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Comparative Evaluation of Retention of 3D Printed Resin Crowns Cemented on Extracted Primary Molars Using Various Luting Cements: An Invitro Study

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ABSTRACT

Aim

This study aimed to assess the retention of 3D-printed resin crowns fabricated using NextDent Crown & Bridge material (NextDent B.V., Soesterberg, The Netherlands) when cemented to extracted primary molars with three commonly used luting agents.

Materials & Methods

Thirty-nine exfoliated primary molars were cleaned and prepared using a uniform shoulder finish line. Digital scans of the preparations were used to design and print customized crowns. The samples were randomly distributed into three groups (n = 13) according to the cement used: conventional glass ionomer cement (GIC), resin-modified glass ionomer cement (RMGIC), and a self-adhesive resin cement (RelyX™ U200). After cementation, all specimens were stored at 37°C for 24 hours. Crown dislodgement was then performed using an Instron universal testing machine at a crosshead speed of 1 mm/min, applying force parallel to the tooth's long axis. The internal surface area of each crown was obtained from the CAD design, and retentive strength (MPa) was determined by dividing the peak load by this area. Statistical analysis was carried out using one-way ANOVA and Tukey's post-hoc test ($\alpha = 0.05$).

Results

The self-adhesive resin cement exhibited the highest retention value (41.70 MPa), followed by RMGIC (28.17 MPa), while the lowest retention was recorded for conventional GIC (18.03 MPa). Significant differences were observed among all three cements ($p < 0.05$), with each pairwise comparison showing statistical significance.

Conclusions

The type of luting agent plays a major role in the retention of 3D-printed crowns on primary molars. Self-adhesive resin cement demonstrated superior performance, whereas conventional GIC showed the weakest retention. Further in-vivo studies are needed to validate these laboratory findings.

Keywords

3D printing, primary molar, luting cement, retention, self-adhesive resin cement.

1.INTRODUCTION

In the past decade, interest in esthetic full-coverage restorations for children has grown substantially, driven by greater parental awareness, increased exposure to dental options through digital media, and a stronger emphasis on appearance among peers.[1,2] Although stainless steel crowns continue to be the standard option following pulp therapy because of their longevity and clinical reliability, their metallic appearance often limits acceptance. This has encouraged the development of tooth-colored alternatives, including prefabricated zirconia crowns, which offer excellent esthetics but require substantial tooth reduction, may cause wear to opposing teeth, and remain relatively expensive.[3]

With advances in additive manufacturing, 3D-printed resin crowns have emerged as a promising alternative for the restoration of primary molars.These restorations provide improved esthetics, good marginal adaptation, and relatively low production cost, while avoiding many of the technical complexities associated with CAD/CAM ceramic systems.[4] Early laboratory and short-term clinical studies have explored their physical properties and performance; however, optimal cementation strategies for securing these 3D-printed crowns in primary teeth have not been clearly established.[4,5]

Retention remains a fundamental determinant of success for any crown restoration. Besides accurate tooth preparation and crown adaptation, the choice of luting agent significantly influences resistance to displacement.[6] Luting cements contribute both mechanical and adhesive retention, reinforcing the crown-to-tooth interface and helping the restoration withstand functional stresses. [7]

Different categories of cements offer distinct bonding mechanisms. Conventional glass ionomer cements (GICs) form chemical bonds with tooth structure but have comparatively lower mechanical strength. Resin-modified glass ionomers (RMGICs) incorporate resin components, enhancing their physical properties through combined acid–base and polymerization reactions.[8,9] Self-adhesive resin cements utilize functional monomers such as 10-MDP to promote chemical and micromechanical adhesion to various substrates, often yielding stronger and more durable bonds.[9-11]

While extensive research has evaluated luting agents for stainless steel and zirconia crowns, significantly fewer studies have examined their performance with 3D-printed resin crowns in primary teeth.[12-15] To date, only a small number of clinical studies have explored the application of 3D-printed crowns in primary molars, most of which have used self-adhesive or dual-cure resin cements and have reported outcomes limited to short-term follow-ups.[4,16,17] In contrast, GIC and RMGIC have been widely used and better studied for other pediatric full-coverage restorations.

Considering the scarcity of existing data, this in-vitro investigation sought to evaluate and compare the retention of 3D-printed resin crowns on extracted primary molars when luted with conventional GIC, RMGIC, and a self-adhesive resin cement.

MATERIALS & METHODS

Ethical aspects and sample

The study received approval from the Institutional Ethics Committee prior to commencement by Government Dental College & Hospital, Nagpur. A total of 39 over-retained, extracted human primary maxillary and mandibular molars with intact crowns or only minor enamel caries were collected. Teeth with gross caries, excessive wear, cracks, or restorations were excluded. All teeth were cleaned using hand scalers, thoroughly rinsed, and preserved in distilled water at 37°C until testing. The samples were then randomly divided into three groups (n = 13) using a simple lottery method.

Tooth preparation and crown fabrication

Each specimen was positioned along its long axis and embedded in auto polymerizing acrylic resin blocks (2 × 2 × 5 cm), leaving approximately 1 mm of tooth structure exposed below the cementoenamel junction. Tooth preparation included 1.0–1.5 mm occlusal reduction and 1.0–1.5 mm uniform axial reduction with a shoulder finish line, carried out using a high-speed handpiece and diamond burs (Mani TC-S21). Undercuts were eliminated and internal line angles rounded to standardize preparations. (Fig 1a)

Prepared teeth were scanned with an intraoral scanner (Shining 3D Tech Co., Ltd. China) and crowns were designed in Exocad. (Fig 1b). The crowns were fabricated with a digital light processing (DLP) 3D printer (Shining 3D Tech Co., Ltd., China) using NextDent Crown & Bridge resin (NextDent B.V., Soesterberg, The Netherlands) as the printing material. After printing, crowns were post-cured per manufacturer instructions and the intaglio surfaces were sandblasted with aluminium oxide. Two small mesial and distal holes and an occlusal channel to accommodate a 22-gauge wire were included in each crown design to permit mechanical pull testing. (Fig 2)

Cementation protocol

Three widely used luting materials were evaluated in this study: a conventional glass ionomer cement (GIC), a resin-modified glass ionomer cement (RMGIC), and a self-adhesive resin cement. The manufacturing details have been provided in Table 1. Two-thirds of the intaglio surface of each crown was filled with the assigned cement and the crown seated on the prepared tooth with finger pressure for 2 minutes. Excess cement was removed with cotton rolls. The self-adhesive resin cement was polymerized for 20 seconds using an LED curing unit. All samples were then immersed in distilled water and maintained at 37°C for 24 hours prior to mechanical testing.

Testing procedure

A 22-gauge wire, pre-positioned through the mesiodistal slot of each crown, was secured to the upper grip of a universal testing machine (Instron) (Fig. 3). Tensile force was then applied along the long axis of the tooth at a crosshead speed of 1 mm/min until the onset of crown displacement was detected, corresponding to the first load peak. Maximum load at dislodgement was recorded (N). Intaglio surface area for each crown (mm^2) was obtained from the Exocad design files. Retentive strength, expressed in megapascals (MPa), was determined by dividing the recorded maximum load at failure (N) by the corresponding bonding surface area (mm^2).[18]

Statistical Analysis

Retentive strength data were tested for normality and homogeneity. Mean retentive strength values among the study groups were compared using one-way analysis of variance (ANOVA). When significant differences were identified, Tukey's post hoc test was applied for intergroup comparisons. The level of statistical significance was predetermined at $\alpha = 0.05$.

RESULTS & DISCUSSION

The highest mean retentive strength was observed with the self-adhesive resin cement (41.70 MPa), followed by resin-modified glass ionomer cement (28.17 MPa) and conventional glass ionomer cement (18.03 MPa), as summarized in Table 2. One-way ANOVA revealed that the type of luting cement had a statistically significant influence on retentive strength ($p < 0.05$). Tukey's post-hoc test showed that self-adhesive resin cement had significantly greater retentive strength than both RMGIC and conventional GIC, and RMGIC was significantly greater than conventional GIC.

With ongoing advancements in digital dentistry, three-dimensionally printed crowns are increasingly being explored as an alternative restorative option for primary teeth due to their esthetic appeal and capacity for individualized design. The clinical performance and longevity of such restorations are strongly influenced by the choice of luting cement.

A systematic review conducted by Virupaxi et al.[15] reported superior retention of stainless-steel crowns when cemented with self-adhesive resin cements. In contrast, the literature demonstrates considerable variation in the type of luting agents employed for zirconia crowns across different studies.[12,13,14,19]

Existing literature has evaluated the mechanical characteristics of three-dimensionally printed resin crowns, including biaxial flexural strength and fracture toughness, in their application to primary teeth, supporting their suitability as a restorative option in pediatric dentistry.[4,5,16,17] However, limited research exists on their bond strength with primary teeth.

In an in vitro investigation, Kim et al.[20] evaluated the shear bond strength between three-dimensionally printed resin materials and various resin-based cements used for pediatric crown restorations. Their findings reported mean SBS values of 23.29 ± 3.88 MPa, 26.14 ± 4.67 MPa, 25.41 ± 4.03 MPa, and 18.79 ± 4.26 MPa for Graphy, Next Dent, Mazic Duro, and VIPI Block Trilux (resin materials), respectively, when self-adhesive resin cement was utilized. However, the investigation was limited to assessing the bond strength between resin materials and luting cements, without incorporating the influence of primary tooth structure during the cementation process. Additionally, only resin cement was evaluated, while RMGIC and conventional GIC warrant further investigation.

The findings of the present in vitro investigation demonstrated that the type of luting cement had a significant influence on the retention of three-dimensionally printed resin crowns on primary molars. Self-adhesive resin cement exhibited the greatest retentive strength (41.70 MPa), while conventional glass ionomer cement showed the lowest values (18.03 MPa), leading to rejection of the null hypothesis.

In the present study, the mean retentive strength values obtained for the 3D-printed resin crowns (NextDent) were higher than the mean micro tensile bond strength of 23.20 MPa reported by Pfeffer et al.[21], who evaluated bonding between a 3D-printed resin specimen and a dual-cure resin cement. The observed variation in values may be attributed to differences in specimen fabrication, and testing protocols employed.

Currently, no official guidelines exist for the bond strength required in crown restorations. However, Matsumura et al. [22] suggested that a minimum bond strength of 10–20 MPa is necessary for crown prostheses, while other studies[23] have recommended bond strength values of 18–25 MPa for ensuring the clinical survival of composite repairs under occlusal forces.

In light of these recommendations and previously reported bond strength data for zirconia crowns cemented with resin-based luting agents, the present findings indicate that both self-adhesive resin cement and resin-modified glass ionomer cement demonstrate higher mean retentive strength values than conventional glass ionomer cement. However, RMGIC, being less technique-sensitive, offers a practical advantage.

The superior performance of the self-adhesive resin cement likely reflects its multimodal bonding mechanism: acidic functional monomers promote chemical interaction with tooth structure, while resin components provide micromechanical interlocking and enhanced cohesive strength. RMGIC showed intermediate performance, combining chemical bonding to tooth structure with resin polymerization for improved mechanical properties compared with conventional GIC.

Nevertheless, three-dimensionally printed resin crowns are associated with certain limitations, such as comparatively lower mechanical strength and reduced wear resistance when contrasted with CAD–CAM composite resin ceramics and conventional ceramic materials. They are also prone to discolouration and surface roughness making them a high maintenance restorative option. Also, the printing process is lengthy and can introduce inhomogeneities like voids or layer inconsistencies. These factors can make it challenging for a clinician to use these crowns.[24]

However, considering its advantages like a precise fit, esthetic look and cost effectiveness more clinical trials and precise bonding protocols for these crowns can be helpful for its use in pediatric dentistry.

CONCLUSIONS

1. Luting cement type significantly influences the retention of 3D-printed resin crowns cemented to primary molars in vitro.
2. Self-adhesive resin cement produced the highest retentive strength; conventional glass ionomer cement produced the lowest.
3. Resin-containing luting agents may be preferred for better retention, but clinical studies are needed to confirm in-vivo performance.

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Table 1: Luting cements in the study.

	Material Manufacturer	Cementation protocol
Conventional glass ionomer luting cement	**GC GOLD LABEL 1 LUTING & LINING CEMENT** GC FUJI Type I, GC CORPORATION 76–1 HASU UNUMA–CHO, ITABASHI–KU, TOKYO, JAPAN	One part powder and one drop of liquid were mixed for 30 seconds. Working time at room temperature was approximately 3 minutes, hardening time was 5-7 minutes. After cementation excess cement was removed using cotton roll.
Resin modified glass ionomer luting cement	**HY-BOND RESIGLASS** Shofu Inc., Higashiyama-ku, Kyoto 605-0983, Japan	One part powder and two drops of liquid were mixed for 30 seconds. Working time at room temperature was about 2-4 minutes, hardening time was 3-5 minutes.
Self-adhesive resin cement	**3M RelyX™ U200 Self-Adhesive Resin Cement,** 3M Center, St. Paul, Minnesota 55144, USA	The cement, which was squeezed equally from the base and catalysis syringes, was mixed for 15 seconds. After removing the excess cement applied, it was polymerized by applying visible light for 20 seconds from each surface of the samples.
Next Dent Crown & Bridge Microfilmed Resin	**NEXT DENT C &B MFH** NextDent B.V., Soesterberg, The Netherlands	

Table 2: Mean retentive strength of the three groups

Group	N	Mean	SD	p-value
GIC	13	18.03	5.94	<0.001*
RMGIC	13	28.17	4.62	
Self-adhesive resin cement	13	41.70	11.51	

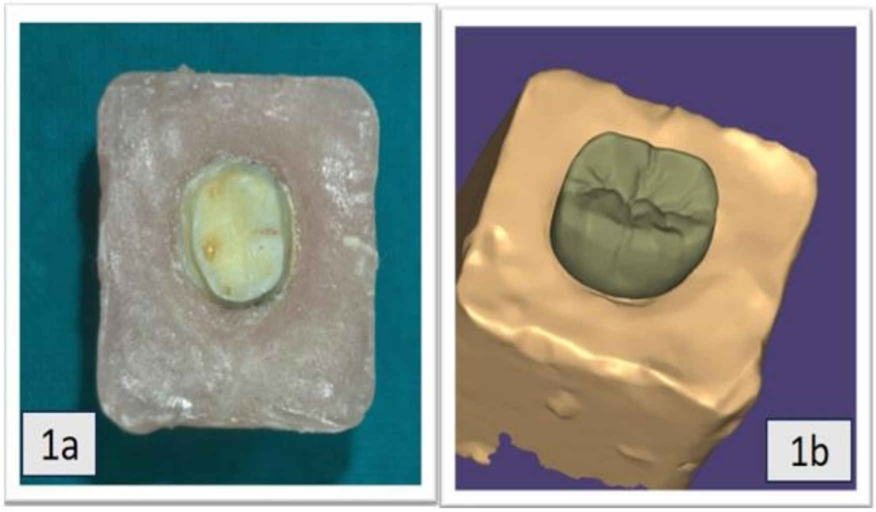
One Way ANOVA test; p≤0.05 indicates a significant difference, SD- Standard deviation, GIC- glass ionomer cement, RMGIC- resin modified glass ionomer cement.

Figure Legends:

Figure 1: Sample preparation: Fig 1a- Crown preparation, Fig 1b- Designing of 3D printed crown in Exocad Software

Figure 2: Wire engaged for testing purpose

Figure 3: Sample attached to Instron Universal testing machine



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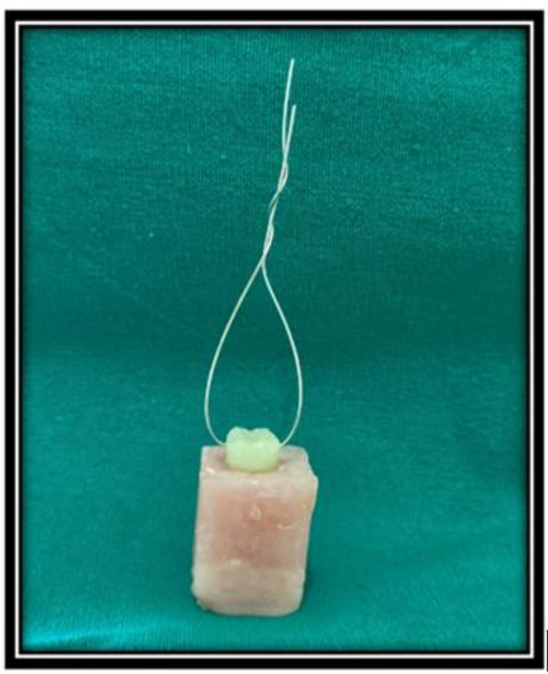

Fig 2: Wire engaged for testing purpose

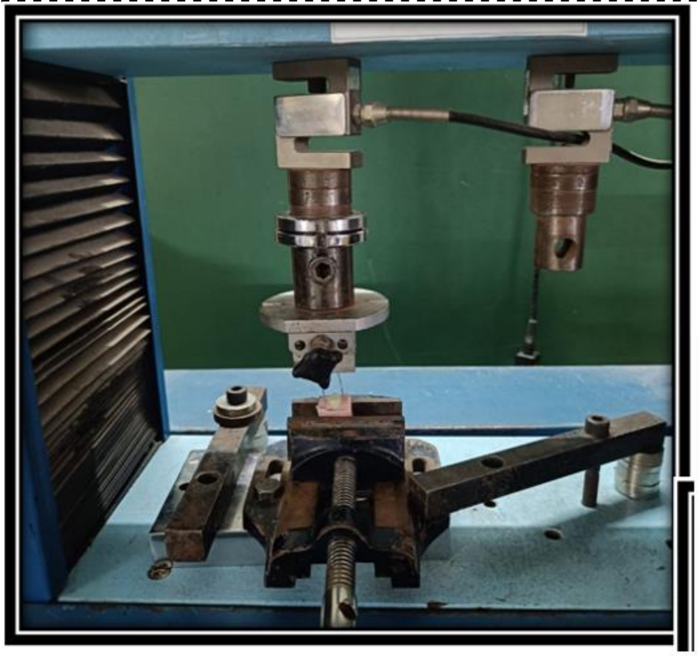

Fig 3: Sample attached to Instron Universal testing machine