Shear bond strength of six restorative materials

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The purpose of this study was to determine and compare the shear bond strength of a conventional glass-ionomer cement, a resin modified glass-ionomer, a composite resin and three compomer restorative materials. Dentin of the occlusal surfaces from sixty extracted human permanent molars were prepared for shear bond strength testing. The specimens were randomly divided into six groups of 10 each. Dentinal surfaces were treated according to the instructions of manufacturers for each material. Each restorative material was placed inside nylon cylinders 2 mm high with an internal diameter of 3 mm, which were placed perpendicular to dentin surfaces. Shear bond strengths were determined using an Universal Testing Machine at crosshead speed of 0.5 mm/min in a compression mode. Conventional glass-ionomer, Ketac-Molar aplicap showed the lowest mean shear bond strength 3.77 ± 1.76 (X ± SD MPa) and the composite resin, Heliomolar showed the highest mean shear bond strength 16.54 ± 1.65 while the mean bond strength of Fuji II LC was 9.55 ± 1.06. The shear bond strengths of compomer restorative materials were 12.83 ± 1.42, 10.64 ± 1.42 and 11.19 ± 1.19 for Compoglass, Hytac and Dyract respectively. ANOVA revealed statistically significant differences in the mean shear bond strengths of all groups (P<0.001). No statistically significant difference was found between the three compomer materials (P>0.5). Ketac-Molar and composite resin showed statistically significant difference (P<0.0005). The mode of fracture varied between materials. It is concluded that the compomer restorative materials show higher shear bond strength than conventional glass-ionomer and resin modified glass-ionomer, but less than composite resin. The fracture mode is not related to the shear bond strengths values.

J Clin Pediatr Dent 25(3): 221-225, 2001

INTRODUCTION

The first glass-ionomer cement developed by Wilson and Kent[1,2] was a product of an acid–base reaction between basic fluoroaluminosilicate glass powder and polycarboxylic acid in the presence of water. Currently, many glass-ionomer products are available for restorative purposes. Composite resins possess superior mechanical properties and better esthetics than glass-ionomer cements, however they require bonding agents because they are usually hydrophobic and thus do not adhere well to teeth.[3] Glass-ionomer cements bond directly to teeth and have a potential effect of remineralization.[3,4]

Disadvantages of conventional glass-ionomer cements compared to composite resins are inferior mechanical properties, namely bending strength, tensile strength, and fracture toughness.[3,5] Highly viscous glass-ionomer cements were designed as an alternative to amalgam for posterior preventive restorations.[3] Example of highly viscous glass-ionomer cements are Ketac Molar. Due to the manipulative and mechanical characteristics, highly viscous glass-ionomers can be used for intermediate restorations, replacing amalgam and for core buildup procedures.[3]

Resin modification of glass-ionomer cement was designed to produce favorable physical properties similar to those of composite resins, while retaining the basic features of the conventional glass-ionomer cement.[6] This goal was achieved by incorporating water-soluble resin monomers into an aqueous solution of polyacrylic acid. In this way the system undergoes polymerization of the resin monomer while the acid-base reaction continues simultaneously.

The resulting resin-modified glass-ionomer cements exhibit many advantages of both resin cements and glass-ionomer cements.[3] Resin-modified glass-ionomer

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cements are more esthetic and less water sensitive than conventional glass-ionomer cements.[7] These light-cured materials display substantially better adaptation to the cavity preparation than the conventional materials.[8,9] This hybrid light-cured glass-ionomer cements has been shown to achieve higher bond strength to dentin when compared with the former chemically-cured glass-ionomer cements.[7,10] This may be, in part, because of the improved mechanical properties and, in part, because of the additional bonding mechanisms other than chemical bonding.[10]

In the search for a new restorative material, an attempt was made to polymerize an acid monomer in the presence of fluoroaluminosilicate glass. This attempt led to the development of a compound that releases fluoride slowly in the oral cavity; it is called a compomer.[11] The compomer shows physical properties quite similar to those of a composite resin.[11-13] At the same time, the acid monomer, which has been polymerized exhibits acidity when in contact with water from the saliva and reacts with the basic glass which contains fluoride.[3, 14]

The purpose of this study was to determine and compare the shear bond strength of a conventional glass-ionomer cement, a resin modified glass-ionomer, a composite resin and three compomer restorative materials.

MATERIALS AND METHODS

The list of materials used and the relevant manufacturers are shown in Table 1. Ketac-Molar Aplicap is a chemical cure glass ionomer, of powder and liquid encapsulated. Fuji II LC is a two component resin-modified glass-ionomer, presented as a powder, liquid and a conditioner. Hytac is a one-component compomer material provided with Hytac OSB, adhesive solution. Dyract is a one-component compomer, provided with a Prime and Bond 2.1 adhesive system. Compoglass is a one-component compomer, provided with Syntac single-component adhesive solution. Heliomolar is a microfilled, radiopaque composite resin, provided with Syntac single-component adhesive solution.

Sixty freshly extracted human permanent molars were used in this study. The teeth were thoroughly cleaned and stored in distilled water containing thymol crystals as a disinfectant. The teeth were cleaned and polished with pumice, using a low speed prophylaxis brush, then embedded in self cure acrylic resin so that the occlusal surfaces were parallel to the acrylic resin block surface. The teeth were then cut by low speed diamond saw (Isomet 2000, Buehler, Lake Bluff, IL, USA). Several cuts were made until a clean dentin surface was exposed. The prepared dentin specimens were polished using a standardized technique with 180, 320 and 600 grit silicon carbide abrasive paper (wet). The specimens were stored in distilled water for 24 hours at 37°C.

The specimens were randomly assigned to six groups of 10 teeth each. Adhesive tape with 3mm diameter was placed on the dentin surface of each specimen and the surface was treated according to the instructions of the manufacturer of each material. Then, each restorative material was placed inside nylon cylinders 2mm high with an internal diameter of 3mm, which were placed perpendicular to dentin surfaces.

Specimens in the group I were restored with Ketac-Molar Aplicap, group II were restored with Fuji II LC, group III were restored with Dyract, group IV were restored with Hytac, group V were restored with Compoglass and group VI were restored with Heilomolar composite resin. All materials were applied according to the instructions of the manufacturers. Specimens were stored in water for 24 hours at 37°C. Shear bond strength of all groups was measured using a universal testing machine (Accuforce, AMETEK, Mansfield and Green Division, Accuforce Elite Test System, Model E-500, USA) at a cross-head speed of 0.5mm/min in a compression mode using a blade parallel to dentin surfaces as the shearing element.

The bond strength at failure was calculated as the recorded failure load divided by the surface area of the inside of the nylon cylinder. The shear bond strengths were expressed in MPa. Results were statistically evaluated using one-way analysis of variance and multiple range Tukey's type test.

Following shearing, the mode of failure was investigated at the tooth surface sites for the de-bonded specimens. Each specimen was examined by one investigator using a stereomicroscope (Wild Photomakroskop M400 Heerbrugg, Switzerland) to determine whether the bond failure was: (a) cohesive bulk fracture, (b) cohesive fracture with a firmly attached, thin and homogeneous layer, (c) mainly adhesive fracture with islands of firmly attached materials, or (d) adhesive fracture.

RESULTS

The shear bond strength results are presented in ascending order in Table 2. The conventional glass-ionomer, Ketac-Molar aplicap showed the lowest mean shear bond strength 3.77 ± 1.76 ($X \pm SD$ MPa) and the composite resin Heliomolar showed the highest mean shear bond strength 16.54 ± 1.65 while the mean bond strength of Fuji II LC was 9.55 ± 1.06. The shear bond strengths of compomer restorative materials were 12.83 ± 1.42, 10.64 ± 1.42 and 11.19 ± 1.19 for Compoglass, Hytac and Dyract respectively.

ANOVA revealed statistically significant differences in the mean shear bond strengths of all groups ($P<0.001$). No statistically significant difference was found between the three compomer materials ($P>0.5$). Ketac-Molar and composite resin showed statistically significant difference ($P<0.0005$).

The mode of fracture is presented in Table 3. Groups I to IV showed mostly dentin-adhesive fracture, indicating an adhesive fracture, while groups V and VI

Table 1. Materials used in the present study

MATERIALS	TYPES	ETCHANT	ADHESIVE	MANUFACTURERS
Ketac-Molar Aplicap	Chemical cured glass-ionomer	Conditioner (25% Polyacrylic acid)	——————-	ESPE / Premier, Norristown, PA
Fuji II LC	Resin-modified glass-ionomer	Conditioner (10% Polyacrylic acid)	——————-	GC America Inc., Chicago, IL
Compoglass	Compomer	——————-	Hytac OSB	Ivoclar North America, Amherst, NY
Hytac	Compomer	——————-	Prime & Bond 2.1	ESPE / Premier, Norristown, PA
Dyract	Compomer	——————-	Syntac Single-Component	Caulk /Dentsply, Milford, DE
Heliomolar	Composite resin	Acid etched (37% Phosphoric acid)	Syntac Single-Component	Ivoclar North America, Amherst, NY

Table 2. Shear bond strengths in Mpa for all groups

Group No.	MATERIALS	MEAN	STANDARD DEVIATION	RANGE
I	Ketac-Molar Aplicap	3.77	1.76	1.83 - 6.69
II	Fuji II LC	9.55	1.06	7.29 - 10.95
II	Hytac	10.64	1.42	8.52 - 13.38
IV	Dyract	11.19	1.19	9.73 - 12.77
V	Compoglass	12.83	1.42	10.95 - 11.52
VI	Heliomolar	16.54	1.65	13.38 - 18.24

showed some attached materials on the specimens indicating some cohesive failures. There were less dentin-adhesive fractures in the Compoglass and Heilomolar specimens. Dyract restorative materials showed no cohesive fractures while Hytac and Fuji II LC showed some cohesive fractures. Ketac-Molar also showed some cohesive fractures.

DISCUSSION

In general, the mean shear bond strengths of resin modified glass ionomer restorative materials is greater than the bond strength of conventional glass-ionomer.[15-20] A previous study reported that the high value of shear bond strength for the resin modified glass ionomer materials is primarily due to the increased cohesive strength of the materials and not the increased adhesion to tooth structure.[21] Fuji II LC, is mainly glass-ionomer with addition of small quantity of resin components[22] such as hydroxethlmethacrylate (HEMA) or Bis-GMA.[23] Polyacrylic acid as used in conjunction with Fuji II LC and the conventional glass-ionomer, acts as a weak etching agent[24] that removes the smear layer, but does not remove smear plugs from the dentinal tubules.[25] These materials rely on the chemical bond to the substrate rather than mechanical bond.

Table 3: Frequency of bond failure type

Group No	MATERIALS	TYPE OF FAILURE
I	Ketac-Molar Aplicap	d c d d d c d a b d*
II	Fuji II LC	d c d b d d b b d d
II	Hytac	b d c d c d d d d b
IV	Dyract	c d d d d d d d d d
V	Compoglass	d a a d d c a d c c
VI	Heliomolar	c c b c a b b d c d

*Mode of bonding failure: a = cohesive bulk fracture; b = cohesive fracture with a firmly attached, thin and homogeneous layer; c = mainly adhesive fracture with islands of firmly attached materials; d = adhesive fracture

Compomer materials, such as Hytac, Dyract and Compoglass provide one bottle adhesive system. The conditioners may play a somewhat different role because they contain monomers, such as HEMA, which seems to play a crucial role on the hybrid layer formation that can infiltrate into demineralized dentin and/or when polymerized, may form a micromechanical bond.[10,25]

As a result of this, the resin modified glass-ionomer materials provide a different pretreatment consisting of a primer or conditioner to pre-treat dentin in order to obtain higher bond strengths.[10,23] In Fuji II LC, pretreatment includes application of polyacrylic acid, which can improve bond strength somewhat, similar to Ketac-Molar.

However, since the former has a HEMA in its liquid content, it gives the material a stronger bond to the tooth substrate. Dyract, Hytac and Compoglass restorative materials provide an adhesive solution that makes the materials bond micromechanically to the dentin in addition to the chemical bond.[3,26] Due to more resin in the materials, it required an adhesive to create a hybrid layer that gives the materials good adherence to the substrates as in composite resin.[3,26]

The present study showed that the highest bond strength of compomer materials was obtained with Compoglass that had a relatively high concentration of the hydrophilic resin monomer (HEMA). Those materials near the composite resin end such as Compoglass exhibited little of the inherent glass-ionomer adhesion to dentin and require a dentin bonding agent to obtain meaningful adhesion.[3,26] While those materials near the glass-ionomer end such as Fuji II LC use only conditioning agents that is rinsed off prior to placing the mixed material.[3,26] In Hytac and Dyract materials, which demonstrated high shear bond strengths, an adhesive was still needed to achieve the interlocked micromechanical bond due to the high contents of resin. In addition, these materials vary in the amount of methacrylate that can undergo photoactivated polymerization, therefore the bond strength is not only dependent on the pretreatment of the dentin but also on the resin composition of the materials.[27,28]

Examination of the fracture sites indicated that the predominant mode of failure in this study was mostly a dentin-adhesive fracture at the material-dentin interface. Heliomolar that has been treated with phosphoric acid showed some firmly attached material on the dentin surface in greater numbers than were treated with polyacrylic acid. This may be due to the deeper penetration and micromechanical interlocking with the Heliomolar material where the dentin surface was treated with the phosphoric acid. In the present study there seemed to be no direct relationship between the mode of fracture and bond strength values, which means that high bond strength values were not necessarily correlated with a cohesive type of fracture.[27]

CONCLUSIONS

1. The compomer restorative materials show higher shear bond strength than the conventional glass-ionomer and resin modified glass-ionomer but less than composite resin to dentin of permanent teeth.
2. No statistically significant difference of the shear bond strengths among compomer materials used in the present study.
3. No direct relationship between the mode of fracture and bond strength values.

ACKNOWEDGEMENTS

I would like to express my sincere thanks and appreciation to Maria Georgescu for her helpful during the experiment, and to Dr. John Legeros for his great helpful in the statistical analysis.

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