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Comparative evaluation of shear bond strength of four commercially available glass ionomer restorative materials on primary teeth: An in vitro study

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Abstract

Aim: To comparatively evaluate the shear bond strength (SBS) and the mode of failure of four glass ionomer restorative materials to dentine of primary teeth.

Materials and Methods: Dentine bond sites were prepared on 20 non – carious primary teeth and were embedded in auto polymerizing acrylic resin in moulds. These were randomly divided into four groups - GROUP I: Zirconomer, GROUP II: Giomer (Beautifil II), GROUP III : Conventional glass ionomer Cement (Fuji IX extra), GROUP IV: Resin modified glass ionomer (Fuji II Light Cure), Cements were placed with the help of customised teflon mould. The specimens were stored in distilled water in an incubator at 37 ^{0} C until testing. The shear bond strength test was performed using a knife-edge blade in a universal testing machine with a crosshead speed of 0.5mm/min, until failure. The specimens of all groups were examined using stereomicroscope at 10x magnification to define the location of the bond failure.

Results: The mean shear bond strength values (SBS) to dentin were: Group I - 2.16 ± 0.70 MPa, Group II - 12.98 ± 1.81 MPa, Group III - 7.26 ± 2.06 MPa, Group IV - 11.00 ± 1.19 MPa. A predominance of mixed type of failure was observed for all the groups followed by adhesive and cohesive type of failure. There was no significant difference in mode of failure between groups.

Conclusion/Clinical significance: Giomer (Beautifil II) is a suitable alternative to conventional restorative materials for primary teeth.

Keywords: Conventional glass ionomer; Giomer; Resin modified glass ionomer; Shear bond strength; Zirconomer.

Introduction

Glass ionomer cement (GIC) was one of the first aesthetic restorative materials introduced in Dentistry by Wilson and Kent in 1970.[1] Despite the benefits of fluoride ion release and uptake by enamel and dentin, similar coefficients of thermal expansion to tooth structure, chemical bonding to both enamel and dentin, tooth colour replication, and biocompatibility, the first commercial glass-ionomer compositions had long setting periods, were prone to dissolution and desiccation during hardening, and had poor wear resistance and fracture strengths once hardened.[1]

The creation of resin-modified glass-ionomer systems was a big step forward in glass-ionomer technology.[2] This resulted in improved mechanical properties, reduced setting time, and lowered moisture sensitivity. The most frequent constituents in RMGIs are fluoro-aluminosilicate glasses, photo-initiators, polyacrylic acid, water, and a water-soluble methacrylate monomer, such as hydroxyethyl methacrylate (HEMA), which may or may not be grafted onto the polyacrylic acid. RMGIs exhibit early and rising strength, whereas traditional GI products release fluoride and bond chemically to tooth structure.[3]

GC Fuji IX GP Extra has a rapid set, reducing early moisture sensitivity significantly. The particle size distribution of the glass powder were modified to achieve faster hardening.[2] GC Fuji IX GP Extra has smaller glass particles size and sets faster. It has superior physio-mechanical qualities as well as excellent wear resistance, allowing it to tolerate masticatory stress.[4]

Fuji II Light Cure is a traditional resin-modified glass ionomer (RMGIC) restorative material. It is a water-based cement that is moisture resistant during placement and has a free-flowing consistency to ensure optimal wetting of the tooth surface.[5] The strong chemical bonding of Fuji II LC to dentine, enamel, and cementum ensures adhesion durability. Fuji II LC releases a substantial amount of fluoride, which helps to protect the adjacent surfaces. The Fuji II LC is rechargeable and may absorb fluoride from external sources.[5]

Giomers are a hybrid of resin composites and glass ionomers that make use of pre-reacted glass filler technology.[6] Pre-reacted glass ionomer (PRG) is pulverised and incorporated as fillers in a polymer matrix. PRG fillers are fabricated by acid–base reactions between fluoride containing glass and poly acrylic acid in the presence of water forming wet siliceous hydrogel. Giomers are fluoride-releasing dental materials that have the benefit of preventing the demineralization of dental tissues. This new category of restorative materials combines the bioactivity and biocompatibility of glass ionomers with the physical and optical qualities of composites, providing dentists with a superior amalgam replacement option. An intermediate adhesive system bonds Giomer chemically to tooth structure.[7]

Zirconomer are novel materials made up of ceramic and zirconia reinforced glass ionomer cements that have the potential to solve the disadvantages of amalgam. They have the strength of amalgam and the fluoride-releasing ability of GICs.[8]

The adhesion of restorative materials to enamel has become a common and predictable aspect of modern restorative dentistry, whereas dentinal adhesion has proven to be more challenging and unpredictable.[9]

Bonding to the enamel is achievable because to its homogeneous composition (hydroxyapatite) in comparison to dentin. The amount of tooth structure available for bonding is reduced in primary teeth and adhesion is particularly challenging as they are smaller, have thinner enamel and dentin, and develop dental cavities more rapidly.[10]

As there is paucity of research on the adhesive ability of glass ionomer cements to primary teeth, the present study was conducted with the aim of assessing and comparing the adhesive ability of four different commercially available glass ionomer cements to primary teeth.

Materials and Methods

Freshly extracted 20 non – carious unrestored primary teeth were collected**.** Roots were removed perpendicular to the long axis of tooth using low speed diamond disc with water coolant. Teeth were sectioned mesiodistally and divided into two halves**.** The buccal / lingual portion of the crown was embedded in auto polymerizing acrylic resin in moulds**.** The specimens were placed perpendicular to the acrylic resin surface.[9] Dentin bond sites were prepared with double faced diamond disc until a clean dentinal surface was exposed. Tooth samples were randomly allocated into four groups (N=4). GROUP I (n=10): Zirconomer, GROUP II (n=10):Giomer (Beautifil II), GROUP III (n=10):Conventional glass ionomer Cement (Fuji IX Extra), GROUP IV (n=10):Resin modified glass ionomer cement (Fuji II Light Cure). Custom made split Teflon mould (3mm diameter x 2mm height) was secured to the tooth surface prior to application of cement. The Teflon mould was stabilized in its place by means of another split metallic ring fitted inside the external cylindrical mould. All the cements were mixed according to the manufacturer's instructions. Cements were placed with the help of a customised Teflon mould**.** After setting of cements, mould was removed. Immediately after the preparation, the specimens were stored in distilled water in individual test tubes in an incubator at 37 ^{0} C until testing. The investigator was blinded with regards to the test groups at this point to avoid bias during testing**.** The SBS testing was conducted after a minimum storage period of 24 hours.

Shear bond strength test

The SBS test was performed using a knife-edge blade, in a universal testing machine with a crosshead speed of 0.5mm/min, until failure.[11-13.] The SBS values were calculated by dividing the load at failure (Newton) by the area of the cylindrical cross-section and expressed in Mega Pascal (MPa).[11,13.]

Mode of failure analysis[11, 14.]

The specimens of all groups were examined using a stereomicroscope at 10x magnification to define the location of the bond failure and categorized as:

Adhesive failure: Occurring purely at restoration – dentin interface.

Cohesive failure: Occurring purely within the material.

Mixed failure: Combination of the adhesive or cohesive mode.

Statistical analysis

The collected data was analyzed with IBM SPSS Statistics for Windows, Version 23.0. (Armonk, NY: IBM Corp). To describe about the data descriptive statistics frequency analysis, percentage analysis was used for categorical variables and the Mean & S.D were used for continuous variables. To find the significant difference in the multivariate analysis the one way ANOVA with Tukey's Post-Hoc test was used. To find the significance in categorical data Chi-Square test was used.

Results

The Mean SBS dentin values were: For Group I: Zirconomer 2.16 ± 0.70 MPa, Group II: Giomer (Beautifil II) 12.98 ± 1.81 MPa, Group III: Glass Ionomer Cement Fuji IX Extra 7.26 ± 2.06MPa, Group IV: Resin Modified Glass Ionomer Cement Fuji II LC 11.00 ± 1.19 MPa. (**Table 1**)

Giomer demonstrated the highest mean SBS followed by Resin Modified Glass Ionomer Cement Fuji II LC, Glass Ionomer Cement Fuji IX Extra and Zirconomer.

Intergroup comparison revealed that the Mean SBS values demonstrated by Giomer was significantly higher than Resin Modified Glass Ionomer Cement Fuji II LC (p=0.031) and Glass Ionomer Cement Fuji IX Extra (p = 0.0005). Resin Modified Glass Ionomer Cement Fuji II LC demonstrated significantly higher Mean SBS compared to Glass Ionomer Cement Fuji IX Extra (p = 0.0005). The Mean SBS value of Zirconomer was significantly lower than other test groups (p = 0.0005). (**Table 2**)

The mode of failure analysis for SBS tested for Group I demonstrated a predominantly Mixed type of failure (70.0 %) followed by Adhesive type of failure (30.0 %). Group II demonstrated a predominantly Mixed type of failure (90.0 %) followed by Adhesive type of failure (10.0 %). Group III demonstrated a predominantly Mixed type of failure (70.0 %) followed by Adhesive type of failure (30.0 %). Group IV demonstrated a predominantly Mixed type of failure (50.0 %) followed by Cohesive type of failure (30.0 %) and Adhesive type of failure (20%). (**Table 3, Graph 1**)

Group I, II, III, IV predominantly demonstrated a mixed type of failure of 70% followed by Adhesive type of failure 22.5% and Cohesive type of failure 7.5%. (**Table 2, Graph 1**)

Chi square test demonstrated a p value = 0.078 which was statistically not significant. There was no significant difference in the mode of failure for all the groups. (**Table 4**)

Discussion

Moisture is frequently a barrier to effective bonding since dentin's intrinsic wetness increases with depth. However, there is also evidence that the dependence is likely to be associated to the specific bonding agent or mechanism.[20] Bond strength values are a gross assessing tool to quantify the effectiveness of bonding restorative materials to dentin on a broad scale. SBS is the least technique-sensitive of the tests, revealing the strength at the bonded interface.[11]

Singh P, Jha M, Arora K, et al (2021) assessed and compared the SBS of packable glass ionomer cement (GIC), Resin- modified glass ionomer cement (RMGIC), compomer, and Giomer to primary teeth. The authors reported a mean SBS value of 14.24 ± 1.13 Mpa on primary teeth for Giomer which is comparable to the Mean SBS value of Giomer reported in the present study. The Mean SBS reported for Resin modified glass ionomer cement was 6.06 ± 1.04 Mpa,[14] which was comparatively lower than the Mean SBS of Resin Modified Glass Ionomer Cement Fuji II LC recorded in the present study. In agreement with the present study, Giomer had the highest Mean SBS value in comparison to the other tested restorative materials.

A detailed search of the print and electronic databases revealed only one in vitro study, assessing the SBS of Giomer (Beautifil II) on primary teeth, while no other published study has assessed the SBS of Giomer (Beautifil II) on primary teeth in comparison with glass ionomer restorative materials. Hence the direct comparison of the results of the present study with existing data is not possible.

Somani R et al (2016) in an in vitro study assessed and compared the SBS of various glass ionomer cements (GICs) to dentin of primary teeth. The authors reported Mean Shear bond strength values of 9.85 ± 1.62 MPa and 7.22 ± 0.87 MPa for Resin Modified Glass Ionomer. Fuji II LC demonstrated higher mean SBS value than Fuji type IX GIC, which was comparable to the present study.[12]

Contrary to the results of the present study, Sadeghi M et al (2015) reported a Mean shear bond strength value of 18.15 ± 3.38 Mpa for Resin Modified Glass Ionomer Cement Fuji II LC, which was comparatively higher to the Mean SBS of Resin Modified Glass Ionomer Cement Fuji II LC reported in the present study.[16]

Pathak AK et al (2021) in an in vitro study compared the SBS of glass ionomer cement Type II (GIC II), GIC IX, and Cention N on primary tooth. The authors reported that Mean SBS of Resin Modified Glass Ionomer Cement Fuji II LC on primary teeth was 4.90 ± 0.23 MPa, which was comparatively lower to the Mean SBS of Resin Modified Glass Ionomer Cement Fuji II LC of the present study. The Mean SBS on primary teeth for Glass Ionomer Cement Fuji IX was 7.38 ± 0.15 Mpa, which is similar to the Mean SBS of Glass Ionomer Cement Fuji IX recorded in the present study. Dissimilar to results of the present study GIC Fuji IX demonstrated higher Mean SBS than GIC Fuji II LC.[18]

In agreement with the results obtained in the present study, Jaidka S et al (2016), while evaluating the SBS of Glass ionomer cement Type IX, chlorhexidine-incorporated glass ionomer cement, and triclosan-incorporated glass ionomer cement on primary human molar teeth, reported a comparable value of Mean SBS on primary teeth for Glass Ionomer Cement Fuji IX of 6.87 ± 0.03 Mpa.[19]

Mohammed NY et al (2018) in an in vitro study assessed and compared the SBS of glass carbomer and a high viscosity glass ionomer (Fuji IX GP) to primary dentin. The authors reported that the Mean SBS of Glass Ionomer Cement Fuji IX on primary teeth was 6.62 Mpa, which was comparable to the Mean SBS of Glass Ionomer Cement Fuji IX reported in the present study.[20]

Verma V et al (2020) reported the Mean SBS value of 4.84 ± 0.76 Mpa on primary teeth for Glass Ionomer Cement Fuji IX , which was lower in comparison to the Mean SBS of Glass Ionomer Cement Fuji IX reported in the present study.[21]

A detailed search of the print and electronic databases revealed only one in vitro study, assessing the SBS of Zirconomer on primary teeth in comparison with other glass ionomer restorative materials.

Nanavati K et al in (2021) while evaluating the SBS of three different glass ionomer based restorative materials on primary molars reported a Mean SBS values of 2.36 ± 1.009 MPa and 3.88 ± 2.08 Mpa on primary teeth for GIC Fuji IX and Zirconomer respectively. While the Mean SBS value reported for Zirconomer is similar to the value reported in the present study, the Mean SBS value reported for GIC Fuji IX is comparatively lower than in the present study. Contrary to the results of the present study, Zirconomer demonstrated higher Mean SBS than GIC Fuji IX.[22]

The resin-based Pre reacted glass fillers and cross-linked polymer matrices in Giomer result in higher compressive strength than the acid-base reaction in glass ionomers. Due to inclusion of the fillers, Giomer demonstrated higher shear bond strength as compared to other glass-ionomer cements, in the present study.[14]

The test material with the second highest Mean SBS values in the present study was Fuji II LC. This could be attributed to the dual mechanism of adhesion which is probably through a combination of a dynamic ion exchange process and micromechanical bonding mechanism.[23]

Although GIC Type IX demonstrated significantly lower Mean SBS values in comparison with Giomer and Fuji II LC, it had significantly higher Mean SBS in comparison with Zirconomer. The bond strength of GIC Type IX, could have influenced by the conditioning agent applied on the dental substrate.[24] In the present study, the liquid component of the GIC was used to condition the tooth surface in accordance with the protocol used by Pereira et al., Holmgren et al., Koenraads et al.[13,24.]

Zirconomer demonstrated the lowest Mean SBS value in the present study. The lower SBS as reported by other investigators of zirconia reinforced glass ionomer might be due to presence of fewer amounts of free carboxylic groups that can chemically bond with dentine. The adhesion between glass ionomer filling material and tooth structure depends on formation of hydrogen bonds originating from the free carboxyl groups in the cement interacting with tightly bound water on the surface of the mineral phase of the tooth. An ion-exchange layer is slowly formed between the tooth and the restoration.[8]

In accordance with previous studies,[11,20.] The fracture sites after debonding were analyzed using stereomicroscope [under 10x magnification] in the present study. The mode of failure analysis for Giomer (Beautifil II) demonstrated a predominantly mixed type of failure (90 %) followed by Adhesive type of failure (10%). Resin Modified Glass Ionomer Cement Fuji II LC demonstrated a predominantly mixed type of failure (50%) followed by cohesive type of failure (30%) and Adhesive type of failure (20%). Glass Ionomer Cement Fuji IX demonstrated a predominantly mixed type of failure (70%) followed by Adhesive type of failure (30%). Zirconomer demonstrated a predominantly mixed type of failure (70%) followed by Adhesive type of failure (30.0%).[16] (Table 3 and Graph 1)

Giomer (Beautifil II), Resin Modified Glass Ionomer Cement Fuji II LC, Glass Ionomer Cement Fuji IX, Zirconomer predominantly demonstrated a mixed type of failure.

Sharafeddin F (2020) also noted mostly cohesive/mixed mode of failure rather than adhesive. These results are consistent with previous studies, which have reported that the strength of the GIC–tooth bond is higher than the inherent strength of the material.[14.] This type of failure has been commonly reported in previous studies for GIC. However, the role of the inherent heterogeneous stress distribution during testing, in producing higher cohesive failures cannot be overlooked. Moreover, under higher magnification, a greater incidence of mixed and cohesive failures has been observed for all testing modes by researchers.[14.]

Bhattacharya P et al (2018) reported greater percentage of the cohesive mode of failure for Zirconomer for dentin bond sites.[13]

Conclusion

Within the limitations and based on the results of the present study, Giomer can be used to achieve desirable bond strength in primary teeth. The findings of this study imply that Giomer can be used as a suitable restorative material in primary teeth. Giomer is an unique restorative material that has the features of both glass ionomer cement and composites, as well as anti-carious capabilities due to fluoride release from this glass-containing material and optimum bond strength, making it an ideal choice for primary tooth restoration. However more studies are needed to investigate the clinical performance of this dental material.

Manufacturer name

Zirconomer: Shofu™ inc. Kyoto, Japan; **Giomer (Beautifil II):** Shofu™ inc. Kyoto, Japan; **BeautiBond:** Shofu™ inc. Kyoto, Japan; **Conventional Glass Ionomer Cement (Fuji IX Extra):** GC ™ Corp, Tokyo Japan; **Resin Modified Glass Ionomer Cement (Fuji II Light Cure):** GC ™ Corp, Tokyo Japan.

Graph 1: Intergroup comparison of mode of failure.

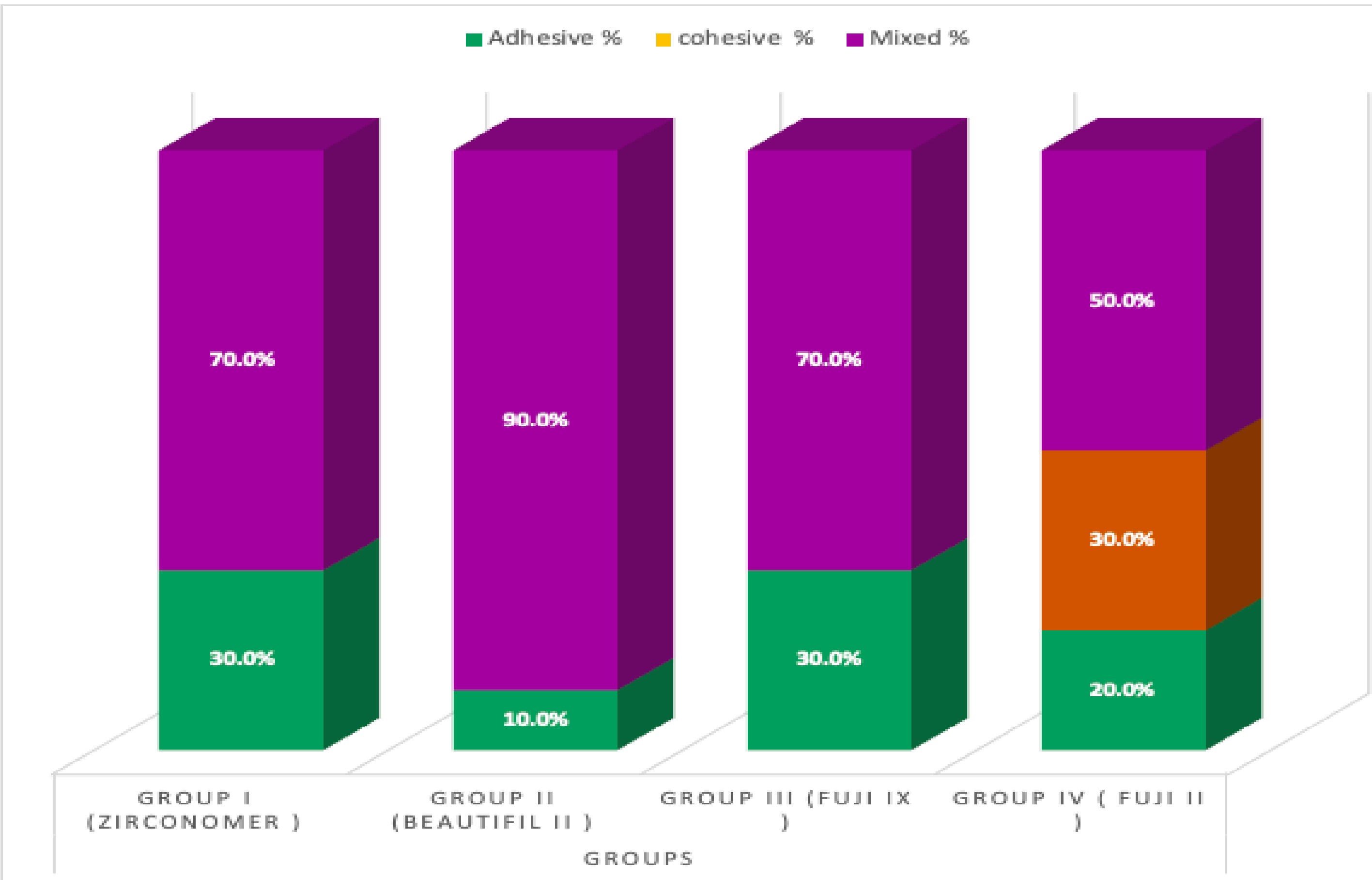

Table 1: Mean values of Shear bond strength in (MPa)

	N	Mean	Std. Deviation	95% Confidence Interval for Mean		Minimum	Maximum
				Lower Bound	Upper Bound		
Group I (Zirconomer)	10	2.16	± 0.70	1.66	2.65	1.30	3.36
Group II (Beautifill II)	10	12.98	± 1.81	11.69	14.28	9.54	14.65
Group III (Fuji IX Extra)	10	7.26	± 2.06	5.79	8.74	2.17	10.02
Group IV (Fuji II LC)	10	11.00	± 1.19	10.15	11.85	9.47	12.78

Table: 2 Inter group comparison Mean values of Shear bond strength using Tukey's Post Hoc Test.

Post Hoc Test - Multiple Comparisons - Tukey HSD						
Groups	Mean Difference (I-J)		Std. Error	p-value	95% Confidence Interval	
					Lower Bound	Upper Bound
Group I (Zirconomer)	Group II	-10.828600*	0.685909	0.0005	-12.67591	-8.98129
	Group III	-5.106200*	0.685909	0.0005	-6.95351	-3.25889
	Group IV	-8.842100*	0.685909	0.0005	-10.68941	-6.99479
Group II (Beautifil II)	Group III	5.722400*	0.685909	0.0005	3.87509	7.56971
	Group IV	1.986500*	0.685909	0.031	.13919	3.83381
Group III (Fuji IX Extra)	Group IV	-3.735900*	0.685909	0.0005	-5.58321	-1.88859
*. The Mean difference is significant at the 0.05 level.						

Table 3: Inter group comparison of Mode of failure

Groups	Mode of failure		
	Adhesive failure %	Cohesive failure %	Mixed failure %
Group I (Zirconomer)	30.0	0.0	70.0
Group II (Beautifil II)	10.0	0.0	90.0
Group III (Fuji IX Extra)	30.0	0.0	70.0
Group IV (Fuji II LC)	20.0	30.0	50.0
Total - (100%)	22.5	7.5	70.0

Table 4: Statistical analyses of mode of failure using Chi-Square Test.

Chi-Square Tests			
	Value	df	p-value
Pearson Chi-Square	11.365[a]	6	0.078
Likelihood Ratio	10.836	6	0.094
Linear-by-Linear Association	0.342	1	0.559
No of Valid Cases	40		
a. 8 cells (66.7%) have expected count less than 5. The minimum expected count is .75.			

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