemented. Five Turkom-Cera™ copings for each master die were tested in this manner. The force at failure was noted, and the failed coping was examined in order to determine the mode of fracture. The mode of fracture was determined using categories as described by Burke (1996) (Table 2).

**Statistics**
The results of the study were statistically tested using one way analysis of variance (ANOVA) and the Scheffe's Post Hoc Test to determine if significant differences between tests groups were related to the luting material used for each group. The non-parametric Kruskal-Wallis test was used to determine the association between mode of fracture and fracture strength. The Chi-square test was used to determine the association between the treatment group and mode of fracture (P>0.05).

**Results**
The mean and median load at fracture, the standard deviation, and the 95% confidence interval for each experimental group was recorded in Table 3. The ANOVA demonstrated at least one pair of mean values differ significantly (P<0.001). Scheffe’s Post Hoc Test showed
This in vitro study was conducted to evaluate the compressive strength of Turkom-Cera™ copings using different luting agents. For this reason, an analogue with the size and shape of a human tooth was used rather than a regular geometric configuration. Metal dies were designed to represent a tooth prepared for a full-ceramic crown, thereby, ensuring a standard size and shape for fabrication.

Within limits, compressive strength studies of crown systems provide a general range of load-bearing capacity in simulated clinical situations. The results of in vitro strength studies may give helpful information for the design of clinical studies which are needed to cite definitive outcomes.

The present study attempted to isolate the cement layer as the only variable. Efforts were made to
standardize the other variables that may have an effect on fracture strength. To avoid the influences of preparation design, loading direction, and loading stylus radius, an identical abutment analogue and loading apparatus were used for all test specimens. In addition, the load was directed vertically in the centre of the occlusal surface down the long axis of each cemented crown.\(^\text{14-17}\)

The methods used in this study were similar to previous studies.\(^\text{5,18-21}\) In this present study, Cr-Co metal dies were used as the supporting structure. The advantages of using such abutments are: maintaining the possibility of standardized preparation, ensuring the die did not break before the coping, and the identical physical quality of materials.\(^\text{5,19,21-23}\) Furthermore, natural teeth show a large variation depending on their age, individual structure, and storage time after extraction, thus, causing difficulties in achieving standard support.\(^\text{24,25}\) However, abutments made of metal do not reproduce the actual force distribution that may occur on crowns cemented to natural teeth. The chemo-mechanical interaction between the dentin and the luting agent cannot be tested using this type of simulation.

Turkom-Cera™ copings cemented with resin luting cement (Panavia F™) gave the highest mean compressive strength (2183.60 N), whereas, Turkom-Cera™ copings cemented with glass ionomer cement (Fuji I™) had the lowest mean compressive strength (1294.40 N).

Different luting cements have been used with all-ceramic crown restorations. An apparent increase in fracture strength of all-ceramic restorations luted with resin luting cement has been reported and is in agreement with the results of previous studies.\(^\text{26-28}\)

An effect similar to results of this study was reported by another researcher. AL-Makramani (2005) examined the effect of different luting cements on the fracture resistance of Procera AllCeram copings. The copings cemented with Panavia F (1953.5 N) exhibited significantly higher compressive strength values than those cemented with zinc phosphate cement (1091.9 N) or glass ionomer cement (784.8 N).\(^\text{30}\)

In contrast Casson et al.\(^\text{39}\) found the zinc phosphate cement group produced a higher mean fracture strength (1216 N) than glass ionomer (754 N) or resin cement (989 N) groups.\(^\text{30}\)

In another study by McCormick et al.\(^\text{31}\) they reported all-ceramic crowns luted with zinc phosphate, glass-ionomer, and composite resin luting cements did not show any statistically significant difference among fracture strengths. However, in that study, a dentinal bonding agent was not used in conjunction with the resin composite luting material, a factor which may explain the apparent divergence between the results obtained by McCormick and those obtained by other studies.

In this present study the zinc phosphate cement (Elite™) group produced a surprisingly higher mean fracture load (1091.92 N) than the glass ionomer cement (Fuji I™) group (784.79 N). Several authors have implicated the effect of the modulus of elasticity of materials on fracture strength.\(^\text{27,30,32}\) Given that high modulus materials are necessary for high stress areas, Casson et al.\(^\text{39}\) has suggested the elastic modulus of cements could lessen the effect of internal flaws in the ceramic crowns. The modulus of elasticity of zinc phosphate cement is generally regarded as being higher than that of glass ionomer cement.\(^\text{32}\)

Examination of the mode of fracture of specimens revealed the majority of Turkom-Cera™ copings cemented with either zinc phosphate cement (90%) or resin luting cement (80%) exhibited a minimal fracture of copings (Figure 4). Only 60% of Turkom-Cera™ copings cemented with glass ionomer cement exhibited minimal fracture. However, data analysis revealed no significant

![Figure 4. Most common mode of fracture (Minimal fracture).](image)
association between mode of fracture and the treatment group or between mode of fracture and fracture strength (P>0.05).

Conclusion
In this study three types of luting agents were tested in vitro in order to determine their effect on the compressive strength of Turkom-Cera™ fused alumina copings.

The luting agents used in this study significantly affected the recorded fracture resistance. Turkom-Cera™ copings cemented with Panavia F™ resin luting cement (2183.6 N) were significantly stronger than Turkom-Cera™ copings cemented with either Elite™ zinc phosphate (1537.4 N) or Fuji I™ glass ionomer (1294.4 N) cements. This study evaluated the fracture strength of Turkom-Cera™ all-ceramic material supported to metal dies. Other studies are ongoing to evaluate the fracture strength of Turkom-Cera™ copings cemented to natural tooth structure.

References
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