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Research Article

In-Vitro Comparative Study of Bond Strength in All-Metal Crowns Using Different Luting Cements and Surface Treatments

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Abstract:
This study aims to measure and compare the bonding strengths of different kinds of metal-crowns with varying luting cement types and surface-treatment techniques. Forty-eight premolars were used in the study, divided equally into three groups. To standardise all tooth preparations, teeth were prepared with the taper set to 0. after verifying 0-degree taper, wax pattern was fabricated on each tooth, a ring was attached on the wax pattern and casting was done. Following casting, the metal-crowns were cemented using resin modified glass ionomer cement (RMGIC) and dual-cure resin cement. Subsequently, all specimens underwent tensile bond strength testing using a universal testing machine at a cross speed of
1 mm/min. In the result both type of luting-agent and surface-treatment had a evident effect on retention. The metal-crowns that didn't underwent any surface-treatment showed the lowest bond-strengths. The group surface-treated by 110 µm alumina sandblasting and ultrasonic-cleaning offered the maximum bond-strength. When it came to luting agents, Dual- cure resin cement had the maximum bond-strength while RMGIC displayed the lowest bond- strength. Among all the surface-treatments investigated in this research, the combination of sandblasting with 110µm alumina and ultrasonic-cleaning yielded the maximum bond- strength. Furthermore, dual-cure resin cement appeared as the most effective luting-agent.

Keywords: Adhesive Systems, Fixed prosthesis, Luting-agents, surface-modifications

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Introduction

Primary goal for physicians is to ensure that the abutment teeth for fixed partial dentures retain their pulpal vitality and durability while simultaneously providing lost function. Integral to achieving this goal is the meticulous selection and application of an appropriate luting agent—a dental cement employed to bond indirect restorations to prepared teeth.1 The primary function of a luting agent is to fill the gap at the restoration-tooth interface and firmly attach the restoration, hence preventing dislodgement during chewing activities. Luting agents are classified as either permanent (long-term) or provisional (short-term), according on the anticipated period of the restoration. Over the course of time, a multitude of luting agents and dental cements have been introduced, each purporting enhanced characteristics and clinical efficacy relative to existing materials.[2]

The use of luting cements in dentistry has a long history; the first dental cements were created using substances like crushed seashells and extracts from resinous plants. The main applications for these primitive cements were dental decay treatment and cavity filling. The dental industry has observed considerable advancements over time, notably in the development of more advanced luting cements.[3]

The process of luting, also known as cementation, involves using cement, an intermediary material, to fix or attach crowns, restorations, and other devices to the tooth structure. Glass ionomer, for instance, has several uses such as restorative material, luting agent, and base. A luting agent is necessary to prevent cavities and chemical and bacterial irritation of the tooth and pulp, in addition to securing the restoration and sealing the gap between it and the tooth structure.[4]

The rapid development of adhesive dental materials has led to significant development in various aspects of clinical dentistry. A key factor in establishing the clinical efficacy of dental restorations is adhesive strength. New dental cements with stronger bonds were created because of the introduction of new adhesive methods and materials for use in restorative dentistry. Newly released dental luting materials consist of resin-modified (hybrid) glass ionomers and composites.[5]

Mechanical tests in dentistry are designed to assess the characteristics and forecast the behaviour of dental materials by simulating actual biological conditions and offering future application methods. Adhesive systems in dentistry have evolved remarkably over time due to advancements and continual improvements. Methods such as bond strength, tensile testing, micro-tensile testing, shear testing, and micro-shear testing are employed to assess the adhesive properties of different materials to one another.[6]

Surface treatment refers to the process of improving a material's surface properties, such as increasing its resistance to wear or corrosion. One of the key elements influencing adhesive joint strength is surface treatment. Pretreatments of joining materials can be applied in various ways, with the three most used forms being electrochemical, chemical, and mechanical methods. The mechanical methods include roughening techniques like abrasion, sandblasting, and grit blasting. A wide variety of metals can be treated using two surface treatment techniques: sandblasting and ultrasonic cleaning.[7]

The purpose of this article is to examine in detail the compressive strengths of modern resin- based cements and dual-cure resin cement, with an emphasis on their use in metal crown restorations. This study aims to clarify the benefits, drawbacks, and clinical implications of selecting one cement type over another by carefully examining their mechanical qualities, handling traits, and clinical performance. Dental professionals will derive significant value from the research conclusions, aiding them in making informed choices regarding luting cement selection and improving the overall quality and longevity of dental crown restorations.

Materials and methods:

An in vitro study was undertaken to analyze and juxtapose the bond strength of all-metal crowns subsequent to undergoing various surface treatments with distinct luting cements. The primary objective of this study was to evaluate the effectiveness of multiple surface treatments in augmenting the bond strength between the metal crown and the prepared tooth structure when employing different luting cements.

Forty-eight extracted premolars were collected and submerged in a saline-water solution in preparation for further treatment. Subsequently, they underwent immersion in a 3% hydrogen peroxide solution to ensure comprehensive cleansing and removal of debris. Following the decontamination process, the 48 extracted teeth were stored in purified water at 37°C to simulate conditions akin to the oral environment.

The tooth was affixed to an acrylic base measuring 3×5cm, and tooth preparation was executed utilizing a straight diamond bur. To ensure uniformity in both height and taper across all 48 tooth preparations, an initial tooth was prepared with the taper set to 0, as gauged using a surveyor. The preparation procedure encompassed the following measurements: reduction of the flat occlusal surface, establishment of 0° axial convergences, chamfering of the finish line, with a mesiodistal width of 3 mm, buccolingual width of 5 mm, and crown height set at 5 mm. Utilizing a dental surveyor, parallelism was meticulously assessed. Subsequent to the verification of the preparation, wax patterns were meticulously crafted. Sprue wax rings were then fashioned around the wax patterns, which were subsequently invested and casted in nickel-chromium metal alloy.

Subsequently, the samples were randomly selected and evenly divided into three groups. (n=16) according to several surface-treatment.

- Group I: Control Group (without surface-treatment)
- Group II: Surface-treatment with 110 µm alumina (Al_2O_3)
- Group III: Surface-treatment with 110 µm alumina with u/s-cleaning.

Groups were divided into 2 sub-groups, for resin modified GIC and for dual cure resin cement.

Group I (control group): In this cohort, the metal crown was affixed without undergoing any surface treatment, employing an equal distribution of resin-modified glass ionomer cement and dual-cure resin. Each material was utilized in eight units, ensuring consistent application and adhesion to the metal crown surface.

Group II: The inner surface of the metal crown underwent treatment with 110 µm Al2O3 sandblasting subsequent to equal luting with resin-modified glass ionomer cement (RMGIC) and dual-cure resin. Eight units of each material were employed for this procedure.

Group III: The metal crown was uniformly affixed with resin-modified glass ionomer cement (RMGIC) and dual-cure resin, followed by surface treatment involving sandblasting (110µm alumina) and ultrasonic cleaning (distilled water for 10 minutes). Eight units of each material were utilized for this procedure.

According to the manufacturer's instructions for RMGIC (Shofu-Hybond), the cement is supplied in both liquid and powder forms. Using a plastic spatula, a uniform amount of one small scoop of powder and one drop of liquid is evenly collected onto a mixing pad, maintaining the standard ratio of powder to liquid (1.6g of powder to 1.0g of liquid).

For the dual-cure cement available in Automix Syringe or Automix Tips, utilize the Automix Tip to dispense the material from the syringe for mixing purposes. The initial setting phase will commence at 2 minutes and extend to 2 minutes and 30 seconds, while the final setting phase will begin between 3 to 4 minutes. An alternative method for curing the cement involves exposing it to a dental curing light for 40 seconds. Subsequently, all samples were immersed in saline at 37°C for 24 hours to mimic oral environmental conditions before debonding. Bond strength measurements were conducted using a universal testing machine (UTM).

Statistical analysis and Testing

The software employed for sample size determination was G*Power Version 3.1.9.6, developed by Franz Faul at the University of Kiel. Based on a power level of 90%, a type I error rate of 5%, and an effect size of 0.65, the calculated minimum sample size for the study was determined to be 48 samples, with 16 samples allocated to each group and 8 samples within each subgroup.

Utilizing a universal testing machine, all samples underwent tensile bond-strength testing, with removal occurring along the insertion path at a speed of 1 mm/min. The resultant values were tabulated and subjected to statistical analysis. Data entry was performed using Microsoft Excel 2021, while analysis was conducted utilizing SPSS statistical software version 23.0. Descriptive statistics, encompassing mean, standard deviation, frequency, and percentage, were employed for data presentation. The significance level was set at five percent.

Based on the normality assessment of the data, intergroup comparisons were conducted using One-Way ANOVA, followed by post-hoc analysis where applicable. Furthermore, depending

on the normal distribution of the data, the Paired t-test was utilized to compare groups across different time intervals. Levene's test was employed to evaluate the homogeneity of variables, while the Shapiro-Wilk test was utilized to assess the distribution of the data.

Result:

Comparison between bond-strength of crowns -luted using resin modified glass ionomer cement: (Table 1)

The average bond-strengths across three groups were as follows: 169.72 for Group-I (Control Group), 211.85 for Group II, and 223.30 for Group-III. Group-III exhibited the maximum bond-strength, This discrepancy in strength among the groups was found to be substantial. Specifically, using One-Way ANOVA unveiled significant differences in bond-strength between Group-I and Group-II, Group-I and Group-III, along with between Group-II and Group-III.

	Mean	Std. Deviatio n	Std. Error	Minimu m	Maximu m	F value	P value
Group I	169.72	16.245	5.743	140.56	188.32	37.727	0.001 (Sig)
Group II	211.85	7.823	2.765	195.74	219.86		
Group III	223.30	13.713	4.848	190.77	233.52		

Table 1

Group I-Control Group, Group II-Sand-blasting With 110 um Alumina, Group III- Sandblasting With 110 um Alumina And Ultrasonic-Cleaning

Comparison between band strength of crowns luted using dual cure: (Table 2)

The average bond strengths across three groups were as follows: 235.99 for Group I (Control Group), 255.24 for Group II, and 279.61 for Group III. Group III exhibited the maximum bond-strength. The observed difference in bond-strength among the samples was determined to be meaningful. Specifically, the statistical-analysis using One-Way ANOVA revealed substantial-difference in bond strength between Group I and Group II, Group I and Group III, as well as between Group II and Group III.

	Mean	Std. Deviatio n	Std. Error	Minimu m	Maximu m	F value	P value
Group I	235.99	8.027	2.838	226.40	247.54	37.727	0.001 (Sig)
Group II	255.24	14.274	5.046	226.12	268.80		
Group III	279.61	9.086	3.212	267.40	290.54		

Table 2

Group I-Control Group, Group II-Sandblasting With 110 um Alumina, Group III- Sandblasting With 110 um Alumina And Ultrasonic Cleaning

Intergroup comparison of bond-strength between resin modified glass ionomer cement and dual-core in groups: (Table-3)

The average bond-strengths were 169.72 in Group I (Control Group), 211.85 in Group II, and

223.30 in Group III. Additionally, the average bond-strengths were 235.99 in Group I (Control Group), 255.24 in Group II, and 279.61 in Group III. In all three groups, comparisons between resin modified glass ionomer cement and dual-cure materials unveiled substantial differences, with the dual-core group consistently exhibiting stronger bonds compared to the resin modified glass ionomer cement group.

	RMGIC		DUAL CORE		P value	
	Mean	Std. Deviation	Mean	Std. Deviation		
Group I	169.72	16.245	235.99	8.027	0.001	Significant
Group II	211.85	7.823	255.24	14.274	0.001	Significant
Group III	223.30	13.713	279.61	9.086	0.001	Significant

Table 3.

Discussion:

The long-term success of dental cast restorations depends on many factors. To ensure that cast crowns stay in place, it's important to choose the right luting cement (the material that holds the crown to the tooth) and consider the roughness of the inner surface of the crown. This research aims to look at how different types of luting cements and surface treatments affect how well crowns stay in place over time. [8]

The analysis of this study shows how luting agents (the materials that hold crowns in place) and different surface treatments affect how well fixed crowns stay in place. Samples that had surface treatments were harder to dislodge, while those without treatment were easier to remove.[9] This matches earlier research by O'Connor et al. in 1990, which found that using micro-blasting on the inside of crowns helps improve retention. The study also found differences in how well crowns stayed in place based on the type of luting cement used. Dual-cure resin cement held the crown the best, while resin-modified glass ionomer cement was the easiest to dislodge. [10]

In Group I, a considerable variation in bond strength between dual-cure resin and resin- modified glass ionomer cement was observed. The dual-cure resin cement exhibited the maximum average bond strength (226.40 ± 247.54 N/mm²), whereas the resin-modified glass ionomer cement had the minimum average bond strength (140.56 ± 188.32 N/mm²).

Resin-modified glass ionomer cement comes in two forms: liquid and powder. The liquid part usually contains water mixed with polyacrylic acid, HEMA, and a type of polyacrylic acid modified with methacrylate.[11] If the cement isn't kept away from saliva or blood during placement, it can wash away or break down early. Compared to resin-based composites, resin-modified glass ionomer cements are generally weaker, with lower strength and resistance to breaking. The study also showed that resin-modified glass ionomer cement has a weaker bond strength than dual-cure resin cement. [12]

By providing stability through both chemical and light activation, a dual-cure resin ensures polymerization even in region that are not covered by the cement. Tri Ethylene Glycol Di methacrylate (TEGDMA) has a high degree of flexibility and reduces shrinkage, and its light- curing mechanism makes controlling the monomer simple.[13] In contrast to resin modified glass ionomer cement, the resin's hydrophobic qualities prevent significant water absorption after curing, producing a strong bond strength.

Group-II samples were treated with 110µm alumina sandblast. The following are the mean bond-strength values that were found: resin modified glass ionomer cement (195.74 ± 219.86 N/mm²) < Dual cure resin cement (226.12 ± 268.80 N/mm²). The outcomes for the dual cure and RM glass ionomer are consistent with the earlier research carried out by V Arora et al. in 2010.[14]

In contrast to group I, the mean band strength value for resin modified glass ionomer cement did not significantly change, but the bond-strength of dual cure resin cement did. In the words of Blixt et al. (2000), sandblasting modifies surface structure, raising wettability and/or providing a larger surface area for luting agent chemical activation. These modifications might make it clearer why certain luting-agents show stronger bonds.[15]

Before applying resin, sandblasting with silica particles that contain aluminum oxide can increase the surface area by creating a silica layer, according to research by Kern and Thompson in 1994.[16] This layer strengthens the bond between the resin and the silica, especially with the help of a silane coupling agent in resin-modified glass ionomer cement. The strong bond between the silica layer and the inner surface of the crown may explain the high adhesion values seen with this cement. It was also found that crown retention improved when the size of the alumina particles used in sandblasting increased from 50 to 110 µm. This is likely due to the increased surface roughness, as noted by Al Jabbari et al. (2012), who found that grit sizes between 50 and 250 µm could make the surface rougher by up to 6.5%, creating a better surface for the luting agent to work. [17]

Comparative analysis of the metal crowns revealed a substantial difference in bond-strength, with all subgroups showing a substantial increase in bond-strength. The values were: resin modified glass ionomer cement (190.77 ± 233.52 N/mm²) < Dual-cure resin cement (267.40 ± 290.54 N/mm²). The process of sandblasting using 110 µm Al_2O_3 followed by ultrasonic cleaning appeared to enhance the bond between the tooth and crown.[18] The presence of loose silica particles on the silica-coated surface after sandblasting may diminish the interface, while their removal through ultrasonic cleaning may strengthen the bond.

Cobb et al.'s study in 2000 found that ultrasonic cleaning, which only removed loose Al_2O_3 particles from the metal surface, minimally reduced the metal's alumina content.

Consequently, most of the alumina remained securely bonded to the alloy surface.[19] The advantages of both cleaning techniques were realized when airborne particle abrasion and u/s cleaning were combined. This study demonstrated the highest crown retention, significantly surpassing that of any single cleaning technique. [10]

This study found a clear difference in the bond strength of metal crowns when luted with dual-cure resin cement after different surface treatments. The bond strength increased consistently: from using 110µm alumina particles (226.12 ± 268.80 N/mm²) to using 110µm alumina with ultrasonic cleaning (267.40 ± 290.54 N/mm²), compared to crowns with no treatment (226.40 ± 247.54 N/mm²).

These results confirm findings from earlier studies. The increased roughness likely allowed more cement to flow into tiny gaps, making it harder for the cement to fail, which explains why resin-modified glass ionomer cement had better retention. Crowns with smoother surfaces had lower retention, while those with surface treatments had better retention.

Subgroups (crowns luted with resin modified glass ionomer cement) were compared, and all surface treatment techniques showed a notable variation in bond strength values. The untreated group's value was noticeably lower. This analysis aligns with former research conducted by different authors.[20,21,22] . Resin modified glass ionomer cement may have a better retentive bond-strength because of its capacity to wet the surfaces involved.

Cementing quality was influenced by the makeup of dual-cure resin cements in addition to pretreatment. These resin cements contain Bis-GMA and other cross-linking monomers, which result in high molecular weight, low polymerization contraction, and quick hardening of polymers with excellent mechanical quality.[23]

When compared to resin modified glass ionomer cement, dual-cure resin materials generally provide higher bond-strengths. This is due to their ability to create long-lasting adherence by forming solid covalent bonds with both tooth structure and restorative materials. Resin modified glass ionomer cement, on the other hand, rely on a mix of adhesive mechanisms, such as ionic bonding with the glass component and chemical adhesion to tooth structure, to provide moderate bond strengths. [24]

In general, dual-cure resin materials form stronger bonds than resin-modified glass ionomer cement. This is because dual-cure resin creates strong, long-lasting bonds with both the tooth and the restoration. It uses different adhesive methods, such as chemical bonding with the tooth and ionic bonding with the glass part. Resin-modified glass ionomer cement, on the other hand, provides moderate bond strength.

Dual-cure resin materials are great for areas in the mouth that experience a lot of pressure because they are strong, flexible, and resistant to breaking. In contrast, resin-modified glass ionomer cement is weaker and more likely to wear down or crack, especially in areas with heavy chewing forces.

In this study, the type of luting agent and surface treatment affected retention. The group with no treatment had the lowest bond strength, even after being sandblasted with 110 µm alumina and cleaned with ultrasound. Dual-cure resin cement had the strongest bond, while resin-modified glass ionomer cement had the weakest bond strength.

Limitations of study:

- Only specimens with metal-crowns were used.
- This research didn't include any specimens that were ceramic or metal-ceramic.
- A few additional surface treatments, like steam cleaning and chemical cleaning, were left out.
- The oral environment was not simulated.

Conclusion:

The following conclusions, given the parameters of the study, could be made:

- Of all the surface treatments employed in this investigation, sandblasting with 110 µm alumina and ultrasonic cleaning produced the highest bond strength.
- The maximum bond strength was demonstrated by dual-cure resin-cement out of both the luting-agent types used.
- When the bond strengths of metal-crowns luted with resin modified glass ionomer cement were compared across various surface-treatment groups, the results showed that the combination of 110 µm alumina sandblasting and ultrasonic cleaning produced the strongest bond.
- When the band strength of metal-crown luted with dual-cure resin were compared across various surface-treatment groups, it showed that the combination of 110µm alumina sandblasting and ultrasonic-cleaning produced the strongest bond-strength.

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Ethical consideration: the research was approved by the Institutional Ethical Committee (ref no. TMDCRC/IEC/21-22/PCB3)

Conflict of interest: None

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