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A Study to Evaluate and Compare the Shear Bond Strength of Different Core Materials - An *in vitro* Study

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ABSTRACT

Purpose: To evaluate and compare the shear bond strength of different core materials.
Materials and method: Eighty extracted non-carious permanent first molar teeth were randomly selected and embedded in an auto polymerizing pink acrylic resin. Specimens were selected on the basis of certain inclusion and exclusion criteria. Four commercially available brands of core materials were selected, (Bulk fill (IVOCLAR), Core X flow (DENTSPLY), Valux plus (3M ESPE) and Resin Modified Glass ionomer cement (GC)). The shear bond strength was tested using an Universal Testing Machine, (Mecmesin UK) using load cell of 500 N. The dimensions of the specimens were entered into the program for computation.
The fracture sites along the dentin core materials interface was evaluated by Scanning electron microscope (Ultra 55, field emission scanning electron microscope, Karl Zeiss) to determine whether the fracture was adhesive or cohesive in nature.
Results: Higher mean shear bond strength was recorded for CORE X FLOW (GROUP II) group followed by BULK FILL (GROUP I) and VALUX PLUS (GROUP III) respectively. Lowest shear strength was recorded for RESIN MODIFIED GIC (GROUP IV).
Conclusion: Resin modified glass ionomer cement can be used as a core build up material in situations where the tooth structure lost is minimal, as it the least shear bond strength and its use may be limited to anterior esthetic zone.

Keywords: Core build up, resin modified glass ionomer cement, composite resin core materials, shear bond strength, fracture site.

INTRODUCTION

Core build-up is a restoration placed, in a grossly destructed tooth to restore the bulk of the coronal portion so as to facilitate the subsequent restoration by means of an indirect extra coronal restoration.[1]

The ideal requisite of any core materials is its strength. This is because stronger the core material greater the resistance to deformation and fracture which provides equal stress distribution, reduced probability of tensile or shear failure, greater stability, and greater probability of clinical success.

The development of resin-modified glass ionomer cements has given another option in the selection of core materials. The ability of glass ionomers and glass cermet's to adhere to both enamel and dentine and the ability to release fluoride along with anti-cariogenic properties, encourages resin modified glass ionomer cement to be the material of choice in core build-up.[2]

The advent of composite resins in the early 1960's, have all the desirable properties that were combined into one single material. Composite resins having adequate strength, and ease of handling along with fluoride releasing property, an added advantage.

The comparison of physical properties like shear bond strength, compressive strength and flexural strength of composite resin core materials with conventional core restorative materials would help the clinician to choose the appropriate and best core material available for the restoration of weakened tooth structure.

Hence, the purpose of the study is to evaluate and compare the shear bond strength of resin modified glass ionomer cement and composite resin core materials.

MATERIALS AND METHODS

The present in vitro study was conducted in the Department of Prosthodontics, The Oxford Dental College, Hospital & Research Centre Bangalore, and Karnataka to evaluate and compare the shear bond strength of four different core materials.

Eighty extracted non-carious permanent first molar teeth were collected from the Department of Oral and Maxillofacial surgery, The Oxford Dental College, Hospital and Research Centre, Bangalore.

All the eighty extracted non-carious permanent first molar teeth were randomly selected and embedded in an auto polymerizing pink acrylic resin. All the mounted specimens were divided into four equal colour coded groups that will be assigned to four different core materials (n=20).

Specimens were selected based on the following inclusion and exclusion criteria.

Inclusion criteria: Non carious permanent first molar teeth.

Exclusion criteria:

- Carious teeth
- Fractured teeth
- Internally and externally resorbed teeth

Specimen Preparation

Eighty (N=80) extracted non-carious permanent first molar teeth used in this study were cleaned and stored in distilled water. Poly vinyl chloride pipe was cut to make a cylinder measuring 5cm in length and 3 cm in diameter as shown in figure 1. Auto polymerizing pink acrylic resin powder and monomer in a ratio of 3:1, was mixed in a porcelain jar. Autopolymerising acrylic resin was then added on to the polyvinyl chloride mould in a dough stage and the molar teeth were embedded as shown in figure 2. All the 80 teeth were mounted in the same manner to obtain 80 specimens as in figure 3. The acrylic resin blocks were then trimmed and polished. Each molar teeth was flattened horizontally at cemento-enamel junction to expose the dentinal surface using 600 grit silicone carbide bur to create a uniform flat surface,[3] as shown in figure 4. The dentinal surface were treated with etchants and adhesives as per the manufacturer's instructions as in figure 5. All the 80 specimens were then divided into four groups and each group consisting 20 specimens.

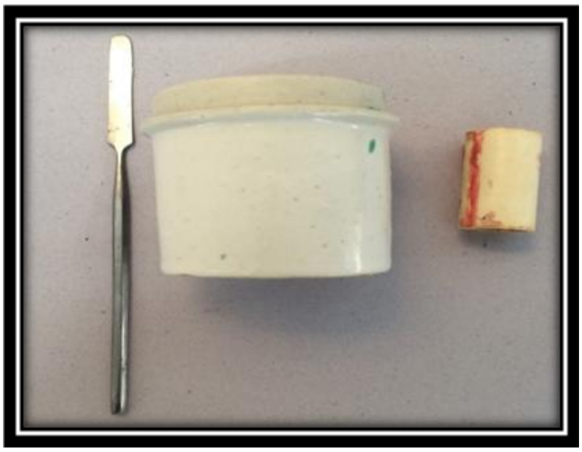

Figure 1: Porcelain Jar with Mixing Spatula And Polyvinyl Pipe

Figure 2: Tooth Mounted in Acrylic Resin

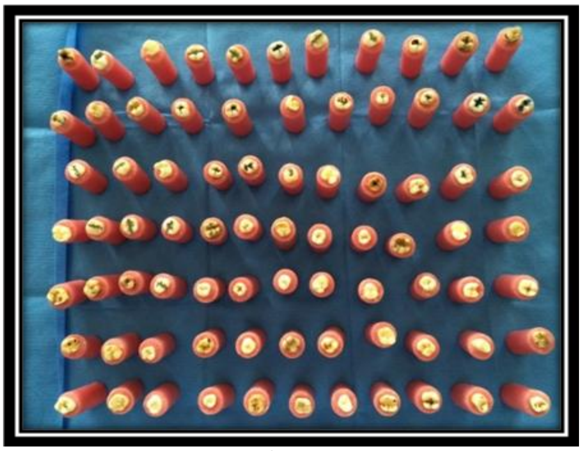

Figure 3: 80 Specimens of Extracted Teeth Mounted In Acrylic Resin

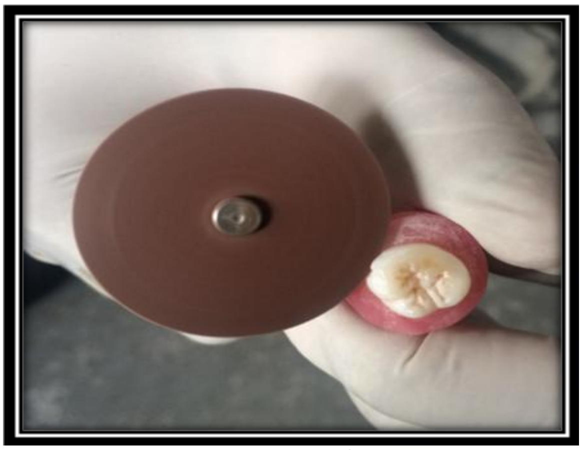

Figure 4: Horizontal Sectioning of Tooth with 600 Grit Carbide Strip

Figure 4(A): Flat Occlusal Surface of Tooth

Figure 5: Core Materials Size of 5 Mm X 5 Mm after Complete Set

Fabrication of Specimens for Shear Bond Strength

The Following core materials were used for core build-up, on extracted permanent first molar teeth, as shown in figure 6:

- Bulk fill –IVOCLAR
- Core X flow-DENTSPLY
- Valux plus-3M ESPE
- Resin Modified Glass ionomer cement (GC)

Specimens were equally divided into four groups, as in figure 7

- Group I - 20 mounted specimen’s with Bulk fill (IVOCLAR) as a core material.
- Group II- 20 mounted specimen’s with Core X flow (DENTSPLY) as a core material.

- Group III-20 mounted specimen's with Valux plus (3M ESPE) as a core material.
- Group IV-20 mounted specimen's with Resin Modified glass ionomer (GC) as a core material

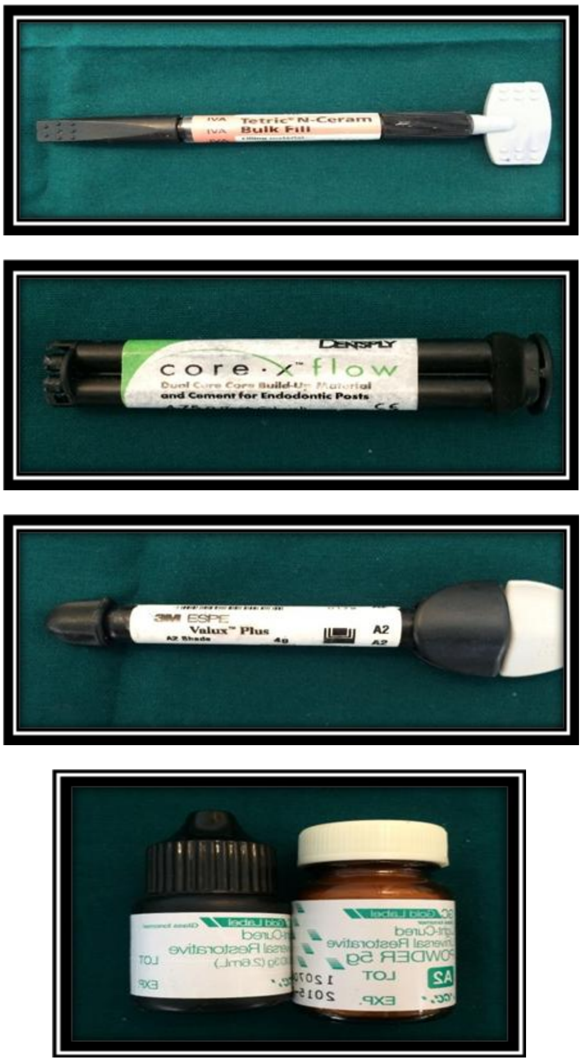

Figure 6: Four Core Build up Materials

Figure 7: Group of 80 Specimens Assigned to Four Core Material

Evaluation of shear bond strength

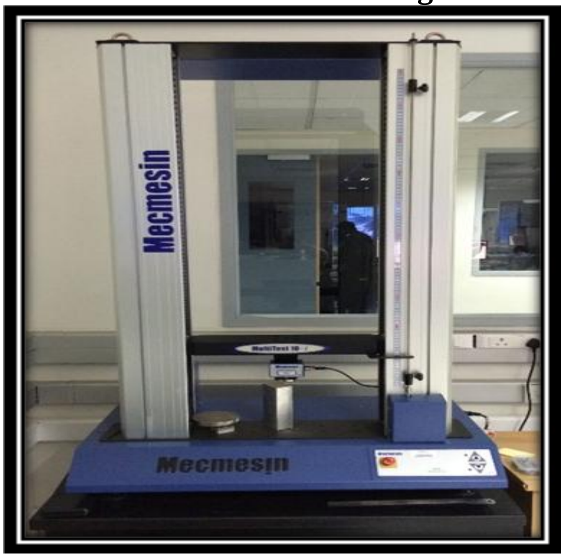

Figure 8: Universal Testing Machine (Mecmesin)

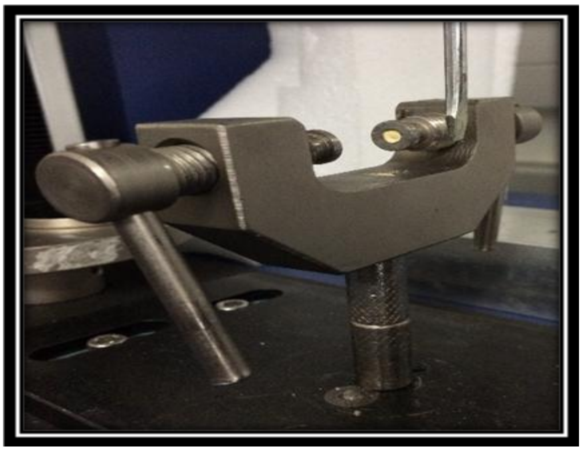

Figure 9: Mounting of Specimens on Mettalic Jig for Shear Bond Strength

The shear bond strength was tested using an Universal Testing Machine, (Mecmesin UK) using load cell of 500 N. The dimensions of the specimens were entered into the program for computation. The distance between the two supporting wedges was 20mm and the crosshead speed was set at 1mm/min. A chisel shaped rod was aligned in the crosshead so that force delivered to the specimen was immediately adjacent and parallel to the dentin surface and perpendicular to long axis of tooth. The specimens were connected to the load measuring cell, which continuously recorded the load applied to the specimens. Shear bond strength was calculated using the formula S= peak load (W)/surface area $(D)^2$ where W is the load at fracture, d is the diameter of the specimen.[4]

Shear bond strength = Load (N) /surface area (mm^2)

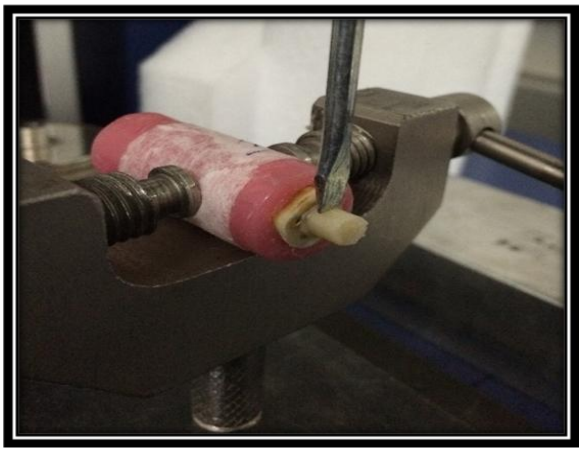

Figure 9(A): Applying Force on Core Material Parallel to Bonded Surface Area of Dentin

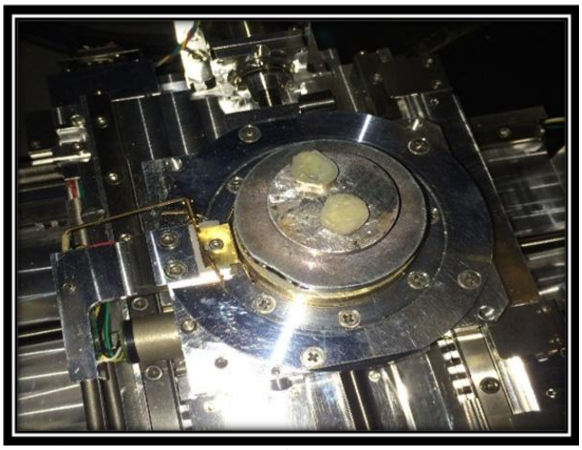

Figure 10: Fractured Sites of Tooth Specimens in Scanning Electron Microscope

The fracture sites along the dentin core materials interface was evaluated by Scanning electron microscope (Ultra 55, field emission scanning electron microscope, Karl Zeiss) to determine whether the fracture was adhesive or cohesive in nature, as in figure 10-10(d).

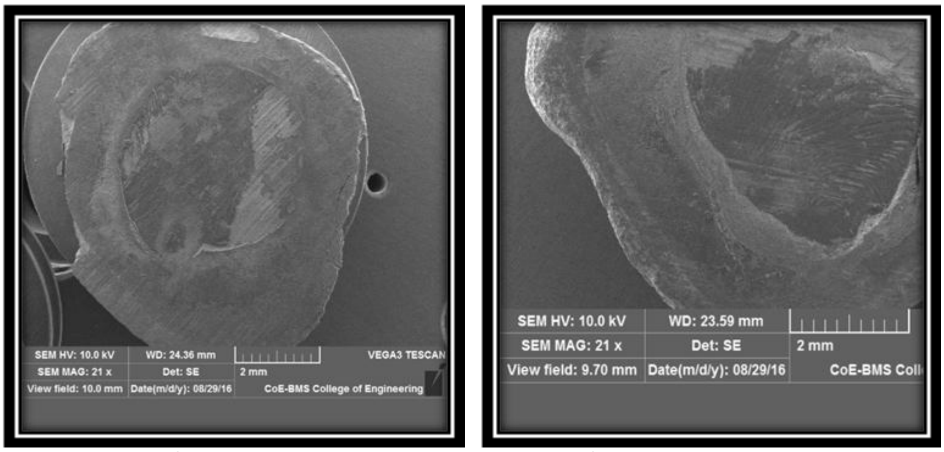

Figure 10(A): Fractured Sites of Bulk Fill Core Material and Dentin Interface Showing Cohesive Failure with Residual Core Material on Dentin Surface

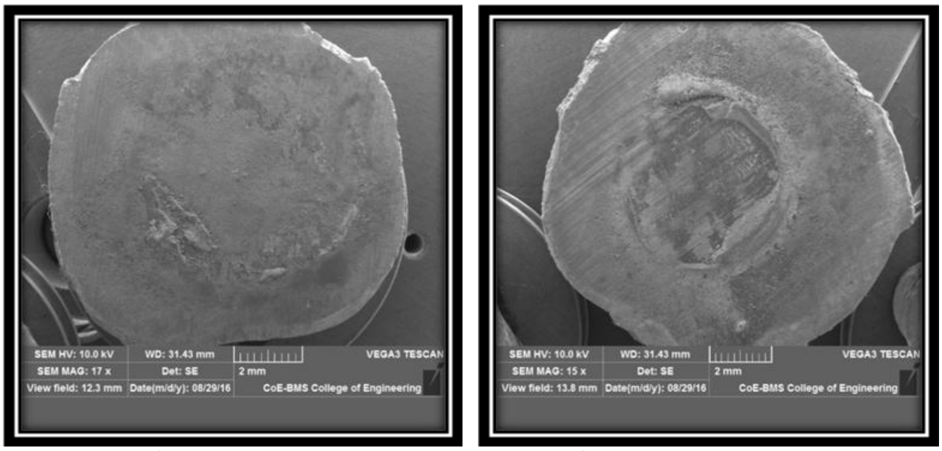

Figure 10(B): Fractured Sites of Core X Flow Core Material and Dentin Interface Showing Adhesive Failure with No Residual Core Material on Dentin Surface

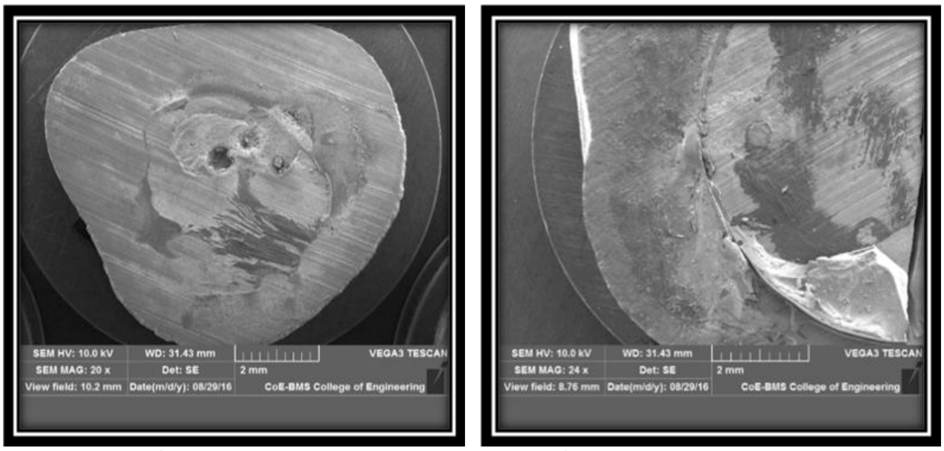

Figure 10(C): Fractured Sites of Valux Plus Core Material and Dentin Interface Showing Cohesive Failure with Little Residual Core Material on Dentin Surface

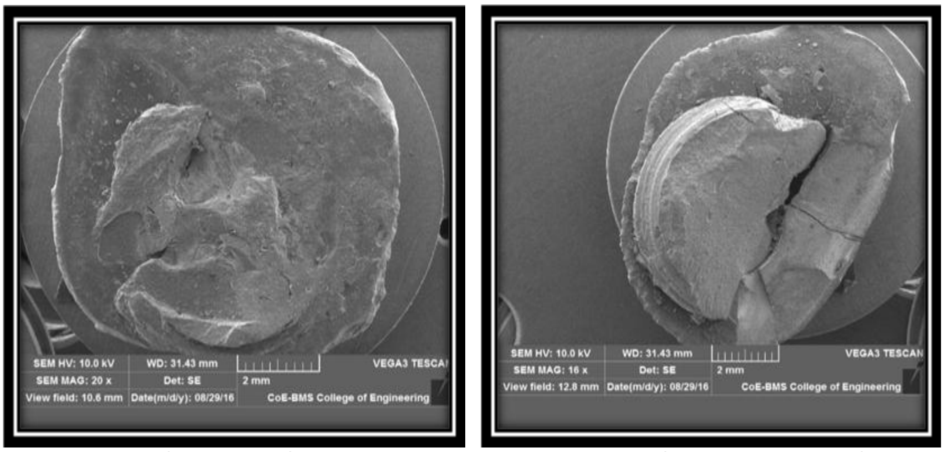

Figure 10(D): Fractured Sites of Resin Modified Gic Core Material and Dentin Interface Showing More of Cohesive Failure with Residual Core Material on Dentin Surface

Statistical Analysis

Data of the shear bond strength values were entered in Microsoft Excel and statistically analysed using One Way Anova, Bonferroni multiple comparison post-hoc test with SPSS version 19 software.

Level of Significance: α=0.0001

RESULTS

All the 80 specimens were distributed randomly into four groups containing 20 specimens in each group (n=20). All the specimens were treated according to manufacturer's instructions and core build up was done. The specimens were subjected to shear loading using Universal Testing Machine. The force at which debonding of specimens occurred was recorded. Corresponding shear bond strength values of that particular specimens were calculated in MPa by dividing the debonding force by area of the debonding surface having radius of 5 mm.

Table I shows the shear bond strength values in MPa obtained for each specimen in the four groups.

Formula for calculating shear bond strength (MPa) = Force (N)/surface area (A) $(mm)^2$

$A = \pi d^2$

A = surface area

Π = constant = 3.14

d = diameter of the cylinder is 5 mm

Table I; Mean Shearbond Strength [Mpa]

Group	Material	Mean	Standard deviation
GROUP I	Bulk fill Composite of IVOCLAR company	7.034	0.718
GROUP II	Core x flow Composite of DENTESPLY company	10.344	1.326
GROUP III	Valux plus Composite of 3MESPE company	5.633	0.639
GROUP IV	Resin modified gic of GC company	4.231	0.411

The results of the study were as follows:

The mean shear bond strength of bulk fill is 7.03 MPa, core x flow is 10.34 MPa, valux plus is 5.63 MPa and Resin modified GIC is 4.23 MPa. The mean shear bond strength values of tested specimens were subjected to statistical analysis.

After mean values of four core materials were recorded, various computations and the P-Value for shear bond strength was calculated and tabulated under TABLE II.

Table II: ANOVA-Shear Strength [MPa]

Material	Group	n	Mean	Standard deviation	Min	Max	F	P-Value
Bulk fill	I	20	7.034	0.718	6.11	8.42	192.176	<0.0001
Core x flow	II	20	10.344	1.326	8.16	12.27		
Valux plus	III	20	5.633	0.639	4.67	6.71		
Resin modified gic	IV	20	4.231	0.411	3.57	4.86		

Table III: Bonferroni Test Multiple Comparisons: Shear Strength [MPa]

Material	Group	n	Mean	Standard deviation	Min	Max	F	P-Value
Bulk fill	I	20	7.034	0.718	6.11	8.42	192.176	<0.0001
Core x flow	II	20	10.344	1.326	8.16	12.27		
Valux plus	III	20	5.633	0.639	4.67	6.71		
Resin modified gic	IV	20	4.231	0.411	3.57	4.86		

*. The mean difference is significant at the 0.05 level.

Table IV: Fracture Locations of Materials Tested

Type of Failure	Bulk Fill	Core X Flow	Valux Plus	Resin Modified Gic
Sample No	**Group I**	**Group Ii**	**Group Iii**	**Group Iv**
1	A	A	A	C
2	A	A	C	C
3	C	A	C	A
4	A	A	A	A+C
5	C	A	C	C
6	A	A	C	C
7	C	A	C	A
8	A	A	C	A+C
9	A	A+C	A	C
10	A+C	C	A	C
11	A	A	C	A
12	A+C	A	C	A+C
13	C	A	C	C
14	A	A	A	C
15	A+C	C	C	A
16	A	C	A	A+C
17	A	A	C	C
18	A	A	A	C
19	C	A	C	C
20	A	A	A	C

A = adhesive failure; C = cohesive failure; C+A = cohesive and adhesive failure

Higher mean shear bond strength was recorded for CORE X FLOW (GROUP II) group followed by BULK FILL (GROUP I) and VALUX PLUS (GROUP III) respectively. Lowest shear strength was recorded for RESIN MODIFIED GIC (GROUP IV). The difference in mean shear strength between the four materials was found to be statistically significant (P<0.001). In order to find out among which pair of materials there exists a significant difference with respect to the strength, multiple comparisons was done using Bonferroni test. The difference in mean shear strength between BULK FILL (GROUP I) and the other materials was found to be statistically significant (P<0.001). The difference in mean shear strength between CORE X FLOW (GROUP II) and the other materials was also found to be statistically significant (P<0.001). The mean shear bond strength recorded for VALUX PLUS (GROUP III) was found to be statistically significant when compared with the mean shear bond strength of the other materials (P<0.001). The mean shear bond strength recorded for RESIN MODIFIED GIC (GROUP IV) was found to be statistically significant when compared with the mean shear strength of the other materials (P<0.001).

All the specimens subjected to shear bond strength were examined under the scanning electron microscope.

The following three types of fracture were found to occur:

Adhesive failure: when the fracture mode occurs or present at the junction of core and tooth surface.

Cohesive failure: when the fracture mode within the core material.

Mixed failure: when the fracture mode is at both the material and at the junction of core and tooth surface.

The fracture locations are detailed in Table IV.

DISCUSSION

In prosthodontics, core materials are used to rehabilitate the mutilated tooth, to receive complete crown and be a part of definitive prosthesis.

All the specimens were subjected to shear bond strength. Their values recorded and the fractured areas were examined under scanning electron microscope and reveal three types of fracture modes:

1. Fracture at the junction of core and tooth structure; Adhesive failure.
2. When the fracture occurred within the core material; cohesive failure.
3. And when fracture occurred in both the core material and at the junction of core and tooth structure; mixed failure which includes both cohesive and adhesive failure.

Resin modified glass ionomer cements are conventional glass ionomer cements with the addition of hydroxyl ethyl methacrylate. Hybrid ionomers have an added advantage of moisture sensitivity and low early strength due to the slow acid base reaction.[5,6]

In the present study mean shear bond strength of resin modified glass ionomer cement was 4.231MPa. The minimum shear bond strength of resin modified glass ionomer cement being 3.57MPa and maximum shear bond strength was 4.86MPa. This may be due to low fracture toughness of resin modified glass ionomer cement.

When specimens with resin modified glass ionomer cement were observed under scanning electron microscope, resin modified glass ionomer cement showed more of cohesive failure. In resin modified glass ionomer cement specimens, 80 percent of fracture occurred at the core material. 10 percent of fracture occurred at core/tooth-structure interface. Remaining 10 percent of fracture occurred both at the material and junction of core/tooth structure interface.

The search for a material that has the combined advantages of fluoride releasing ability of glass ionomer cement and durability of composites led to the introduction of polyacid modified composite or compomer.[7]

There are many composite build-up materials available; most of them are either self-cured, light cured or dual-cured. As the core build up restorations are thicker restorations, the chemical curing capability is considered an added advantage. This is because during the build-up of a restoration, material is placed incrementally and can reach several millimeters in thickness. On light curing, however, the intensity of the light is greatest at the surface and generally decreases as it penetrates deeper within the material.

Packable composites are a new class of highly filled resin composites with a filler distribution that gives them a consistency that differ from that of hybrid composite. They are mainly characterized by more viscosity than conventional composite resins and are superior for stress bearing posterior restoration .[8]

The mean Shear bond strength of Bulk fill packable composite resin was 7.03MPa. The minimum shear bond strength being 6.11MPa and maximum shear bond strength was 8.42MPa.

When specimens with bulk fill were observed under scanning electron microscope, bulk fill showed more of cohesive failure. In bulk fill specimens 70 percent of fracture occurred at core/tooth-structure interface. 20 percent of fracture occurred at the core material. Remaining 10 percent of fracture, occured both at the material and junction of core/tooth structure interface. This is probably due to more densely packed filler particles and adhesive nature of packable composite. The filler particles in the bulk fill composites are arranged tightly thereby increasing bond surface area and bond strength.

A study done by Jale G et al measured the compressive shear bond strength of packable composite, amalgam, ormocer and hybrid composite. The shear bond strength were 1,777.40N/mm, 1,751.80N/mm, 1,871.40N/mm 1,294.30 N/mm, respectively. This in vitro study, concluded that packable composite did not show superior performances than a hybrid composite and an amalgam.[8]

Specimens with Core x flow as core material had mean shear bond strength of 10.34 MPa, The minimum shear bond strength being 8.16 MPa and maximum shear bond strength was 12.27 MPa due to its higher filler concentration and high density of filler particles, that is 1.95 grams per centimeter cube. This filler concentration also increases the shear strength, hardness, flexural strength and modulus of elasticity, and also tends to reduce polymerization shrinkage. The resultant surface, densely packed with fillers helps in better bonding with the tooth structure.

When the specimens with core x flow as core material were examined under scanning electron microscope core x flow showed more of adhesive failure. In core x flow specimens, 90 percent of fracture occurred at core/tooth-material interface. 10 percent of fracture occurred at the core material. This probably, could be because of higher concentration and density of filler particles.

Specimens with Core x flow as core material had mean shear bond strength of 10.34 MPa, The minimum shear bond strength being 8.16 MPa and maximum shear bond strength was 12.27 MPa due to its higher filler concentration and high density of filler particles, that is 1.95 grams per centimeter cube. This filler concentration also increases the shear strength, hardness, flexural strength and modulus of elasticity, and also tends to reduce polymerization shrinkage. The resultant surface, densely packed with fillers helps in better bonding with the tooth structure.

When the specimens with core x flow as core material were examined under scanning electron microscope core x flow showed more of adhesive failure. In core x flow specimens, 90 percent of fracture occurred at core/tooth-material interface. 10 percent of fracture occurred at the core material. This probably, could be because of higher concentration and density of filler particles.

Studies done by Gaurav J et al compared the shear bond strength of three dual-cure composite based core buildup materials namely ParaCore, FluoroCore, and MultiCore. Shear bond strength values obtained were 4.33 MPa, 10.08 MPa, 18.64 MPa. The results showed that composites with higher percentage of Urethane Dimethacrylate showed increased monomer conversion. Hence, replacement of some low-molecular-weight triethylene glycol dimethacrylate with Urethane Dimethacrylate, increases the molecular weight per reactive group, thus decreasing polymerization stress and increasing their ability to flex, thereby greater bond strength.[9]

Valux plus is a hybrid composite with filler particle size of 20 nm dispersed in bis-phenyl glyceryl methacrylate and tri-ethylene glyceryl dimethacrylate matrix. The mean Shear bond strength of valux plus was 5.63 MPa. The minimum shear bond strength of valux plus core material being 4.77MPa and maximum shear bond strength was 6.71MPa. This can be attributed to low percentage of high-molecular-weight urethane dimethacrylate monomer in composite resin composition. The filler content of valux plus is 60 percent which may be another contributing factor for low shear bond strength values.

When the specimens with valux plus as core material were examined under scanning electron microscope valux plus showed more of cohesive failure. In valux plus specimens, 60 percent of fracture occurred at core/tooth-material interface. 10 percent of fracture occurred at the core material. 30 percent of fracture occurred both at the material and junction of core / tooth structure interface.

A study by Cohen et al compared the fracture strength of three core restorative materials; lanthanide reinforced composite, silver amalgam, and hybrid glass ionomer. This study showed that all failures occurred either when the core material fractured or when the tooth fractured. It was concluded that, composite resin core material showed greater fracture resistance than amalgam and glass ionomer core materials.[3]

The shear bond strength of resin modified glass ionomer cement was markedly less (4.23MPa), when compared to bulk fill (mean shear bond strength 7.03MPa) and core x flow composite core materials (mean shear bond strength (10.34 MPa).

The specimens wherein the core materials when built with bulk fill, valux plus and resin modified glass ionomer cement, were studied under scanning electron microscope, analysis of the fracture site revealed the presence of a thin layer of the core material on the surface of the dentin (cohesive fracture). The specimens wherein the core materials, when built with core x flow, were studied under scanning electron microscope, analysis of the fracture site revealed the absence of a thin layer of the core material on the surface of the dentin (adhesive fracture). The scanning electron microscope analysis and shear bond strength supports that core x flow material was stronger of all the four materials.

Scientific evidence when collected and analysed systemically can provide useful and current information to dental practitioners. A thorough understanding of the proper use of a core material will enable clinicians to provide an optimum restoration.

CONCLUSION

Within the limitations of this in vitro study, the following conclusions were drawn:

1. Core x flow had the highest shear bond strength.
2. The shear strength of bulk fill, and valux plus was less than core x flow but higher than resin modified glass ionomer cement.
3. Shear bond strength of glass ionomer cement in the present study was found to be least when compared to the shear bond strength of composite resins.
4. Resin modified glass ionomer cement can be used as a core build up material in situations where the tooth structure lost is minimal, as it had the least shear bond strength and its use may be limited to anterior esthetic zone.

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