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Original Research

Comparative Evaluation of Shear Bond Strength of Three Commercially Available Glass Ionomer Cements in Primary Teeth

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Abstract:

Background: This study aims to comparatively evaluate the shear bond strength (SBS) of three commercially available glass ionomer cements - Miracle Mix (MM) (GC America Inc., Alsip, USA), Ketac Molar (KM) (3M Corp., Minnesota, USA) and amalgomer CR (AM) (Advanced Healthcare Ltd., Kent, England) in primary teeth and later examine the mode of the adhesive failure at the interface.

Materials and Methods: Totally, 90 extracted sound primary molars were selected, and dentin on the buccal surface of crowns was exposed. Specimens were randomly assigned into three groups according to the restorative materials being tested. SBS tests were performed, and the obtained values were statistically analyzed using ANOVA and Tukey tests ($P < 0.05$). SBS mean values on were recorded in megapascals (MPa) and the mode of failure was assessed using a scanning electron microscope.

Results: SBS (in MPa) was - MM-5.39, KM-4.84, AM-6.38. The predominant failure mode was cohesive.

Conclusion: Amalgomer CR exhibited statistically significant higher SBS of 6.38 MPa to primary teeth and has better adhesion to the primary teeth compared to the other test materials and can be considered as a restorative material in pediatric dentistry. However, the results of this study should be corroborated with further investigation to reach a definitive conclusion.

Key Words: Glass ionomer cement, pediatric dentistry, primary tooth, shear bond strength.

Introduction

Restorative dentistry in children is one of the most challenging branches in dentistry as children have variable levels of cooperation, lesser attention span and require stringent safety measures. The primary teeth restoration differ from permanent teeth due to the limited lifespan of teeth, different morphology of primary molars, lower biting forces in children and their susceptibility to caries.[1-3]

An ideal restorative material in children requires minimal cavity preparation, have adequate strength and wear properties, be easy to place with a certain amount of adhesion to tooth structure, and not be moisture sensitive during placement and setting.[4] Glass ionomer cement (GIC) seems to meet most of these requirements along with particular advantages like ability to leach fluoride, coefficient of thermal expansion similar to tooth, chemical bonding to enamel and dentin, dimensional stability, insolubility in oral fluids at intraoral temperatures, excellent biocompatibility,[5] better esthetics and less sensitivity to dentin moisture[6] making it highly appropriate for use in children.

The adhesiveness of restorative materials to tooth structure is an important factor in current restorative technique.[7] It prevents micro leakage, secondary caries, marginal discolorations and pulpal damage. With effective adhesion, removal of healthy dentin for retentive undercuts becomes unnecessary. Adhesions are usually evaluated by the determination of tensile and shear bond strength (SBS). Some of the commercially available GICs are silver reinforced GIC - miracle mix (MM) (GC America Inc., Alsip, USA). High viscosity GIC -ketac molar (3M Corp., Minnesota, USA) and the more recent ceramic reinforced glass ionomer amalgomer CR (Advanced Healthcare Ltd., Kent, England), which are used in children. Thus, the present study was conducted to determine the SBS of the above-mentioned GICs in primary teeth *in vitro*. This study comparatively evaluates SBS as the values of bond strength vary greatly with the method used, and it is advisable not to focus on absolute values of bond strength, but rather to compare different types or brands of materials.[8]

Materials and Methods

Totally, 90 human deciduous non-carious primary molars that had been extracted for therapeutic purposes were collected, cleaned and stored in distilled water at room temperature.

Criteria for selection of teeth

- No caries/cracks
- Intact crown enamel.[9]

The teeth after selection were randomly assigned into three test groups of 30 each. The tooth samples were embedded in a polyvinylchloride pipe using cold cure acrylic (DPI, India) with buccal surface exposed, and color coded according to the material used with duct tape (Figure 1). Enamel on the buccal surface was removed using a high-speed diamond disc. The buccal surfaces were used for testing SBS because it showed the least variation and provided the most favorable conditions for testing an adhesive.[10] The exposed dentinal surface was the ground flat, and the final surface was prepared with 320 grit wet silicon carbide paper to create a fresh surface. Surface was cleaned with pumice and rubber cup as it was found that polishing the dentin surface with pumice slurry reduced the layer of surface debris and did not affect the bond strength to dentine significantly.[11] Teeth were rinsed and dried. The flattened dentin surface of all the specimens was treated with dentin conditioner for 20 s, rinsed thoroughly with water and dried using absorbent paper. All three restorative materials i.e., Miracle Mix (MM) (GC America Inc., Alsip, USA), Ketac Molar (3M Corp., Minnesota, USA) and ceramic reinforced glass ionomer amalgomer CR (Advanced Healthcare Ltd., Kent, England) were manipulated according to manufacturer's instructions and placed on the smoothened buccal surface of the respective samples using a template bearing a hole measuring 3 mm diameter and 2 mm depth and stabilized using scotch tape (3M Corp) (Figure 2). The excess material was removed, and the restoration was coated by dental varnish (Copalite, Cooley & Cooley Ltd., Tx, USA). All the samples were stored in distilled water for 24 h at room temperature and subjected to thermo cycling between 5° ± 2° and 55° ± 2° in a water bath for 100 cycles with a dwell time of 30 s.[12]

Test procedure

The mounted samples were subjected to SBS test in a Universal Testing Machine (Instron Corporation, USA) using a knife edge blade running at a cross-head speed of 1 mm/min (Figure 3). The results were recorded in megapascals (MPa).[4,6,7,10,12-14] Following this, the specimens were observed under stereo microscope for adhesive and cohesive failure.

Shear strength of each sample is calculated using the formula:

Shear strength (MPa) = Break force/bonding surface area

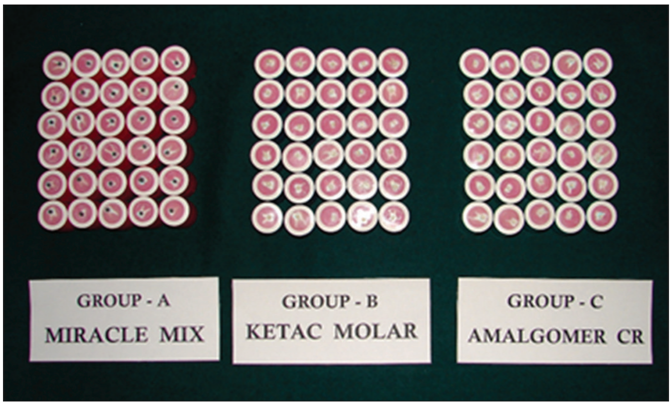


Figure 1: Tooth samples

The data obtained were subjected to statistical analysis using One-way ANOVA and Tukey's test. Chi-square test has been used to find if there is any significant association between the failure and the groups ($P = 0.347$).

Results

The SBS of Miracle Mix ranged from 3.62 MPa to 7.32 MPa with a mean of 5.39 MPa, of Ketac Molar ranged from 2.80 MPa to 6.46 MPa with a mean of 4.84 MPa and amalgomer CR ranged from 4.72 MPa to 8.37 MPa with a mean of 6.38 MPa (Graph 1 and Table 1). Three types of fractures were recorded - Adhesive fracture (Figure 4), cohesive fracture (Figure 5) and mixed type of fracture (Graph 2 and Table 2). The Chi-square statistic (Pearson's Chi-square) revealed that there was no significant association between the failures and the groups ($P = 0.347$).

Discussion

GIC systems have become important dental restorative materials for use in children as they are easy and practical to use,[15] leach fluoride and adhere to tooth structure. Our study showed the SBS of miracle mix to be 5.39 MPa. These results

Figure 2: Material placed using template

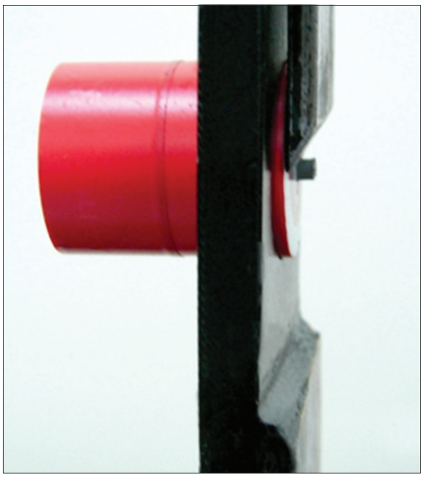


Figure 3: SBS testing in Universal testing machine

Table 1: SBS of tested samples.

Descriptives								
SBS	**n**	**Mean**	**SD**	**SE**	**95% Confidence Interval**		**Minimum**	**Maximum**
					Lower bound	**Upper bound**		
MM	30	5.39118	0.95738	0.17479	5.03369	5.74867	3.6202	7.3253
KM	30	4.844850	0.95686	0.17469	4.48755	5.20214	2.8000	6.4626
Amalgomer CR	30	6.38390	0.92191	0.16831	6.03965	6.72815	4.7232	8.3717
Total	90	5.53998	1.13329	0.11946	5.302617	5.77734	2.8000	8.3717

SBS: Shear bond strength, MM: Miracle mix, KM: Ketac molar, SD: Standard deviation, SE: Standard error

Table 2: Type of failures.

Fracture*Group cross tabulation				
Count	**Group**			**Total**
	MM	**KM**	**Amalgomer CR**	
Fracture				
Mixed failure	2	3	3	8
Adhesive failure	3	7	2	12
Cohesive failure	25	20	25	70
Total	30	30	30	90

MM: Miracle mix, KM: Ketac molar

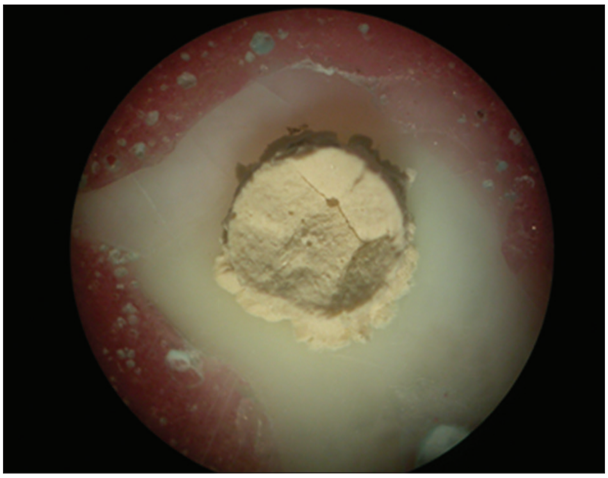


Figure 4: Adhesive fracture

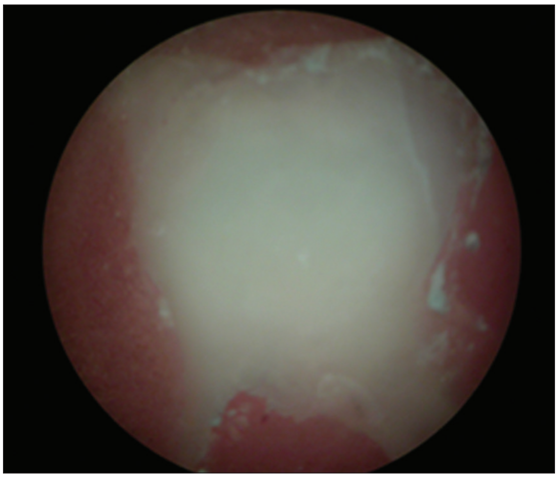
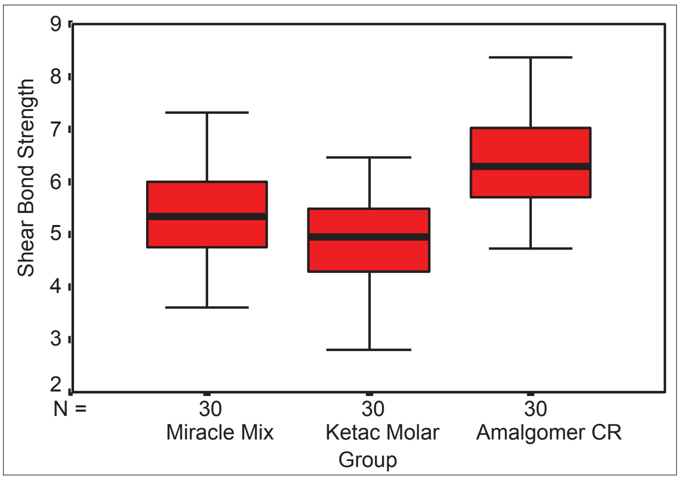


Figure 5: Cohesive fracture

are slightly higher than the values of the SBS of miracle mix in permanent teeth, which were found to be 4.08 MPa.[14] Another



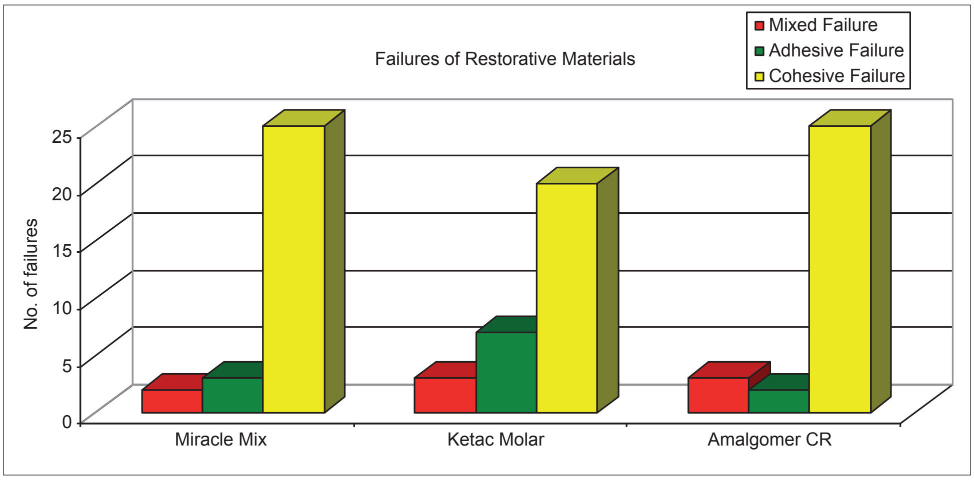
Graph 1: SBS of tested samples

study conducted in 1996 put the value of SBS of miracle mix at 5 MPa without pre-treatment and 6 MPa with pre-treatment that is almost in accordance with our values.[16]

The present study showed the SBS of ketac molar, which is a high viscosity, condensable, improved, restorative GIC to be 4.84 MPa. A study conducted in 2001 showed its SBS to be 3.77 MPa, which is slightly lesser than our value.[13]

Amalgomer CR exhibited SBS of 6.38 MPa, which is significantly higher than that of miracle mix (metal admixed) and ketac molar (high viscosity GIC). This finding has no precedent. The mean SBS was statistically insignificant between miracle mix and ketac molar though miracle mix had slightly higher bond strength than ketac molar.

In all the three restoratives, cohesive failure was the most common type of fracture. This means that adhesion between the restorative material and tooth is higher than the tensile strength of the cement itself and is considered as a superior property of the adhesive system because it shows that there is no further need for higher bond strength.[17] In our study, there was no significant association found between the type of failure and the restorative materials. Similar observations were made in other bond strength studies.[4,18] This finding is also in agreement with some studies, which proposed that the adhesive bond is usually not broken in shear bond testing and failure is usually cohesive within the restorative material.[19,20]



Graph 2: Types of failures

The SBS of miracle mix is low. This could be because this cement is brittle and fractures easily. Ketac molar, a high viscosity GIC has the lowest SBS among the tested restoratives. This may be due to the probability that it has not reached its optimum tensile strength after only 24 h. It is expected to mature and strengthen over a period of several months.[21] It can also be attributed to its intrinsic brittleness.[4] Amalgomer CR showed significantly higher SBS. This could be due to micronization and treatment of the main glass components. More importantly, the tensile strength, flexural strength and fracture toughness of the cement is much higher than conventional GICs.[22] These properties in turn made amalgomer CR more resistant to shear stress.

In general, the lower values of bond strength may be due to the fact that maximum achievable bond strength for glass ionomers is only reached after the cement has undergone its maturation process and some GICs require several months to become stable.[23] At full maturation, the cement at the interface will have become very viscous, and its initial reactions with the tooth substrate will have ensured close adaptation. The bond strength increases to become eventually limited by the cohesive tensile strength of the cement rather than by its adhesive strength alone.[24]

The study gives an overview of SBS of commercially available material in the market, but it may not be an accurate value due to the complex nature of adhesion mechanism to enamel and dentin. The brittle nature of GIC invariably results in cohesive failure rather than failure within the ion exchange layer. Consequently, the true bond strength of ion-exchange layer is not known.[25] Though the ion exchange layer of the cement to the tooth interface seems to have been adequately developed in our *in-vitro* study, which is evident by the cohesive type of failure, it is questionable whether the positive dentinal fluid flow characteristic of what goes on in the mouth took place at all. This being the case, higher bond strengths to dentin can be expected *in-vivo*.[4]

Conventional glass ionomers seldom perform well in the SBS tests because of their inherent weakness, which leads to their cohesive failure under these conditions. However, conventional GICs have other desirable properties like limited setting shrinkage, good elasticity and the ability to show self-repair mechanism once cracks appear within them. All these factors help in the survival of restorations in the oral environment.[24] Also, due to the relatively small setting contraction and coefficient of thermal expansion, the requirements for adhesion are less in GICs.[8]

Although the result of the current study showed that the SBS of amalgomer CR to primary teeth is significantly higher than the rest, the physical and clinical qualities of each material are important in determining, which material is most suitable for a particular clinical situation. Only long-term clinical trials can determine whether *in vitro* laboratory study results correlate within *in-vivo* experience.

Conclusions

Within the limits of the present *in vitro* study, we can conclude that:

1. Amalgomer CR has better adhesion to the primary teeth compared to miracle mix and ketac molar.
2. Amalgomer CR can be considered as a restorative material in pediatric dentistry.

However, the results of this study should be corroborated with further investigation to reach a definitive conclusion. Ultimately, only long-term clinical trials can determine whether *in-vitro* laboratory study results co-relate with *in-vivo* experience.

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