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Shear Bond Strength of Resin Modified Glass Ionomer Cement Bonded to Different Tooth-Colored Restorative Materials

Nadia Malek Taher, BDS, MSc; Nasrien Z. Ateyah, BDS, MSc

Abstract

Aim: The aim of this study was to determine *in vitro* the shear bond strength (MPa) and the type of bond failure when resin-modified glass ionomer cement (RMGIC) was bonded with different tooth-colored restorative materials.

Methods and Materials: The RMGIC tested was Fuji II LC (FL) and the tooth-colored restorative materials used were composite resin Point-4 (P4), Compomer Dyract AP (DY), and Ormocere Admira (AD). A total number of 60 FL specimens were prepared using Teflon molds. The specimens were divided into six equal groups. Each group of ten specimens was bonded to a tested tooth-colored restorative material as follows: Group I - etched FL bonded to P4; Group II - non-etched FL bonded to P4; Group III - etched FL bonded to DY; Group IV - non-etched FL bonded to DY; Group V - etched FL bonded to AD; and Group VI - non-etched FL bonded to AD. The specimens were stored in distilled water at 37°C for 24 hours. The shear bond strength was measured in a universal testing machine, and the fractured surfaces were examined under a stereomicroscope.

Results: The results of the shear bond strength indicated the lowest mean value (14.46 MPa) was in Group III, and this was significantly different from the values of other groups ($p<0.05$). However, Groups V and VI recorded the highest mean values (24.5 MPa and 28.39 MPa) which were significantly different ($p<0.05$) when compared to other groups. Groups I, II, and IV showed no significant difference with mean values of 20.06, 19.99, and 20.1 MPa which were significantly different from other groups ($p<0.05$).

Conclusion: AD showed the highest shear bond strength to RMGIC. All groups demonstrated a cohesive failure in FL except for Group IV where a cohesive failure in DY was recorded. AD showed good shear bond strength when laminated with FL.

Keywords: Resin-modified glass ionomer cement, RMGIC, shear bond strength, cohesive failure

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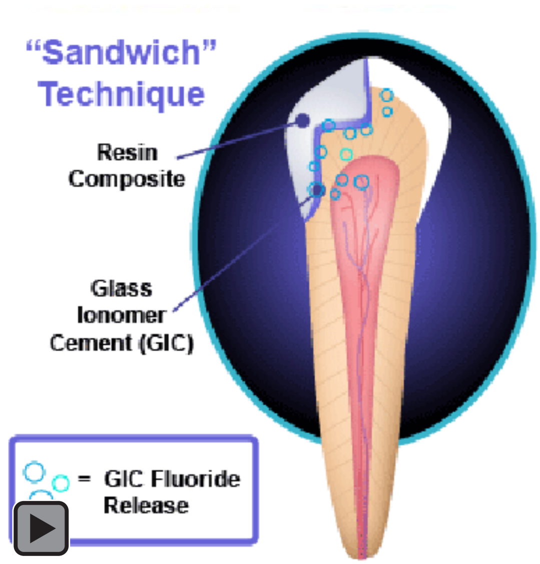
Introduction

The use of laminate or the "sandwich" method is one of the recommended composite restorative techniques used in dentistry, and it is currently the subject of several studies.[1] This technique was developed by McLean et al.[2] in 1985 who used the dentin adhesive properties of glass ionomer cements (GICs) to seal cavities and reduce micro-leakage. The technique benefits from the advantages of GIC fluoride release in combination with esthetic resin material to enhance clinical serviceability.[3,4,5,6] The concept of the lamination technique is to use two different restorative materials to form one restoration. The rational behind the technique is to make the most of the physical and esthetic properties of each material. These esthetic restorative materials bond to tooth structure, and the GIC offers long-term fluoride release that can be recharged with a neutral topical fluoride application.[7]



The first laminated restorations used conventional auto-cure GIC which develops mechanical interlock between it and composite resin. However, failure occurred due to sensitivity to moisture and the progressive loss of the GIC.[8] The bond strength between conventional GICs and composites is limited by the low cohesive strength of glass-ionomers due to the lack of chemical bonding. This could be attributed to the difference in the setting reactions between dental composites and conventional GICs.[5]

Resin-modified glass ionomer cement (RMGIC) was introduced as both a restorative and base material because it demonstrated improved mechanical and physical properties over conventional GICs.[9] It was also reported the flexural strength of RMGIC was significantly improved and showed a true adhesive bond to resin composites[4] compared to cured conventional GIC.[5]

Dyract AP (DY) (Dentsply, Konstanz, Germany) as a "compomer" combines the polymers of composite with the characteristics of glass ionomers which may include adhesion to tooth structure and cariostatic properties due to fluoride release.[7] However, all compomer systems provide dentin bonding agents similar to those used with composites. Therefore Dyract was combined with Dyract PSA and marketed with Prime and Bond NT (Dentsply, Konstanz, Germany).[10] However, compomers have a significantly lower fluoride release than glass ionomer and because their mechanical properties and wear resistance are inferior to composite resins there is little indication for their use.[7]

Meanwhile, a new generation of material was introduced in late 1998 based on the new organically modified ceramic or ormocer. The ormocer composite consists of inorganic-organic copolymer. Its complex composition is poorly understood, and the bonding capability is unknown. However, it is already being widely used in modern technology.[11,12]

Studies on the lamination technique in the dental literature were limited when composite resin restorative materials were the only composite materials available. Since there is some confusion in the literature on the effect of etching GIC on the shear bond strengths with different esthetic tooth-colored restorative materials, the aim of this *in vitro* study was to measure the bond strength of these restorative materials when bonded to RMGIC with and without acid etching. In addition, the location of bond failure after de-bonding was assessed.

Methods and Materials

Three esthetic tooth-colored restorative materials were used in the present study:

- Composite resin Point-4 (P4) = (Kerr, Salerno, Italy)
- Compomer Dyract AP (DY) = (Dentsply, Konstanz, Germany)
- Ormocere Admira (AD) = (Voco, Cuxhaven, Germany)

The materials were bonded to Fuji II (FL) (GC Corporation, Tokoyo, Japan) (a light cured reinforced glass ionomer restorative material) as shown in Table 1.

Sixty specimens of FL were prepared using a Teflon mold. The Teflon mold had a central hole measuring 8.5 mm in diameter and 2.5 mm in depth. The hole was filled with FL using a plastic instrument and covered with a glass microscope slide to produce a smooth surface and to facilitate light curing. It was then cured for 40 seconds. A light curing unit (ESPE Elipar high light, Germany) was used for all light-curing procedures. The tooth colored restorative material was added on top of the FL by means of a second split Teflon mold (5 mm x 3 mm) with a hole centered on the first specimen and held in place with an aluminum ring. The restorative material was cured according to the manufacturer's instructions from the top of the specimens. After curing, the second split mold was removed.

The 60 FL specimens were divided into six equal groups of ten specimens each as shown in Table 2. In Group I, the FL cement surface was etched for 15 seconds with 37.5% phosphoric acid etching gel (Kerr, Detroit, MI, USA), washed, and dried. Optibond Solo Plus (Optisolo ethyl alcohol, Kerr, Detroit, MI, USA) was then applied for 15 seconds with a light brushing motion, lightly air thinned for three seconds, and then light cured for 20 seconds. Composite resin P4 was thereafter applied then cured for 40 seconds. In Group II the same procedures were performed as in Group I but without etching the FL surface. In Group III the FL surface was etched as was done in Group I, then Prime 2 Bond NT was applied and left undisturbed for 30 seconds and cured for 20 seconds as recommended by the manufacturer. DY was applied and cured for 40 seconds. In Group IV, DY was applied without etching the FL surface. In Group V the FL surface was etched with the same etchant gel as in Groups I and III, washed, and dried. AD bond single dose (Voco, Cuxhven, Germany) was then applied, left undisturbed for 30 seconds, and then cured for 20 seconds. Thereafter, AD was applied and light cured for 60 seconds. The last Group VI was similar to Group V except the FL surface was not etched.

The specimens were immersed in distilled water at 37ºC for 24 hours. The shear bond strength for each specimen was measured using a universal testing machine (Instron 8500, Instron Corporation, Canton, MA, USA). The shear bond strength was measured at a cross-head

Table 1. Materials studied.

Material	Code	Type	Manufacturer
Point-4	P4	Composite Resin	Kerr, Salerno, Italia
Dyract AP	DY	Compomer	Dentsply, Konstanz, Germany
Admira	AD	Ormocere	Voco, Cuxhaven, Germany
GC Fuji II LC	FL	Light-cured reinforced restorative GI	GC Corporation, Tokyo, Japan

speed of 0.5 mm/min. The fractured surfaces were examined under a stereomicroscope (Swift Instrument International microscope series 80, Japan).

Means and standard deviations were calculated for each group and analyzed using a one-way analysis of variance (ANOVA). In addition, Tukey's test at a 5% level of significance was used to determine specific pair wise group differences. The significance of difference between the groups was analyzed. Bond failure data were also analyzed statistically using the Tukey's test at a 5% level of significance.

Results

The results of the shear bond strength testing are presented in Table 2 and graphically in Figure 1. The maximum shear bond strength values were recorded with Group VI (28.39 MPa). On the other, hand Group III displayed the minimum shear bond strength of (14.46 MPa). The Tukey's test showed the bond strengths for Group I, Group II, and Group IV were nearly similar (20.06, 19.99, and 20.15 MPa) and showed no significant differences, but they were significantly different from Groups III, V, and VI, respectively. Group III was significantly different from all other groups, however, Group V and VI showed significant differences between each other.

Sites of bond failures for all groups are presented in Table 3. All bond failures were cohesive in FL except Group IV where it was cohesive in the filling material (DY) itself. The Tukey's test revealed Group IV was statistically different from other groups. However, all other groups showed no statistical significance difference ($p<0.05$).

Table 2. Mean values (MPa) and standard deviation (SD) of the shear bond strength for etched and non-etched FL bonded to different tooth-colored restorative materials.

Tooth-Colored Restorative Materials	Resin Modified GIC FL	
	Etched	Non-Etched
Point-4 (P4)	20.06 (3.05) a*	19.99 (3.46) a
Dyract AP (DY)	14.46 (2.93) b	20.15 (2.43) a
Admira (AD)	24.52 (2.52) c	28.39 (2.75) d

*Identical superscript letters indicate mean values with no significant differences.

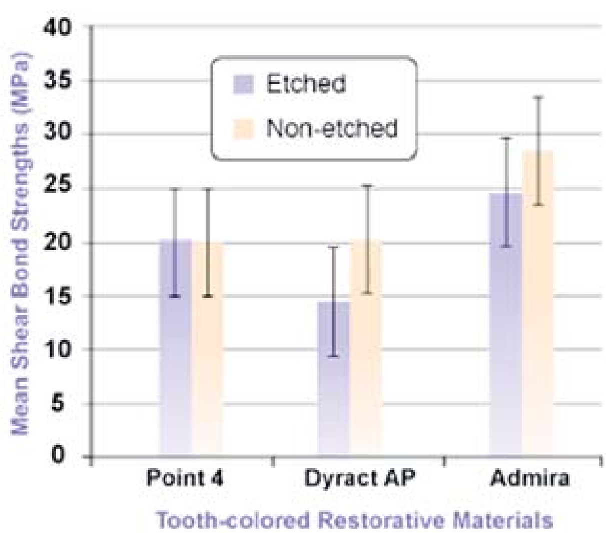


Figure 1. Mean values (MPa) of shear bond strength for etched and non-etched FL bonded to different tooth-colored restorative materials.

Table 3. Type of failure between etched and non-etched FL and different tooth-colored restorative materials.

Tooth-Colored Restorative Materials	Resin Modified GIC FL	
	Etched	Non-Etched
P4	Group I 10 (B)	Group II 10 (B)
DY	Group III 2 (A) 8 (B)	Group IV 10 (C)
AD	Group V 10 (B)	Group VI 10 (B)

A = adhesive failure, B = cohesive failure in the glass ionomer, C = cohesive failure in the restorative material.

Discussion

FL is mainly a glass ionomer with the addition of a small quantity of a resin component such as hydroxethlmethacrylate (HEMA)[7] or Bis-GMA[13] and a photo initiator.[14] In addition, the glass ionomer is silanized to promote adherence within the resin matrix. The photo-initiated reaction results when the methacrylate groups graft onto the polyacrylic acid chain cross-linking with methacrylate groups of the HEMA or when HEMA is polymerized.[7] Those materials were claimed to be a tri-cured set through three reactions: acid-base, chemically activated polymerization, and photo-activated polymerization.[4]

Glass Inomer Cement (GIC)

Contradiction was found in the literature regarding etching or not etching GIC. In general, acid etching improves the bond strength of composites to conventional glass ionomers.[15,16] It was claimed etching with phosphoric acid (35%) preferentially attacks the matrix of the hardened GIC resulting in a rough and porous surface providing a retentive surface to increase the adhesion of composite resin.[17]

Another study concluded there was no consistent difference in bond strength between composite resin and etched, or non-etched GIC.[18] However, the bond/shear strengths of the composites bonded to the cured RMGIC were consistently higher than those of the composites bonded to the conventional GIC even with acid etching.[5] A similar conclusion was reported by Farrah.[4] The findings in this study are in agreement with another study[19] which demonstrated etching the hybrid ionomers with phosphoric acid had no statistical effect on bond strength when compared with the non-etched group. In the present study, Group II (19.99 MPa) showed no significant difference than Group I (20.01 MPa). At the same time, a statistical difference with DY and AD was reported between etched and non-etched FL groups. Speculation is the RMGICs are not susceptible to acid etching due to their high resin content.

Most failures occurred cohesively within the FL cement itself (except in Group IV, where the cohesive failure was within the DY). This seems to be a typical finding and may be because RMGIC contains numerous air inclusions.[20] These air inclusions can act as stress points giving rise to the increased likelihood of cohesive failure within the cement itself which was seen as the most common mode of failure.[20] This same phenomenon can also occur in resin-based systems, but the number of defects within the resin are much less than with GIC.[20] The previous statement could be the explanation for the cohesive failure within the DY (Group IV) itself rather than FL where the DY probably has weaker cohesive bonds than the adhesive bond to FL or the cohesive bond of FL itself.

It was concluded the better the bond between dentin and composite the higher the percentage of cohesive failure within each sample.[10]

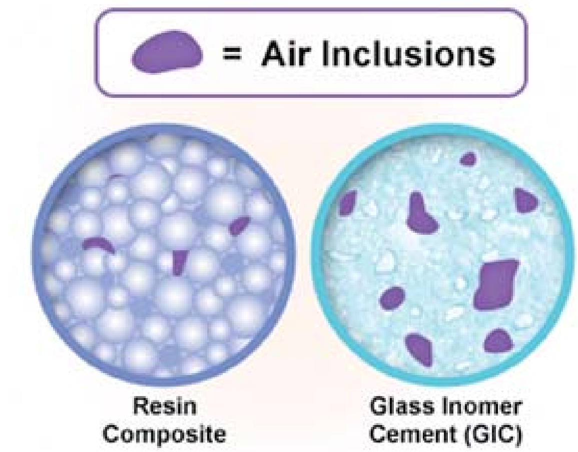
In the present study the highest shear bond strength was obtained with Group VI, where a cohesive failure in FL was reported in all samples.[4,20] It can be concluded the bond between FL and AD was stronger than the tensile bond strength of FL itself.[20] This also indicates the chemical bond between FL and AD is stronger than with the other restorative materials P4 and DY.[4]

An analysis of the de-bonded surfaces revealed adhesive failure occurred along the GIC/composite interface in 55.6% of specimens.[4] Results in the present study differ because a cohesive failure occurred in the FL itself in all specimens. However, since the parameters in bond strength studies are not standardized it becomes very difficult to compare results with any validity.

DY, as a compomer material, is a polyacid-modified composite resin containing either or both of the essential components (basic glass and acidic polymer) of a GIC but at levels insufficient to promote the acid base cure reaction in the absence of light.[21] After initial light-activated polymerization, the traditional glass-ionomer reaction slowly emerges through the uptake of water, activation of carboxylic groups of the dimethacrylate monomer, and the establishment of an acid-base reaction.[14,22]

DY was combined with Dyract PSA (Primer Sealer Adhesive), a self-conditioning single step, as an acetone-based agent containing acidic monomers. It is marketed with Prime and Bond NT.[10] When they were introduced, acid etching was not required by manufacturers.[14] It was subsequently demonstrated the use of an acid etch procedure significantly improved both the retention and marginal leakage of the compomers.[23]

Luo et al.[24] stated conditioning the teeth with 36% phosphoric acid gel improved the seal of Prime & Bond NT resulting in a more gap-free restoration compared with the no-etch technique.



Increased shear bond strengths to dentin were observed using Dyract, phosphoric acid etching, and acidic primer under moist bonding surfaces.[25] Also, it was reported the tensile bond strengths of DY to dentin were improved under the same circumstances.[26]

It was postulated PENTA (of Prime and Bond) has a low pH and acts as a self-etching agent when in contact with the dentin surface which affects the adhesion.[25] The Prime and Bond 2.1 adhesive system uses the elastomeric resin plus the addition of cetylamine hydrofluoride and acetone solvent.[25] To the authors' knowledge no study has been done on laminating glass ionomer with compomer.

The result of the present study showed the lowest bond strength was found between etched FL and DY. There is no obvious scientific explanation for this finding. Speculation is DY (a compomer material) is set by the polymerization of c=c of methacrylate which is delayed acid-base reaction between glass and acid molecules.[14] While GIC is claimed to be a tri-cured set, another contributing factor could be the different bonding used with different materials where both the viscosity and chemical composition of the bonding agent influence the resin glass-ionomer bond. It has been reported failure occurred cohesively within the bonding agent or adhesively between the bonding agent and GIC with the highest viscosity bonding agent.[27] There is a possibility a low pH bonding agent dissolves the GIC surface which causes a mechanical attachment.[6] In the present study the pH of the bonding was not measured.

Ormocer is a class of material representing novel inorganic-organic copolymers in a formulation which allows for modification of its mechanical parameters. These inorganic-organic copolymers are synthesized from multifunctional urethane and thioether (methlacrylate alkoxysilanes) as sol-gel precursors. Alkoxysilyl groups of the silane permits the formation of an inorganic Si-O-Si network by hydrolysis and poly-condensation reactions.[11] The methacrylate groups are available for photochemical polymerization. The result of the present study revealed the highest bond was achieved between FL whether etched or non-etched and AD (24.52 MPa and 28.39 MPa). The bond was higher than with either P4 or DY. The matrix of ormocer employing multifunctional methacrylate is a rigid matrix[11], while composite resin (P4) is a mixture of di-functional monomers.[14]

Several mechanisms that could be involved in the chemical adhesion between FL and AD are as follows:

- Increased availability of unsaturated double bonds in the air-inhibited layer of the RMGIC,
- Un-polymerized HEMA on FL could increase the surface wetting capability of the bonding agent as well as the bond strength when polymerized,
- Unsaturated methacrylate pendants which are available on the polyacid chain within the polymerized FL may also form ionic bonds with the resin bonding agent.[4]

However, both RMGIC and dental composites are cured by a free radical initiator system which provides the potential of chemical bonding between these two materials.[5] The bond between FL and AD is higher than with other tooth-colored restorative materials (P4 and DY). The similarity in composition of this chemistry may play a major role in the high value of adhesion.[4] The inclusion of resin-based setting reaction in FL seems to be the primary reason for an improved chemical bond.[5] There are many factors such as wet ability, viscosity, and contact angle that influence bond strength values.[27] It is also possible the bond strength could be influenced by the presence or absence of any chemical bonding mechanism that could occur between the two materials when a lamination technique is used. It was not possible to answer all questions raised by this study and further studies are recommended.

Conclusion

- This present study showed a chemical bonding did exist between FL and esthetic tooth-colored restorative materials.
- Etching the surface of RMGIC (FL) did not improve the bond.
- The lowest bond value was found when DY was bonded to etched FL (Group IV).
- All failures were cohesive in the FL except in Group IV where cohesive failure was in DY itself.
- The highest bond value was reported with non-etched FL bonded to AD (Group VI).
- The use of FL (RMGIC) as a base material in the lamination technique for AD restorations is recommended.

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About the Authors

Nadia Malek Taher, BDS, MSc

Dr. Taher is an Associate Professor in the Department of Restorative Dental Sciences of the College of Dentistry at King Saud University in Riyadh, Kingdom of Saudi Arabia

e-mail: nmataher@hotmail.com

Nasrien Z. Ateyah, BDS, MSc

Dr. Ateyah is an Associate Professor in the Department of Restorative Dental Sciences of the College of Dentistry at King Saud University in Riyadh, Kingdom of Saudi Arabia

e-mail: nzateyah@hotmail.com