ORIGINAL RESEARCH

Comparative Evaluation of Shear Bond Strength of Bonded Space Maintainers Using Ormocers, Nanofilled and Glass Fiber-reinforced Adhesive Composites

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Abstract

Background: Space maintainers (SMs) are used to preserve the space created by premature loss of primary teeth. The most commonly used is the band and loop (B&L) SM. As this SM has several drawbacks, such as poor esthetics and gingival health, laboratory procedures for fabrication, and multiple seating procedures, various bonded SMs were introduced. This study aims to compare the shear bond strength of bonded SMs using ormocer, nanofilled, and short glass fiber-reinforced adhesive composites with the conventional B&L SM luted with type I glass ionomer cement (GIC).

Materials and methods: Sixty intact extracted primary molars were randomly divided into four groups ($n = 15$). In group I (control), conventional B&L SMs were luted with type I GIC, whereas ormocer, nanofilled, and glass fiber-reinforced composites (GFRC) were used to bond the SMs in groups II, III, and IV, respectively. Shear bond strength of all the specimens was analyzed using a universal testing machine, and the obtained data were subjected to statistical analysis.

Results: The highest shear bond strength, that is, 68.82 ± 16.81 MPa, was exhibited by GFRC, followed by 51.04 ± 23.28 MPa with nanofilled composite, 45.3 ± 18.27 MPa with ormocer, and the least in the control group, that is, 42.17 ± 17 MPa.

Conclusion: Glass fiber-reinforced resin composite has better resistance against shear force than the other three study materials, and this was significantly higher ($p = 0.001$) than conventional B&L SMs.

Keywords: Bonded space maintainers, Glass fiber-reinforced composites, Nanofilled, Ormocer.

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Introduction

The early loss of deciduous teeth will lead to unwanted mesial and distal movements of deciduous and permanent teeth, resulting in decreased arch length.[1] A space maintainer (SM) helps maintain the space created by the lost primary tooth until the eruption of its successor. The best time to place an SM is immediately after the loss of the tooth because the amount of tooth displacement is greater in the first 6 months following the loss of the tooth.[2] The most commonly used SM is the band and loop (B&L) SM, but the fabrication of banded SMs requires elaborate instrumentation, tedious lab work, and the possibility of band distortion while transferring from the cast onto the tooth cannot be excluded. Moreover, banded teeth are prone to caries and decalcification. After the introduction of enamel etching and bonding in dentistry, direct bonded SMs have been investigated clinically. However, it has been shown that the longevity of banded SMs is limited with conventional adhesive composites due to a lack of strength and other mechanical properties needed to withstand masticatory forces in children.[3] With the advent of newer resin composites with better bond strength and mechanical properties, bonded SMs are more promising for withstanding masticatory forces in children.

As there is limited information published on the comparison between conventional B&L SMs and bonded SMs, the aim of this study is to determine the strength of bonded SMs using new and improved adhesive composites and to compare them with conventional B&L SMs, luted with type I glass ionomer cement (GIC).

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Conflict of interest: None

Materials and Methods

Ethical clearances for the study were obtained from the Institutional Ethics Committee. Sixty noncarious human primary second molars (exfoliated or extracted as they were over-retained) were collected, thoroughly cleaned, and stored in phosphate buffered saline solution at room temperature. Primary second molars with no buccal and/or lingual caries, no developmental malformations, with sufficient intact crown enamel, and intact buccolingual surfaces were included in this study. Primary second molars with buccal and/or lingual caries, cracks, restorations, and fractured teeth were excluded from the study.

All the 60 deciduous second molar teeth were mounted on individual acrylic blocks, and a primary canine made of dental stone was placed at an average distance of 8–10 mm from the mesial surface of the primary molar crown to mimic the mesial abutment teeth for placement of SMs. Stainless steel (SS) wire (0.7 mm) was used to make a loop, similar to the loop of a B&L SM, and the loop was placed resting against the distal surface of the primary canine below the contact area. Randomization was done, and the samples were divided into four groups (15 in each group).

Group I: Control group—conventional B&L SM luted with type I GIC (GC Fuji I, Tokyo) (Fig. 1).

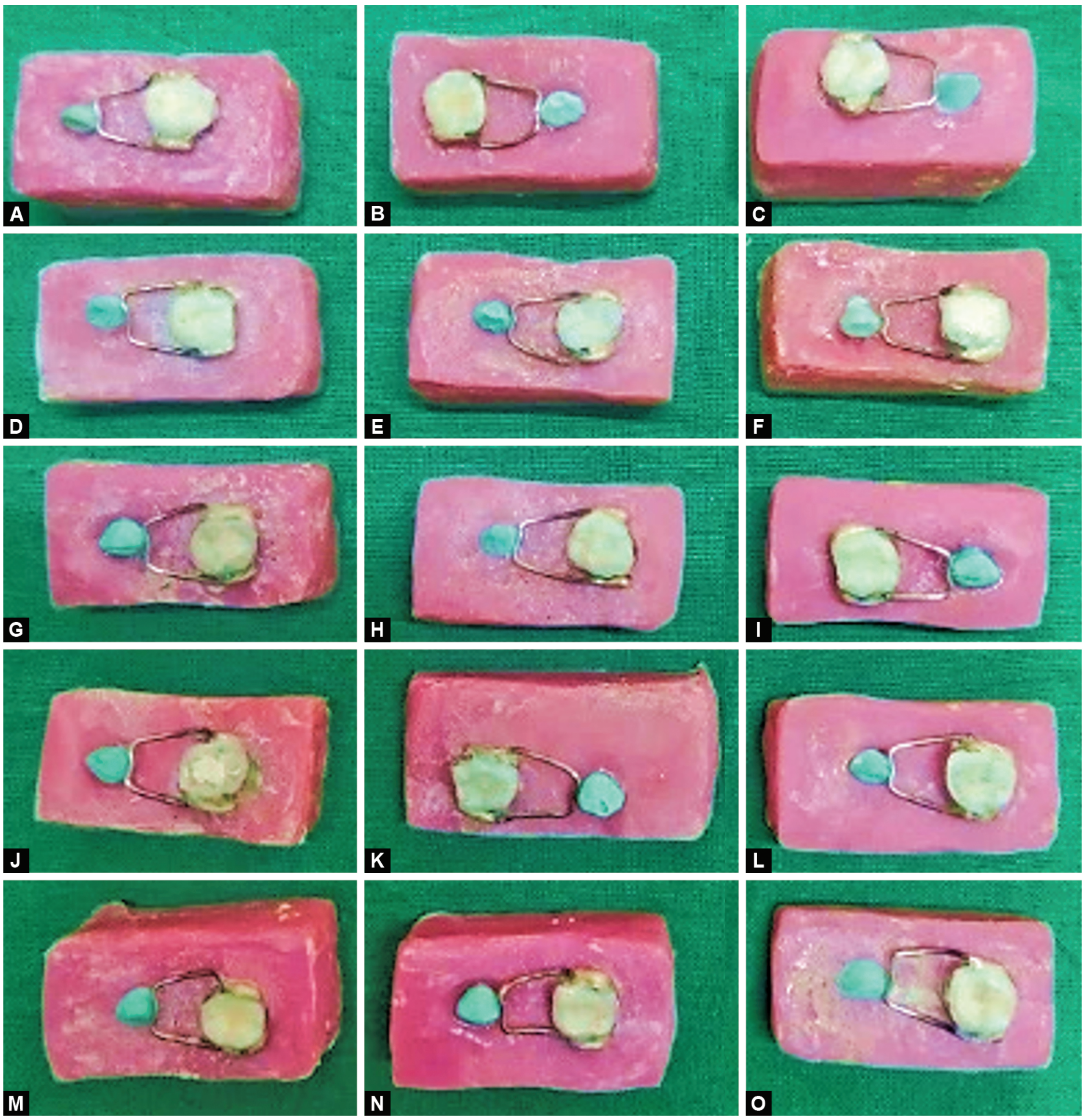
Group II: SS wire loop bonded with ormocer (organically modified ceramic-based composite) (Admira, VOCO GmbH, Germany) (Fig. 2).

Group III: SS wire loop bonded with nanofilled composite (Filtek Z350 XT composite, 3M ESPE, St Paul, Minnesota) (Fig. 3).

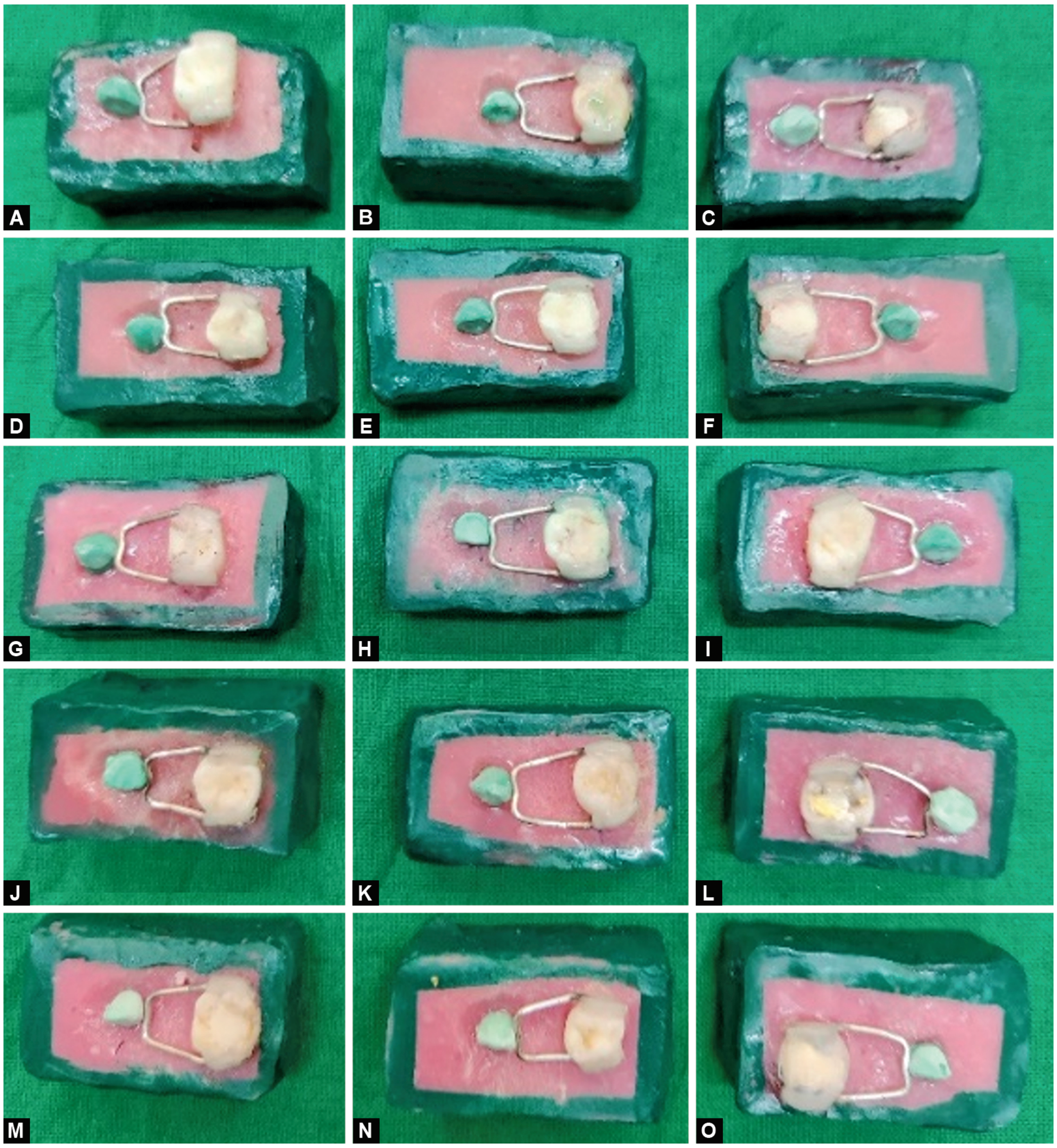
Group IV: SS wire loop bonded with short glass fiber-reinforced composite (GFRC) (EverX Posterior, GC, Tokyo, Japan) (Fig. 4).

In group I, band pinching is done with 0.005 × 0.180 inches band material (Dentomech, India) using curved hoe pliers (Metro Orthodontics, India) on the primary second molar crown mounted on an acrylic block. The band is then transferred to the impression, and a cast is made with dental stone (Gem Stone, India). The SS wire loop is soldered to the band on the cast, and the B&L SM is luted with type I GIC on the primary second molar teeth.

In groups II, III, and IV, after 20 seconds of etching with 37% phosphoric acid (Ivoclar Vivadent, N Etch, Schaan, Liechtenstein) on the buccal and lingual surfaces of the sampled teeth, they were rinsed with water for 30 seconds and air-dried for 15 seconds. The fourth-generation bonding agent (Adper Scotchbond Multipurpose, 3M ESPE, St Paul, Minnesota) was applied using an applicator brush on the buccal and lingual surfaces of the teeth, and curing was done according to the manufacturer's instructions. The SS wire loop was positioned on



Figs 1A to O: Group I (control group)—conventional B&L SM



Figs 2A to O: Group II—bonded SM with ormocer composites

the middle third of the buccal and lingual surfaces of the primary second molar teeth mounted on acrylic blocks. Approximately, 1.5 mm thickness of either of the adhesive composites, namely ormocer, nanofilled, and GFRCs, were applied over the buccal and lingual surfaces of the teeth in groups II, III, and IV, respectively. The SS wire loop was embedded in the adhesive composite and cured with a light curing device (Dentsply, United States) for 40 seconds.

All the samples were subjected to thermocycling (Thermal-cycler, Taurus Scientific, Ohio, United States) at 55°C for 15 seconds to simulate real oral thermal conditions. Testing for shear bond strength was carried out using a universal testing machine (Dak Systems Inc. Series 7200, Mumbai, India) (Fig. 5), in tensile mode at a cross-head speed of 1 mm/minute. The mounted teeth were secured to the Instron's attachment apparatus using a clamp. A 0.3 mm SS wire loop was inserted below the loops of the B&L SM and bonded SM samples. To engage the stainless-steel wire loops, a custom-made jig was clamped to the attachment apparatus of the Instron machine. Each sample was tested until the B&L or bonded loop was completely detached from the primary second molar tooth. For each specimen, the maximum force needed to remove the band was recorded and expressed in newtons (N) (1 MPa = 1 N/mm^2), and shear bond strength was then calculated by dividing the peak load values by the band surface area. All the values were subjected to statistical analysis (analysis of variance and *post hoc*).

Results

The control group showed the lowest shear bond strength, that is, 42.16 ± 17.1 MPa, followed by group II with 45.34 ± 18.27 MPa, group III with 51.04 ± 23.28 MPa, and group IV, which showed the highest shear bond strength of 68.82 ± 16.81 MPa. This difference is statistically significant ($p = 0.001$) (Table 1).

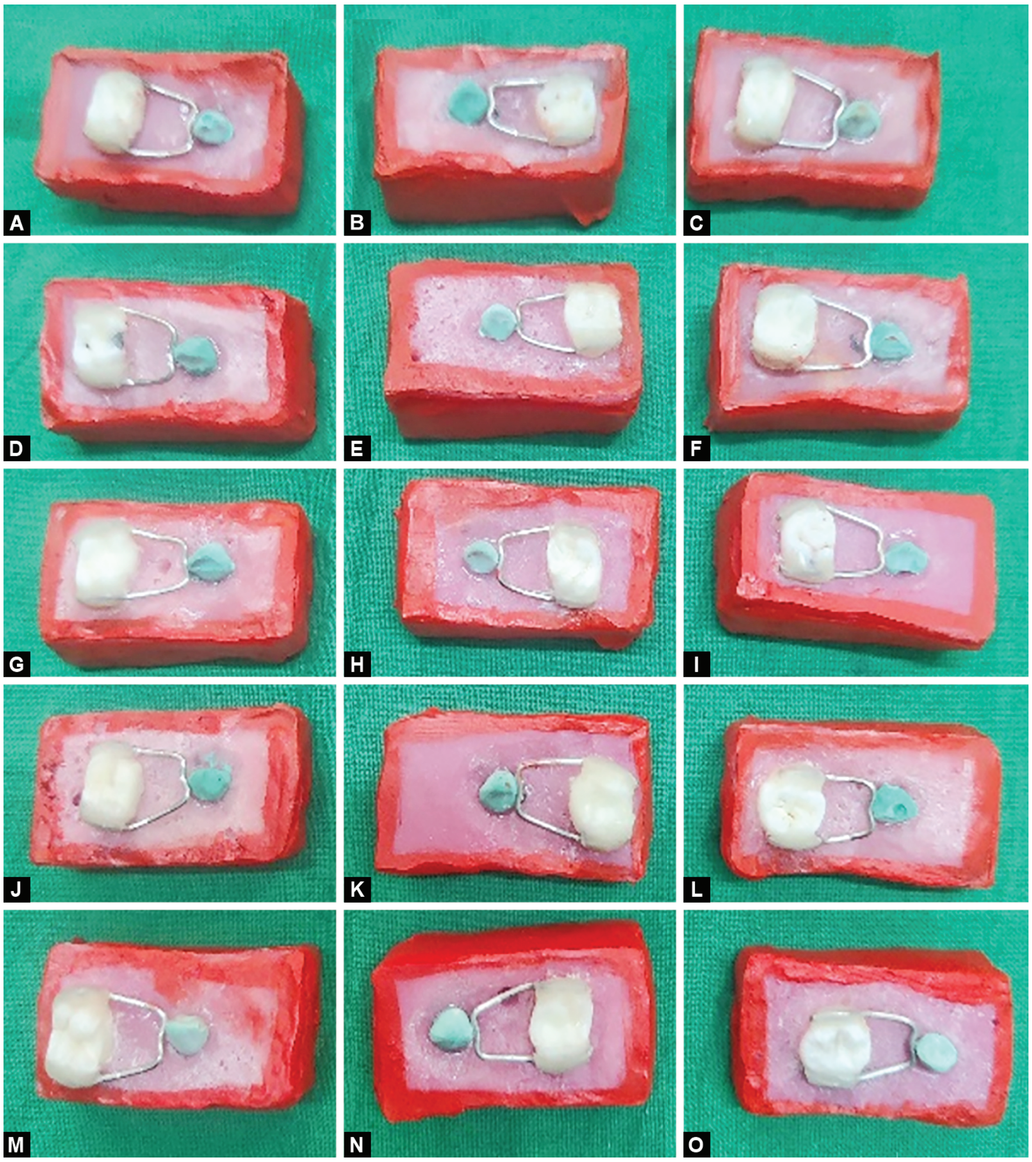
During the intercomparison of the mean values, when compared to the control group, groups II and III showed a mean difference of −3.18 and −8.87, respectively, which are statistically not significant ($p > 0.05$). In contrast, group IV showed a mean difference of 26.66, which is statistically highly significant ($p = 0.002$) (Table 2).

During intercomparison among the three study groups, when group II was compared with group III, a mean difference of 5.69 was found, which was statistically not significant ($p = 0.845$). However, when group II was compared with group IV, there was a mean difference of 23.48, which was statistically highly significant ($p = 0.007$). When group III was compared with group IV, the mean difference was 17.79, which was also statistically not significant ($p = 0.062$) (Table 3).

Discussion

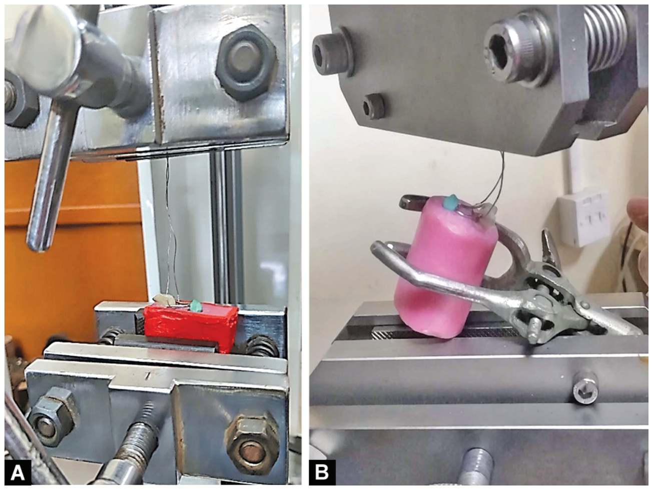
The mean shear bond strength was found to be the highest with short GFRC. Intercomparison showed statistically significant differences between group II and group IV ($p = 0.007$) and between group I and group IV ($p = 0.002$), indicating that GFRC is more resistant to distortion due to shear forces compared to B&L SMs and ormocer composites. This is attributed to its improved mechanical properties without affecting the degree of conversion of the resin matrix, due to the presence of short glass fibers. The recently introduced short glass fiber-reinforced EverX composites have been used in load-bearing areas as they possess excellent physical properties, such as high fracture toughness and load-bearing capacity. The EverX composite shows high fracture resistance because it is made of E-glass fibers (8.6 wt%) and barium glass fillers (67.7 wt%). These 1–2 mm length E-glass fibers enhance mechanical properties when incorporated within the composite material and control crack propagation by transferring stress, reducing polymerization shrinkage, and minimizing marginal microleakage through proper orientation.[4] Similar results were found in a study done by Behl et al. and Garoushi et al.

In contrast to opaque-colored carbon or zirconia fibers, Behl et al.[5] and Garoushi et al.[6] found that adding glass fibers to dental composites will enhance their mechanical properties without

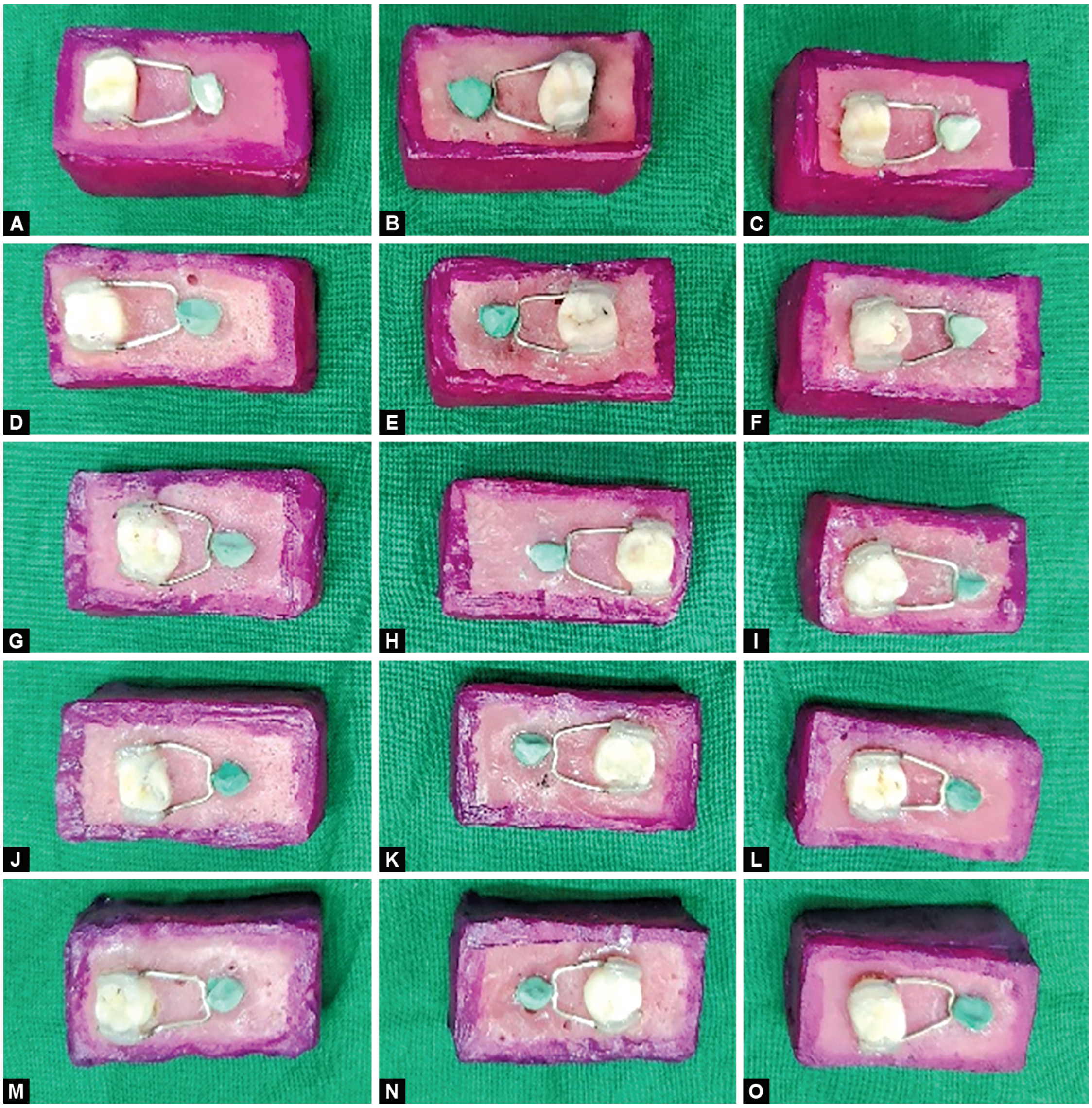


Figs 3A to O: Group III—bonded SM with nanofilled composites changing the degree of resin matrix conversion. However, in a study conducted by Callaghan et al.,[7] lower wear volumes and wear rates were observed in longer fibers compared to short fibers because short fibers can easily cluster, resulting in weak regions. Additionally, no coupling agent was used in their study. In contrast, the present study evaluated shear bond strength using a fourth-generation bonding agent, which likely contributed to the higher shear bond strength observed with short GFRCs.

The GFRC exhibited better shear bond strength than nanofilled composites, but on intercomparison, it is not statistically significant. These results are similar to the studies of Preethy et al.[8] and de Jesus Tavarez et al.[9] and may be attributed to the nanoparticle size of the resin with high polymerization shrinkage than GFRC. However, nanofilled composites are superior to ormocer and B&L SMs. Sahoo et al.[10] concluded that nanocomposites exhibited higher shear strength than ormocer composites due to the greater amount of fillers in nanocomposites. In these nanocomposites, water is absorbed into the matrix at a lower rate. Kaur et al.[11] found



Figs 5A and B: Testing of samples for shear bond strength under universal testing machine



Figs 4A to O: Group IV—bonded SM with glass fiber-reinforced adhesive composites

Table 1: Mean values of shear bond strength (MPa) of control and study groups

			95% CI for mean			
Groups	*Study materials*	*Mean ± standard deviation (SD)*	*Lower*	*Upper*	*F*	*p-value*
Group I	Type I GIC	42.1667 ± 17.0016	32.7515	51.5819	5.868	0.001**
Group II	Ormocer composite	45.3467 ± 18.2796	35.2237	55.4696		
Group III	Nanofilled composite	51.04 ± 23.2895	38.1427	63.9373		
Group IV	GFRC	68.8267 ± 16.8126	59.5161	78.1372		

**Highly significant; CI, confidence interval; F, Fischer-Snedecor distribution; MPa, megapascal; *p*, probability

Table 2: Intercomparison of shear bond strength between control group and study groups

Groups	*Description*	*Mean ± SD*	*Mean difference*	*p-value*
Group I	Type I GIC	42.1667 ± 17.0017	3.1800	0.968^{NS}
Group II	Ormocer composite	45.3467 ± 18.2797		
Group I	Type I GIC	42.1667 ± 17.0017	8.8733	0.581^{NS}
Group III	Nanofilled composite	51.0400 ± 23.2895		
Group I	Type I GIC	42.1667 ± 17.0017	26.6600	0.002*
Group IV	GFRC	68.8267 ± 16.8127		

*Significant; NS, not significant; *p*, probability; SD, standard deviation

Table 3: Intercomparison of shear bond strength among study groups

Groups	*Description*	*Mean ± SD*	*Mean difference*	*p-value*
Group II	Ormocer composite	45.3467 ± 18.2797	5.6933	0.845^{NS}
Group III	Nanofilled composite	51.0400 ± 23.2895		
Group II	Ormocer composite	45.3467 ± 18.2797	23.4800	0.007*
Group IV	GFRC	68.8267 ± 16.8127		
Group III	Nanofilled composite	51.0400 ± 23.2895	17.7867	0.062^{NS}
Group IV	GFRC	68.8267 ± 16.8127		

*Significant; NS, not significant; *p*, probability; SD, standard deviation

that nanocomposites have high strength than ormocer composites, because it has both bisphenol A glycidyl methacrylate (Bis-GMA) and bisphenol A ethoxylate methacrylate (Bis-EMA), which make them more resistant to degradation. However, ormocer showed lesser strength than nanocomposites and GFRC due to the presence of triethylene glycol dimethacrylate, which resulted in solvent susceptibility and a plasticizing effect.[10] According to Kalra et al.,[12] ormocers have lower wear resistance and exhibit more cytotoxity than nanocomposites, which indicates that their qualities are inferior to those of hybrid composite materials. However, in contrast, the studies done by Efes et al.[13] and Mahmoud et al.[14] compared ormocer, nanofilled, nanoceramic, and a hybrid composite and concluded that there were no statistical differences among the materials.

When compared to self-adhesive resin cement, Zareen et al.[15] and Kaur et al.[16] found that the shear peel bond strength of conventional luting GIC was lower because some GICs take several months to become stable and the maximum bond strength for glass ionomers is only reached after the cement has gone through its maturation process. GICs have a number of drawbacks, including poor wear resistance, low fracture toughness, and dissolution from water sorption, which gradually weakens the cement and encourages the growth of bacteria and microleakage, potentially leading to secondary caries.[17]

Further research with long-term clinical trials involving a large number of samples must be conducted to determine the clinical efficiency and longevity of GFRC, and to evaluate its potential as an alternative to traditional B&L SMs.

Conclusion

Within the limitations of the present study, GFRC demonstrated higher shear bond strength. Since higher shear bond strength increases the retention of the composite and enhances its longevity in the oral cavity, contributing to the long-term success of bonded SMs, it can be concluded that GFRC performs better than other study materials as well as traditional B&L SMs luted with type I GIC. They ensure better patient cooperation and are also economical, as only a chairside technique is involved. Their regular use in pedodontic practice is more promising.

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