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COMPARATIVE EVALUATION OF THE BONDING OF GLASS-IONOMER CEMENT MODIFICATION TO DENTAL COMPOSITE ESTABLISHED BY DENTAL ADHESIVES

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ABSTRACT

Objective: To evaluate the influence of the application of various adhesives on the strength of the bonding established amongst resin-modified glass-ionomer cement (RMGIC) and resin composite restoration (RBC).

Materials and method: Twenty discs were made-up with (RMGIC) and divided into four groups (n = 5) based on the adhesive resin system applied. Cylinders of resin composite were bonded to the RMGI discs utilizing different adhesive resin systems in the first three groups. While the fourth group was used as a control receiving no adhesive resin treatment. Microshear bond strength was measured and the data was registered with computer software in MPa.

Results: The results revealed that applying different adhesive resin systems statistically significantly increased the bond strength between the tested materials.

Conclusion: Microshear bond strength of (RMGIC) to resin composite improved considerably using different adhesive resin systems. The outcomes vary depending upon the type of adhesive resin system utilized.

KEYWORDS: *Resin composite, adhesive resin systems, glass-ionomer, bond strength.*

INTRODUCTION

It is well documented that chemical bonding to the tooth tissues, biocompatibility and fluoride release were recognized advantages of glass ionomer cement since their introduction to the dental practice [1,2]. In contrast, such material suffered from shortcomings in its properties, accordingly has been modified by adding polymerizable functional groups [hydroxyl-ethyl methacrylate] forming resin-modified glass ionomer cement (RMGIC), enjoying improvements over their precursors regarding their

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clinical application and properties[3]. Though, still being deliberated inferior in their properties when compared to the resin composite.

Thus, glass ionomer cements (GICs) are frequently employed clinically as a base beneath resin composites, sealing the dentin and its tubules by forming a consistent bond with the underlying tooth structure [4]. This procedure was referred to as 'sandwich technique" [5]. The lamination technique in the badly broken teeth and compound cavities has been indicated for relieving the polymerization stresses generated by the of RBCs [6].

Nevertheless, in the lamination technique one of the decisive aspects for longevity of these restoration is a consistent bonding between the GIC and the resin composite restorative. Several investigations presented that the failure of such restorations was due inability to achieve proper bond between glass ionomer and composite resin [7]. Such bond is micromechanical intermediated by the adhesive bonding system. A chemical bond is also established between the resin in RMGIC and that present in the bonding system [8]. No doubt abundant factors and aspects have driven the bond between the two aforementioned materials based upon the structure and the properties of each [9].

Several studies presented that the resin-modified glass-ionomer (RMGIC) application in the sandwich technique results in a better bond strength to composite resin if compared to the conventional GIC[10]. In spite of prevalent use of GICs in extensive restorations, only limited studies have assessed its bond to composite resins using different adhesive resin systems. The application of the bonding agents would enhance the wettability of GIC surface, resulting in an improvement of the bond between resin composite and both conventional GIC and RMGIC [11].

Praiseworthy that adhesive resins have improved lately in several aspects. The gold standard etch-and-rinse systems form a micromechanical bond to hard tooth structure, which is essential for bonding to conventional glass ionomer cement. On the other hand, a chemical bond is established between the resin component of the resin-modified glass ionomer cement and the adhesive system. [10] It is worth to mention that, self-etching priming adhesives used acidic resin monomers, eliminating the rinsing step and diminishing the technique sensitivity [12]. Comparison between etch and rinse systems and others like the two-step self-etching ones, resulted in similar adhesion potential to the tooth tissues. Contrariwise, all-in-one systems displayed more debatable performance [13].

Yet, the bond between resin composite and GIC employing those adhesive systems is still unidentified. [11] Thus, it would be considered advantageous to recognise how the recent adhesive resins, interact with GICs acclaimed for the laminate technique. Accordingly, the aim of the current investigation was to measure the bond strength between RBC and RMGIC employing different adhesive systems.

MATERIALS AND METHOD

Preparation of the specimens

Light-cured RMGIC (Vitrebond, 3M ESPE, USA) (**Table 1** lists the materials used) was use, the specimens were constructed in two layers and embedded in moulds (2 mm thickness, 15 mm diameter). A total of 20 discs were prepared, a mylar strip was placed over the mould for better placement of the RMGIC. The curing was done against mylar strip to standardize specimens' surfaces and to achieve smooth surface finish. The specimens were light-cured with LED light curing unit with light intensity 1500 mW/cm^2 (Radii Plus, SDI Limited, Australia).

Grouping of the study specimens

The RMGIC discs were randomly assigned into four groups (n=5) according to the adhesive resin used. Where, 1 (etch-and-rinse adhesive), 1 (two-step self-etching primer adhesive), and 1 (all-in-one adhesive) were employed. In all groups, the resin adhesives were applied to the RMGIC substrates following manufacturers' instructions **(Table 2)**.

Group 1: 3M™ Single Bond Universal (SBU) (3M ESPE, St. Paul, MN, USA) was employed on the substrate surfaces.

Group 2: Clearfil SE Bond (CSE) (Kuraray Medical Inc, Tokyo, Japan) was applied on RMGIC substrate.

Group 3: Clearfil S3 Bond (CS3) (Kuraray Medical Inc, Tokyo, Japan) (all in one adhesive) was used on RMGIC substrate.

Group 4: This group served as the control and did not receive any adhesive resin.

Preparation of resin composite microcylinders:

For the microshear test [14], prior to the adhesive resin polymerization, four tygon tubes (R-3603, Norton Performance Plastic Co., USA) with (internal diameter 0.9mm - a height 0.5mm) were placed on each treated substrate. After the adhesive resin was light polymerized, the bonded tubes were then filled with resin composite (Z250, 3M ESPE, USA) smoothly pressed, and light activated for 40 seconds. All bonded specimens were stored in distilled water at 37 ◦C for 24 hours before testing. After the storage period, the tygon tubes were removed to reveal the resin composite micro-cylinders. The specimens were checked under a stereomicroscope (Olympus, Tokyo, Japan) at a magnification of 20× prior to microshear testing. Any specimens that presented a detectable defect was excluded and replaced.

Mircroshear bond strength testing:

Microshear bond strength was tested using universal testing machine (LRX-Plus-Lloyd Instruments Ltd., Fareham, UK). The wire and loop method was selected, where a thin wire with a diameter of 0.2mm was looped to contact the connection between the RMGIC discs and composite bonded assembly, placed as close as possible to the interface to ensure force application parallel to the bonded surface [15]. A shear force at a crosshead speed 1.0mm/min was applied on all the samples till fracture, and the results in MPa were expressed using computer software.

1.1. Statistical analysis

For each group, data was presented as mean and standard deviation (SD) values. Data was subjected to analysis by one-way analysis of variance ANOVA followed by Tukey post-hoc test (with significance level $P \leq 0.05$). The sample size was determined according to one-way ANOVA study. It was calculated with a power of 90% and significance level of 95%. A total sample size of 20 specimens was used. Sample size was calculated using G power version 3.1.9.7. (Heinrich-Heine-Universitat Dusseldorf, Dusseldorf, Germany). Statistical analysis was performed with IBM® SPSS® (SPSS Inc., IBM Corporation, NY, USA) Statistics Version 23 for Windows.

TABLE (1): Materials, descriptions and manufacturers used in the study:

Material	*Composition*	*Manufacturer*
	Restorative Materials	
Vitrebond	**Powder:** Glass fiber, Diphenyliodonium chloride **Liquid:** Copolymer of acrylic and itaconic acid, Water 2-Hydroxyethyl methacrylate	3M ESPE Dental Products, St. Paul, MN, USA
Filtek Z250 Universal Restorative - Shade A3	**Organic matrix:** Bis-GMA (bisphenylglycidyl dimethacrylate) UDMA (urethane dimetacrylate) Bis-EMA (ethoxylated bisphenol-A dimethacrylate) Camphorquinone **Filler:** Zirconia/silica (82% by weight, 60% by volume; average particle size 0.6 μ m)	3M ESPE Dental Products, St Paul, MN, USA
	Adhesive resin systems	
3M™ Single Bond Universal adhesive system (Etch and rinse) (SBU)	MDP phosphate monomer, HEMA, ethanol, Vitrebond copolymer, filler, water, initiators, dimethacrylate resins, silane.	3M ESPE Dental Products, St. Paul, MN, USA
Clearfil SE Bond (Two-step self-etch primer) (CSE)	**Primer:** 10-methacryloyloxydecyl dihydrogen phosphate (MDP), HEMA, hydrophilic dimethacrylate, dl-camphorquinone, N, N-diethanol ptoluidine, water **bond:** MDP, bis-phenol A diglycidylmethacrylate (Bis-GMA), HEMA, hydrophobic dimethacrylate, dlcamphorquinone, N,N-diethanol-p-toluidine, silanated colloidal silica	Kuraray Medical Inc, Tokyo, Japan
Clearfil S3 Bond (All-in-one adhesive) (CS3)	MDP, diglycidylmethacrylate, bis-GMA, HEMA, hydrophobic dimethacrylate, dl-camphorquinone, ethyl alcohol, water, silanated colloidal silica	Kuraray Medical Inc, Tokyo, Japan
(Acid etchant)	37% Phosphoric acid gel	(3M ESPE Dental Products, St. Paul, MN, USA)

TABLE (2): Materials, descriptions of the application of adhesive resin systems used in the study:

Material	*Manufacturers' instructions for the application*
3M™ Single Bond Universal adhesive system (Etch and rinse)(SBU)	37% phosphoric acid (3M ESPE Dental Products, St. Paul, MN, USA) for 15 s, followed by rinsing and drying for 5 s using an air syringe, immediately after etching, apply 2–3 consecutive coats of adhesive for 15 seconds with gentle agitation using a fully saturated applicator. Gently air thin for 5 seconds to evaporate solvent. Light-cure for 20 seconds.
Clearfil SE Bond (Two-step self-etch primer) (CSE)	Apply primer for 20 seconds then dry with mild air flow. Apply bond then air flow gently. Light-cure for 10 seconds.
Clearfil S3 Bond (All-in-one adhesive) (CS3)	Apply bond then dry with high-pressure air flow for more than 5 seconds. Light-polymerization for 10 seconds.

RESULTS

The means of microshear bond strength values and standard deviations SD were designated in **(Table 3)**.

The highest mean microshear bond strength was found with the application of Clearfil SE Bond (two-step self-etch primer) (CSE) (22.51 ± 1.81) MPa. This was followed by Clearfil S3 Bond (all-in-one adhesive) (CS3) (16.15 ± 2.01) MPa. Then 3M™ Single Bond Universal adhesive system (SBU) (13.36 ± 2.74) MPa. Meanwhile, the control group showed the statistical significant lowest mean microshear bond strength (4.43 ± 1.32) MPa.

One-way ANOVA revealed that utilizing adhesive resins between resin composite and RMGIC significantly increased the microshear bond strength values (P = 0.001). In addition, the type of adhesive resin system had a significant effect on the bond strength values (P = 0.001). Tukey post-hoc test showed that application of two-step self-etch adhesive system resulted in the highest bond strength to RMGIC (P = 0.05).

TABLE (3): Microshear bond strength values without and with the application of the adhesive resin systems:

Control		3M™ Single Bond Universal adhesive system [SBU]		Clearfil SE Bond (CSE)		Clearfil S3 Bond (CS3)		P-value
Mean	SD	Mean	SD	Mean	SD	Mean	SD	
4.43	1.32	13.36	2.74	22.51	1.81	16.15	2.01	<0.001*

: Significant at P ≤ 0.05.

DISCUSSION

Glass ionomer cements would be applied as a base material beneath resin based composite restorations to substitute the destructed tooth structure, providing seal and establishing a reliable chemical bond [4]. Worth to mention that, among the primary goals of tooth restorations is their longevity, which is critical in the deep preparations and gingival areas of proximal cavities. In composite resins, the polymerization shrinkage and its stresses might lead to gap formation between the tooth and the restoration, resulting in unfavourable consequences[16] **.** Accordingly, laminate technique**,** [5] is especially beneficial in such cases.

In the current investigation, RMGIC was selected rather than a conventional GIC since several researches revealed that the former exhibit improved mechanical properties and better bonding than do the conventional ones [17] .The light-curing reaction in some RMGICs takes place in stages, acid-base reaction, followed by polymerization of free radicals of methacrylate and Hydroxy ethylmethacrylate (HEMA) groups initiated by visible light and the relevant initiators and lastly the continuation of curing of methacrylate groups through a self-cured chemical reaction[18] **.**

It is worth to mention that, the two materials glass ionomer and resin composite are bonded micromechanically, along with formation of an air-inhibited layer on the surface resulting in a rise in the number of unsaturated carbon double bonds, which might give rise to improved chemical bond strength to composite[18] .Generally, RMGICs enjoyed better mechanical properties, including higher cohesive strength and lower modulus of elasticity, compared with conventional ones. Furthermore, RMGIC has better handling properties and is considered less sensitive to moisture due to the resin existence[8] .

In modern dentistry, one of the critical issues is the surface treatment of the tooth substrate for the establishment of a reliable bond with RBC restoration. In the meantime, conditioning of tooth-colored restoratives, like GIC, to bond to RBCs is still debatable [19]. Based on the aforementioned reasons, the bond strength of RMGICs to composite was assessed in our study.

In general, in this research it was revealed that appropriate bond was recognized between the two tested material by means of the adhesive systems. This has been suggested in many investigations, confirming the results of our study[11,20] . Worth mentioning that direct lamination of the RMGIC restoration with RBC without the application of any bonding agent resulted in a significantly lower bond strength than that recorded in all other adhesive groups, such results were in a harmony with those of Becci et al [21].

Since a mechanical bond between the two restorative material is essential, the absence of such adhesion between the two material may be the reason for the decreased bond strength. Further, the RMGIC has lower cohesive strength once compared to resin composite material [9] Further, the presence dissimilarities in the properties and chemistry of those materials, all that might have contributed to the failure of adhesion without utilizing adhesive resin [10].

With reference to the adhesive resin systems used, previous studies have shown that the use of self-etch bonding agents resulted in better bond strength between glass ionomer and resin composite when compared to etch-and-rinse systems, which was in a line with the findings of the present study[8,20].

It was demonstrated that in the etch –and-rinse systems, the application of phosphoric acid compromises the surface layer of RMGIC by dissolving the fillers beneath the surface layer matrix of the cement; thus, decreasing the cohesive strength of RMGIC and consequently, bond strengths between the materials decline[8,19] . On the other hand, since etch-and-rinse systems have high technique sensitivity requiring separate rinsing and drying steps, which might adversely affect GIC generating microcracks during drying of its surface [16]. Additionally, etching and rinsing of RMGIC can decrease methacrylate groups and HEMA on its surface through the interference with the oxygen-inhibited layer and consequently, eliminating the agents involved in chemical bonding. Thus, reducing its bond strength to resin composite restorations[13].

Furthermore, the majority of etch-and-rinse bonding systems incorporate considerable amount of solvents in the structure, which might significantly decline bonding if they are not completely evaporated from the GIC surfaces[11].

Regarding this study, with respect to the etch and rinse system (SBU) acidity was offered by phosphorylated monomers in an aqueous solution, without the use of a separate etching step. Such step enhanced micromechanical bonds between the tooth structure in particular enamel and materials like dental composites [22]. However, it might have an adverse effect in conjunction with another restorative material like RMGIC [23]. However, a study by Zhang *et al*.[11] showed no significant differences in bond strength by decreasing the etching duration recommended by the manufacturer.

In contradiction with our findings, a study found that the bond between resin composite and RMGIC was enhanced using etch and rinse adhesive system when compared to the self-etch treatment. Yet, the etching time where they reported increased bond strength was 30 s [24]. In opposition, phosphoric acid etching for more than 15 seconds has been identified as a cause of glass ionomer surfaces deterioration[8,18].

Concerning the self-etch bonding agents, in the current study, two self-etch systems of CSE Bond and CS3 Bond were utilized for comparison. The comparison between the test groups in the present study presented a higher bond strength between GIC and composite resin restorative with the use of self-etch primer system (Clearfil SE Bond) compared with other groups. This was followed by S3 Bond, while the lowest bond strength was recorded in the Single Bond group. CSE Bond is a two-step self-etch primer without fluoride, which contains acidic monomers 10-Methacryloyloxydecyl dihydrogen phosphate (10-MDP) and dissolves the surface of RMGIC to produce a mildly etched GI surface [18]. The pH of these two self- etch systems was 2 (CSE Bond) and 2.7 (CS3 Bond) and it is possible that CSE Bond primer can result in a more effective etching of the surface compared to CS3 Bond due to its higher acidity, resulting in a higher bond strength. The viscosity of the bonding agent is one of the aspects affecting bond strength. It was described that higher bond strength between RMGIC and resin composite is attained with a decrease in the viscosity of bonding agent due to the lower contact angle, resulting in better wettability by the bonding agent[25] . Hence, in our study the higher bond strength values of CSE Bond might be explained by its lower viscosity compared with CS3 Bond.

Previous studies on self-etch bonding systems revealed that such agents can bond to the calcium in tooth structure;[18] thus, might be capable of bonding to calcium and strontium in the GIC structure and displaying a higher bond strength[11].

Self-etch adhesives were known of being capable of penetrating and bonding to calcium silicate materials, consequently their application on initially set material (GIC) was acclaimed [26]. In two-step "self- etch primer, as CSE the separation of the primer acidic monomer from the adhesive would enhance proficient bonding. Besides, the presence of methacryloxydecyl phosphate (MDP) which would be responsible for the formation of ionic chemical bonds [27].

CONCLUSIONS

According to the results of the current investigation, it might be concluded that:

In the lamination technique, lower bond is achieved in case of immediate layering of RMGIC with RBCs without the application of adhesive resin systems. On the other hand, the application of the latter systems was accountable for the establishment of reliable consistent bonding.

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