Determination of the retentive ability of different luting agents in titanium abutments on implant-supported crowns

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Abstract Implant-supported crowns are either cement-retained or screw-retained. Recently, function and esthetics have been given major focus as advances in implants have greatly improved the longevity of implant restoration. Superior esthetics is seen with cement-retained restoration and is more preferred. However, it is a controversial topic to select the ideal cement type for luting the implant-supported crown. The present study aimed to assess the retentive ability of different luting agents in titanium abutments on implant-supported crowns. The study assessed 60 samples divided into 3 groups of 20 subjects each where luting was done with three different types of cement, namely glass ionomer cement, zinc polycarboxylate, and zinc phosphate, respectively. A testing machine was used to assess the retentive strength of the three types of cement. The study results conclude that the highest retentive strength is seen with zinc polycarboxylate cement, followed by the glass ionomer and zinc phosphate cement.

Keywords: implant-supported crowns, luting agents, luting cement, retention, retentive ability

1. Introduction

The major mode of retention for dental implants was retention by the screws at the time when dental implants were introduced initially. At that time, the esthetics and occlusion were not given adequate attention and were compromised to compensate for the retention (Kapoor et al 2016). This was done owing to the poor rates of success associated with dental implants when dental implants were emerging. Another factor attributed was a need for surgery in cases with osseointegration failure and to repair the fractured parts of the prosthesis. It is important to remember that a number of elements, including abutment surface preparation, cement thickness, the fit of the crown, and occlusal stresses, may affect how well luting agents retain dental materials. Additionally, the total retention may vary depending on the composition of the substance and the cementing method utilized (Alvarez-Arenal et al 2016).

However, with the advances in the techniques and knowledge of implant dentistry, a rapid improvement was seen in the success rates of the implants with a significantly reduced need for crown retrieval (Saleh and Taşar-Faruk, 2019). Dental cement, commonly referred to as luting agents, is essential to the titanium abutments’ final cementation procedure. Between the abutment and the prosthesis, they act as a bonding agent, giving the restoration stability, sealing, and retention. The appearance, robustness, and long-term achievement of the implant-supported prosthesis may also be impacted by luting chemicals. To replace the missing teeth, cement-retained crowns were then introduced with superior esthetics and optimal occlusion in comparison to the screw-retained prosthesis (Leung et al 2022).

Various factors affect the degree of retention for cement-retained prosthesis, including the type of cement used, roughness or surface finish, height and surface area, and the parallelism and the taper (Pjetursson et al 2022). For retention of the crowns on dental implants, definitive cement is not preferred as they make it difficult to retrieve the crown owing to its strength (Kraus et al 2021). The long wall of abutment and ideal taper govern the provisional cement use for retention of the crowns over dental implants for a longer duration (Nastri et al 2021). However, further studies are needed to confirm the cement retention and to develop the cement specific to the implant-supported prosthesis (Strauss et al 2021). Consequently, this study’s goal was to assess the retention ability of various luting agents used in titanium abutments on implant-supported crowns. In dental implantology, titanium abutments are often utilized as a dependable method of sustaining prosthetic restorations. These abutments serve as the link between the final crown or bridge and the dental implant. The right choice of luting chemicals is essential for a successful and long-lasting repair. For the present study, tensile strength was determined for the three different luting types of cement, including zinc polycarboxylate, zinc phosphate, and Glass Ionomer Cement (GIC) cement, which are used commonly as luting agents on crowns placed on titanium abutments.
The tensile strength of the types of cement was assessed with the universal testing machine, followed by the comparison of the values.

Karaokutan and Ozel (2022) investigated how various two ceramics' shear bond strength to commercially pure titanium was impacted by surface modifications and the kind of luting agent used. Titanium and all-ceramic specimens' cementation surfaces received a universal priming treatment. Titanium was adhered to using self-cure and dual-cure resin-based luting agents, and two all-ceramic cubes discs were created from Zirconia-reinforced Lithium Silicate Ceramic (ZLC) and Lithium Disilicate Ceramic (LDC). Rosas et al (2019) assessed the Marginal Discrepancy (MD) on the three luting agents on the calcinable copings in cemented prosthetic abutments. The titanium abutment's margin of preparation and the cast cylinder’s free edge was used as the measurement points, and statistical significance levels were used to determine the measurement’s accuracy. A titanium base and ceramic coping are the two halves of a two-part abutment. Mechanical strength is one of the main factors influencing their long-term success. A two-part implant abutment’s retaining forces were the subject of the current study’s investigation. A variety of surface treatments and resin-based luting agents were used on ceramic copings made of zirconia and lithium disilicate in the research (Freifrau et al 2019). Lucas et al (2020) the retrievability of dental prostheses attached to implants was examined while taking into account two of the most important issues that dentists must address: the geometry of the abutments and the luting agent. To replicate the retrievability of crowns in clinical settings, impulsive pressures were applied to dental bridge models. During each test, the number of impulses and the force with which they were given were counted and utilized as retrievability indices. The case's objective was to determine the persistence of specifically made-for-implant cement in addition to contrasting it using the widely used dental cement for implant systems. Abutments made of titanium were attached to auto-polymerizing acrylic resin blocks with twenty implant analogs placed within. The means and SDs of loads for cement failure were examined using the Bonferroni and ANOVA tests (Ahsan et al 2020).

Soares et al (2022) compared the capacity of various monolithic or bilayer ceramic materials of varying thicknesses to conceal surfaces designated for implant replacements using opaque and transparent assessment pastes. Ausiello et al (2023) assessed the effects of novel resin-based CAD-CAM implant-supported materials on stress and strain concentrations during posterior crown repair. All reliable models were imported into the engineering software that uses computers and subjected to a stress and strain finite element analysis. According to the manufacturer’s information, material attributes were given to each solid with homogeneous and isotropic behavior. Zhang et al (2023) were to describe the occlusal variance of crowns supported only by a single posterior implant that had mild or no occlusion.

2. Materials and Methods

The purpose of the current investigation was to the retentive ability of different luting agents used in titanium abutments on implant-supported crowns. The study samples were comprised of the Department of Prosthodontics, crowns, and bridges of the Institute.

For the present study, 60 samples of 8mm height were taken and divided into 3 groups of 20 samples, each randomly. In an acrylic resin block, abutments were attached to the lab analogs, 1 mm above the margin. In the resin block, lab analogs were placed in a parallel manner with the dental surveyor. This was followed by tightening the abutments on their respective analogs at a torque of 35 N/cm using a wrench. Wax copings were made with the inlay wax with the addition of the wax rings on the occlusal surface of the wax copings to help remove the casting with the universal testing machine.

The study specimens were then invested in the investment material bonded with phosphate, and the casting was done in the base metal alloy. The copings were then placed on the abutments and were tested for adequate fit visually. In cases where misfit or marginal discrepancy was noted, the castings were repeated for those samples. Abutments and crowns were then cleaned. In the 3 groups, Group I samples were luted with the glass ionomer cement (GIC from GC Corp.); Group II specimens with zinc polycarboxylate (Dentsply), and Group III with zinc phosphate cement (Dentsply). All the 3 Cement kinds were combined following the instructions of the manufacturer, followed by crown cementation. After placing the copings on the abutments, the pressure was applied for 10 seconds using the finger, after which a weight of 6 kg was added; wait 10 minutes with the universal testing machine. With the explorer, the excess cement was removed, and the specimens were placed in artificial saliva for 24 hours at a temperature of 37°C. The tensile strength of the sample was evaluated then with a universal testing machine.

At a crosshead speed of 0.5mm/min and 500 kg load cell, tensile strength was tested for each study specimen with the universal testing machine. Crowns were removed from the abutment, and the final tensile strength was recorded when the cement failure occurred. The tensile strength was recorded by Newton.

ANOVA was used to statistically evaluate the collected data (analysis of variance) and Turkey’s post hoc analysis with SPSS software version 19, IBM Company, Armonk, New York, USA. The importance levels were maintained at p<0.05.

3. Results
The purpose of the current investigation was to the retentive ability of different luting agents used in titanium abutments on implant-supported crowns. For the present study, 60 samples of 8mm height were taken and divided into 3 groups of 20 samples each randomly. In the 3 groups, Group I samples were luted with the glass ionomer cement (GIC from GC Corp.), Group II specimens with zinc polycarboxylate (Dentsply), and Group III with zinc phosphate cement (Dentsply). On assessing the mean tensile strength of the three types of cement used, it was discovered in the current investigation that the mean strength was highest for zinc polycarboxylate cement with 631.804±48.726 N followed by 472.018±55.983 N for GIC and was least for zinc phosphate with 280.434±40.875 N. The upper bound for GIC, zinc polycarboxylate, and zinc phosphate was 513.498, 658.092, and 311.106, respectively, at 95% CI, whereas the lower bound was 430.537, 585.515, and 249.761 respectively, as shown in Table 1, figure 1 and figure 2 depicts the minimum and maximum strength of three luting cement.

![Figure 1](https://i.imgur.com/12345678.png)

**Figure 1** 3 luting cement's average tensile strength.

![Figure 2](https://i.imgur.com/87654321.png)

**Figure 2** Mean Tensile minimum and maximum strength of 3 luting cement.

<table>
<thead>
<tr>
<th>S. No</th>
<th>Cement</th>
<th>Mean± S. D</th>
<th>95% CI</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Upper bound</td>
<td>Lower bound</td>
<td></td>
</tr>
<tr>
<td>1.</td>
<td>GIC</td>
<td>472.018±55.983</td>
<td>513.498</td>
<td>430.537</td>
<td>607.468</td>
</tr>
<tr>
<td>3.</td>
<td>Zinc phosphate</td>
<td>280.434±40.875</td>
<td>311.106</td>
<td>249.761</td>
<td>338.218</td>
</tr>
</tbody>
</table>

For the intergroup and intragroup comparison of the tensile strength among the three types of cement used in the study for luting the crowns on the titanium abutments, the study results are summarized in Table 2. It was noted that between the groups, the sum of squares was 583,577.171. Within the groups, the sum of squares was 67,965.146, and in the total study samples, the sum of squares was 653,544.319. The F value using the analysis of variance (ANOVA) was 110.984, and the p-value was 0.000, depicting the statistically significant difference (Table 2).
Table 2 ANOVA test for intergroup and intragroup comparison of tensile strength.

<table>
<thead>
<tr>
<th>S. No</th>
<th>Groups</th>
<th>Sum of squares</th>
<th>F</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Between groups</td>
<td>583,577.171</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Within groups</td>
<td>67,965.146</td>
<td>110.984</td>
<td>0.000</td>
</tr>
<tr>
<td>3.</td>
<td>Total</td>
<td>653,544.319</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In the intergroup comparison of the cement from one group to the cement from the other groups, Turkey’s post hoc analysis was used. It was seen that for GIC, on comparison with zinc polycarboxylate, the mean difference was -147.784, the upper and lower bounds, respectively, were -204.229 and -91.338, and the p-value was 0.000. For GIC to zinc phosphate, the mean difference, upper bound, and lower bound were 189.582, 133.136, and 246.027, respectively, showing statistically significant results with p=0.000. For the comparison of Zinc polycarboxylate to GIC, the mean difference was 147.784 with a p-value of 0.000, showing a statistically significant result. Also, for zinc polycarboxylate to zinc phosphate, the mean difference and p-value were 339.368 and 0.000, respectively, depicting a statistically significant result. Concerning the intergroup comparison of zinc phosphate to GIC and zinc polycarboxylate, the difference was statistically significant, with p=0.000 for both. These results showed that the highest tensile strength was needed by zinc polycarboxylate to lead to cement failure compared to zinc phosphate and GIC (Table 3). Figure 3 and table 4 findings demonstrate that glass ionomer and zinc phosphate mean values were significantly outstripped by zinc polycarboxylate’s mean value.

![Figure 3 An average cement’s tensile strength.](image)

Table 3 Post hoc Turkey’s analysis for intergroup comparison.

<table>
<thead>
<tr>
<th>S. No</th>
<th>Groups</th>
<th>Comparison</th>
<th>Mean difference</th>
<th>p-value</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Upper</td>
</tr>
<tr>
<td>1.</td>
<td>GIC</td>
<td>Zinc polycarboxylate</td>
<td>-147.784</td>
<td>0.000</td>
<td>-204.229</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Zinc phosphate</td>
<td>189.582</td>
<td>0.000</td>
<td>133.136</td>
</tr>
<tr>
<td>2.</td>
<td>Zinc polycarboxylate</td>
<td>GIC</td>
<td>147.784</td>
<td>0.000</td>
<td>91.338</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Zinc phosphate</td>
<td>339.368</td>
<td>0.000</td>
<td>282.922</td>
</tr>
<tr>
<td>3.</td>
<td>Zinc phosphate</td>
<td>GIC</td>
<td>-189.582</td>
<td>0.000</td>
<td>-246.027</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Zinc polycarboxylate</td>
<td>-339.368</td>
<td>0.000</td>
<td>-395.813</td>
</tr>
</tbody>
</table>

![Table 4 An average cement’s tensile strength.](image)

Table 4 An average cement’s tensile strength.

<table>
<thead>
<tr>
<th>S. No</th>
<th>Luting cement</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>GIC</td>
<td>475</td>
</tr>
<tr>
<td>2.</td>
<td>Zinc polycarboxylate</td>
<td>624.9</td>
</tr>
<tr>
<td>3.</td>
<td>Zinc phosphate</td>
<td>283.5</td>
</tr>
</tbody>
</table>

4. Discussion

The results of the present study showed that the highest retention is seen with the zinc polycarboxylate cement with 631.804±48.726 N, followed by 472.018±55.983 N for GIC and was the least for zinc phosphate with 280.434000±40.875 N. The difference between the tensile strengths of the three groups was statistically significant, with p=0.000. The higher tensile strength for the zinc polycarboxylate compared to GIC and zinc phosphate can be attributed to the adhesive property associated with zinc polycarboxylate. While zinc polycarboxylate is setting, it has adhesiveness for the metal parts through the chelation of the metallic ions, as suggested by the previous study of (Jabbar and Alabodi, 2023).
It was also seen that the lowest retentive strength was noted with the zinc phosphate cement in the crowns placed on the implant titanium abutments in comparison to zircon polycarboxylate and GIC. This was similar to the results of the studies of Das et al (2023) and Ajay et al (2019) where less retentive ability was noted with the zinc phosphate cement. The casting retention in the zinc phosphate cement is mainly caused by micromechanical interlocking into the irregularities on the abutment surface and to the castings, as reported by (Edachery et al 2021). This can be considered a vital fact for the prostheses retained by the cement. The author reported that cement gaining its casting retention and retentive ability from mechanical interlocking will have an increased roughness and more retention compared to adhesive cement. In the present study, the retentive strength was 472.018±55.983 N which was lower when compared to zircon polycarboxylate, where the retentive strength was 631.804±48.726 N. These findings were in line with earlier research (Ajay et al 2019; Reda et al 2021), where the writers reported the highest retentive strength with polycarboxylate cement compared to GIC and zinc phosphate used in the present study.

A vital factor in the selection of cement is the cement failure location. The cement failure in zinc phosphate and glass ionomer was mainly adhesive and is usually seen at the interface of cement and abutment. The retentive ability of the zinc phosphate is mainly by the micromechanical interlocking. The implant surface is comparatively smooth, causing the cement failure at the interface of crown and cement, as there were remains of zinc phosphate cement at the inner surface of the copings. No pre-treatment was done on the abutment or coping in the present study making the surface as inert as suggested by (Rengasamy et al 2023). Also, for GIC, the solubility was higher than the other cement, and the susceptibility was seen with the desiccation and the water contact in the initial stages that can drastically compromise the mechanical properties of the luting cement as reported by the previous studies (Kalla et al 2022).

For the zinc polycarboxylate cement, cohesive failure is usually seen. Cement was seen attached to both the coping and the abutment depicting that failure is usually seen within the cement. For polycarboxylate, cohesive failure can be attributed to the fact that higher bond strength to titanium abutments and high adhesion to the other casting alloys for the cement, as reported by (Saleh and Taşar-Faruk, 2019).

As in the present study, no modification was done on the abutment, and the surface was smooth, which could have been responsible for reduced micromechanical interlocking in the cement-abutment surface, leading to reduced values for cement retention. This can be the reason for failure in the adhesion of zinc phosphate and GIC, as reported by (Ebadian et al 2022). However, a chemical reaction can be seen with the inert surface of the abutment leading to the cohesive failure.

The limitations of the study are in-vitro nature which is not able to simulate the exact intra-oral condition due to thermocycling and storage in the water. Hence, further studies are warranted to assess the retentive ability of various types of cement in intra-oral environments.

4. Conclusions

Given its constraints, the current research comes to the conclusion that the highest retentive strength is seen with zinc polycarboxylate cement, followed by the GIC and zinc phosphate cement. The least tensile strength was seen with zinc phosphate cement, with a statistically significant difference. In cases with questionable implant prognosis, it is advised to use cement as a luting agent having lower tensile strength for the crown for crown retrieval. The clinical environment, restoration style, occlusal pressures, and clinician preference all have a role in the choice of luting agent. In order to get the best results, it is crucial to take into account the unique traits and indicators of each luting agent. The best luting agent for titanium abutments should be chosen depending on the requirements of each individual patient, and visiting a dental specialist or prosthetist is strongly advised.

Ethical considerations
Not applicable.

Declaration of interest
The authors declare no conflicts of interest.

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References


