Covering of fiber-reinforced composite bars by adhesive materials, is it necessary to improve the bond strength of lingual retainers?

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ABSTRACT

Objectives: The objectives were to evaluate the shear bond strength (SBS) of fiber-reinforced composite (FRC) retainers when bonding them to teeth with and without covering the FRC bars using two different adhesive systems.

Materials and Methods: Hundred and twenty extracted human maxillary premolars were randomly divided into eight groups (n = 15). FRC bars (4 mm length, Everstick Ortho®, Stick Tech, Oy, Turku, Finland) were bonded to the proximal (distal) surfaces of the teeth using two different adhesives (Tetric Flow [TF, Ivoclar Vivadent, Switzerland] and resin-modified glass ionomer cement [RMGIC, ODP, Vista, CA, USA]) with and without covering with the same adhesive. Specimens were exposed to thermocycling (625 cycles per day [5–55°C, intervals: 30 s] for 8 days). The SBS test was then performed using the universal testing machine (Zwick, GMBH, Ulm, Germany). After debonding, the remaining adhesive on the teeth was recorded by the adhesive remnant index (0–3).

Results: The lowest mean SBS (standard deviation) was found in the TF group without covering with adhesive (12.6 [2.11] MPa), and the highest bond strength was in the TF group with covering with adhesive (16.01 [1.09] MPa). Overall, the uncovered RMGIC (15.65 [3.57] MPa) provided a higher SBS compared to the uncovered TF. Covering of FRC with TF led to a significant increase in SBS ($P = 0.001$), but this was not true for RMGIC ($P = 0.807$). Thermal cycling did not significantly change the SBS values ($P = 0.537$). Overall, eight groups were statistically different (ANOVA test, $F = 3.32$, $P = 0.034$), but no significant differences in bond failure locations were found between the groups (Fisher's exact tests, $P = 0.92$).

Conclusions: The present findings showed no significant differences between SBS of FRC bars with and without covering by RMGIC. However, when using TF, there was a significant difference in SBS measurements between covering and noncovering groups. Therefore, the use of RMGIC without covering FRC bars can be suggested, which can be validated with *in vivo* studies.

Key words: Adhesive, bond strength, fiber-reinforced composite, resin-modified glass ionomer cement

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INTRODUCTION

The teeth that have been moved orthodontically have a tendency to return to their former positions. Orthodontic fixed retainers are applied as long-term retention of maxillary and mandibular anterior teeth.[1-3] Zachrisson introduced multi-strand

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wires in 1982, which were bonded to six anterior teeth from canine to canine.[4] Some clinical studies showed these retainers had a significant failure (2.9–47%) during a short-term follow-up. These investigations count various factors as the causes of fixed retainers' failures: Corrosion, lower abrasion resistance and erosion due to chewing or tooth brushing, wire thickness, and periodic slag forces.[5-9] Furthermore, the failure of retainers may lead to a significant dental relapse.

Studies have shown the acceptable compatibility of metal bonded retainers with periodontal health.[5,10-13] However, the limitations have been esthetic problems and the fact that these retainers may not be used in patients who were allergic to nickel. As a result, alternatives can be applied like fiber-reinforced composite (FRC) retainers.[14]

Diamond and Orchinde fined glass fibers as alternatives to multi-strand wires.[15,16] FRCs have the appropriate flexural strength to act as a restorative material *in vivo*.[17,18] Based on the study of Tahmasbi *et al*., FRC bars had enough strength to withstand simulated forces (equal to 2 years).[19] Comparing FRC retainers to flexible wire retainers, the basic advantage of FRC bars is the high transparency, which make them almost invisible. Therefore, the retainers may be bonded near the incisal edge, which have biological and biomechanical advantages. Despite these benefits, one of the FRC retainers' drawbacks is that they should be supported by composite coverage. Hence, bonding in interproximal contacts is necessary which, in turn, may lead to the creation of calculus and decay and may endanger periodontal health.[2] Moreover, the bonding process of FRC retainers is technique sensitive.[20]

Conventional glass ionomer cements (GICs) have been evaluated for the bonding of orthodontic brackets due to their anti-caries features.[21,22] These cement have a similar thermal expansion coefficient to dental structures and their advantage in comparison to composite resin is the fluoride-releasing capability that prevents secondary decay.[23,24] However, there is a clinical limitation in using this material due to its low bond strength.[25] The other disadvantages of GICs include its short working time, sensitivity to be contaminated with saliva, and its hydrophilic characteristics.[26-28] These problems were solved by the introduction of the resin-modified GICs (RMGICs). Their rapid hardening after exposure to light cure makes them less sensitive to moisture.[26-28]

The previous studies evaluated the effect of various adhesive systems on the shear bond strength (SBS) of FRC retainers.[29-31] Orthodontic adhesives encounter thermal changes in the mouth. Different factors such as air temperature, moisture, and airspeed during breathing can change the mouth's temperature.[32] Even though, the prediction of changes is difficult during a test, the evaluation of the effect of these stresses on bond strength is significant. Therefore, Bishara *et al*. recommended thermal cycling as part of the new adhesive test protocol.[33]

Despite manufacturers' advice, some orthodontists prefer to use FRC bars without composite coverage to facilitate the cleansing of interproximal spaces.

Thus, the primary purpose of this study was to evaluate the SBS of FRC retainers when bonding them to the teeth using two different adhesive systems (Tetric Flow [TF]/RMGIC): With and without covering the FRC bars with adhesives.

MATERIALS AND METHODS

For this *in-vitro* study, samples included 120 maxillary first premolars that were randomly divided into eight groups of 15 each. The inclusion criteria were intact buccal and proximal surfaces, lack of decay, hypoplasia, or enamel defect. The samples were placed in normal saline while the research was conducted. This study was approved by the Ethical Committees of the Mashhad University of Medical Sciences.

Specimen Preparation

The tooth surface was cleaned by rubber cup and pumice powder and then etched with 35% phosphoric acid gel (Ultra-Etch, USA) for 30 s and after rinsing and drying, unfilled resin (Whalendent/unfilled Coltene, Alstatten, Switzerland), Tetric Flow (Tetric EvoFlow, Ivoclar Vivadent, Switzerland), and RMGIC (ODP, Vista, CA, USA) were applied for bonding procedures. Subsequently, FRCs (Everstick Ortho®, Stick Tech, Oy, Turku, Finland) were placed. The fibers that reinforced the FRCs were E-glass and unidirectional to polymerize FRC. They were maintained at 5–8°C, and their cross sections were circular with a diameter of 0.75 mm. They were applied routinely in the clinic as a retainer due to the appropriate thickness and conformity to tooth curvature. Thereafter, the halogen light curing unit (Astralis 7, Ivoclar, Vivadent, Schann, Liechtenstein) was used. To simulate the oral condition, a thermal cycling device was employed (Willytec, Munich, Germany) and specimens were maintained at a temperature of 5–55°C at 30 s intervals to simulate thermal fluctuations. The SBS was also measured with a universal testing machine (Zwick, GMBH, Ulm, Germany).

Experimental Groups

Group 1

A layer of margin bond (unfilled resin, Coltene/Whaledent, Alsstatten, Switzerland) was applied to the etched surface with a brush. Then, with a mild air burst, this layer was thinned and cured over 20 s using light cure device (Astralis 7). Subsequently, a thin layer of TF was placed on the teeth. FRC bars, with the length of 4 mm, were then cut and placed on the enamel surface of the teeth, and the excess TF was removed with a scaler.

To assure equal sizes of the FRC and adhesive in all specimens, an aluminum foil with dimensions of 4 mm × 1.5 mm was used. The prepared mold was placed on these surfaces before curing in order to achieve similar samples. These series were cured for 40 s using the Astralis 7.

Group 2

All the procedures were similar to the Group 1, but in this group, FRC bars were completely covered by TF.

Group 3

A thin layer of RMGIC was placed on the etched surface. Then, a 4 mm FRC was placed on it. The mold was then placed, and the series were cured for 40 s.

Group 4

This group was completely similar to the Group 3, but the FRC bars were covered by RMGIC.

Groups 5–8

These were similar to Groups 1–4 but the samples in these groups were thermocycled (Willytec, Munich, Germany) after bonding the FRCs to the teeth and before the mounting process in acryl (5–55°C at 30 s intervals). Overall, 625 cycles were performed daily, and the total process was performed in 8 days.

Shear bond strength measurement

Thereafter, the samples of the first four groups were mounted in acrylic using a surveyor device (JM Ney Company, Hartford, Connecticut, USA) [Figure 1]. Using this tool, the distal surface of the tooth (on which the FRC were bonded) was perpendicular to the horizon to secure the Zwick device blade occluso-gingivally on the bonded FRC. Subsequently, the mounted specimens were placed in distilled water for 24 h at room temperature. At this point, the SBS measurement process was performed using the Zwick device, and FRCs were debonded by applying the shear force of the blade at the speed of 1 mm/min. Then, the maximum required force to debond FRCs was registered based on Newton and transferred to Megapascal by dividing to FRC bonded cross section (4 mm × 1.5 mm = 6 mm^2).

Adhesive Remnant Index

After debonding, fibers and the enamel surfaces were evaluated by employing 10 times magnification lenses. The remaining adhesive on the teeth was registered with adhesive remnant index (ARI) as follows:[19,34]

- 0: No adhesive remained on the tooth
- 1: Fewer than half of the adhesive remained on the tooth
- 2: More than half of the adhesive remained on the tooth
- 3: All of the adhesives remained on the tooth.

Figure 1: Surveyor device

Statistical Analysis

To evaluate the normality of the data, the Kolmogorov–Smirnov test was used. The ANOVA test was performed to compare mean values of SBS rates of the groups. One-way ANOVA tests were performed in addition to the *post-hoc* test to determine the exact factor, which influenced the SBS measurements as the groups were related together and were not independent. Fisher's exact test was also conducted to determine the significant difference in ARI scores among the groups. The significance level was defined as $P < 0.05$.

RESULTS

In this research, 120 teeth were categorized into eight groups of 15 samples. The FRC's SBS was evaluated based on bonding with two adhesives of TF and RGMI and the effect of FRC covering among half of the groups, and that of thermal cycles among the other half of the groups. The Kolmogorov–Smirnov test showed that the eight groups were acceptable with an error level of 5% assuming data normality. The results of the SBS tests are provided in Table 1.

Based on the present findings, the lowest bond strength was found in Group 1 (12.6 ± 2.11 MPa), and the highest bond strength was found in Group 2 (16.01 ± 1.09 MPa). The findings showed that the type of material (TF, RMGIC) and covering and noncovering factor influenced by each other, but thermocycling factor did not influence of those two other factors. This means that SBS of FRC was not affected by thermal cycling [Table 2].

When TF was used for bonding, the covering provided by TF caused a significant increase in bond strength ($P = 0.001$). One-way ANOVA test findings showed that when applying RMGIC for bonding, covering, or noncovering had no

Table 1: Shear bond strength in different experimental groups

Group	Description	*n*	Mean* (SD)	ANOVA test	
				F	*P*
1	TF	15	12.60 (2.11)[a,c,e]	3.32	0.034
2	TF (covered)	15	16.01 (4.25)[a,b]		
3	RMGIC	15	15.65 (3.57)[c,d]		
4	RMGIC (covered)	15	15.41 (2.92)[e]		
5	TF + thermocycling	15	12.85 (2.29)[b,d]		
6	TF (covered) + thermocycling	15	14.77 (3.14)		
7	RMGIC + thermocycling	15	14.32 (3.34)		
8	RMGIC (covered) + thermocycling	15	14.12 (3.61)		

*The groups with similar alphabetical letters are statistically different ($P<0.05$). TF – Tetric Flow; RMGIC – Resin-modified glass ionomer cement; SD – Standard deviation effect on the FRC SBS and that SBS was similar in the two groups (*P* = 0.807).

In fact, without covering, RMGIC had higher bond strength compared to TF without covering, and the bond strength was comparable to TF with covering [Table 1]. When FRC was covered, there was no significant difference between the two bonding materials (TF, RGMI) (*P* = 0.497). This means that the covering of FRC by TF or RMGIC leads to similar bond strength.

Related information to the bond failure position (ARI scores) are provided in Table 3. Based on the Fisher's exact test analysis, the type of failure was similar in various groups (as the ARI score 3 frequency was zero, it was deleted). Therefore, the failures of all groups were cohesive.

DISCUSSION

Covering of FRC bars to improve bond strength has many disadvantages. By covering of FRCs, the volume of bars will increase, and oral hygiene will be jeopardized. RMGIC is frequently used as this material can absorb and release fluoride. As FRCs are maintained for long periods of time, this material can help to prevent decay and may be appropriate for bonding FRC retainers. Without covering of FRC bars, the current study indicated that RMGIC had a higher SBS compared TF. The previous studies on RMGIC also reported satisfactorily bond strength to the enamel surface.[29-31,35]

Our findings showed that the thermal cycling process had no significant effect on bond strength. Tezvergil *et al*. showed that when thermal cycling was performed, the bond strength of FRC was increased.[36] However, in most of the studies that have evaluated the thermal cycling effect on bond strength, a decrease in bond strength was confirmed after thermal cycling.[33,35,37,38] The reasons for such a decrease in SBS are assumed to be the difference in the linear coefficient of the thermal expansion of the adhesive, FRC, tooth, and bracket, and also water absorption during thermal cycling may lead to hygroscopic expansion and may decrease bond strength.[37-41] According to our findings, if TF were used as an adhesive the FRC should have been completely covered to increase bond strength. On the other hand, results indicated that, if RMGIC were applied for bonding of FRC, then covering of the FRC did not lead to increase in bond strength.

Table 2: The effect of different factors on each other (type of material, covering, thermocycling)

Factors	Mean square	*F*	*P*
T × F-R	5.047	0.484	0.488*
T × C	3.986	0.383	0.537**
F-R × C	62.165	5.967	0.016***
T × F-R × C	4.443	0.426	0.515

*T factor (thermocycling) and F-R (type of material) have no influence on each other (*P*=0.448), **T factor (thermocycling) and C factor (covering) have no influence on each other (*P*=0.537), ***F-R factor and C factor have influence on each other (*P*=0.016)

Table 3: The ARI scores in different experimental groups

Group	Description	0 (%)	1 (%)	2 (%)	Fisher's exact test*
1	TF	8.3	41.7	50.0	0.92
2	TF (covered)	8.3	50.0	41.7	
3	RMGIC	0	50.0	50.0	
4	RMGIC (covered)	0	66.7	33.3	
5	TF + thermocycling	0	41.7	58.3	
6	TF (covered) + thermocycling	16.7	50.0	33.3	
7	RMGIC + thermocycling	8.3	41.7	50.0	
8	RMGIC (covered) + thermocycling	0.0	58.3	41.7	

TF – Tetric Flow; RMGIC – Resin-modified glass ionomer cement; ARI – Adhesive remnant index

This study showed that if the clinician does not choose to cover FRC, it is better to use RMGIC as an adhesive material. For TF, the average of SBS among 60 samples was 14.06 ± 3.31 MPa. However, the average of RGMICwas 14.87 ± 3.35 MPa.

According to the present findings, RMGIC is a better adhesive for FRC bonding when compared to TF. It should be noted that TF has a micromechanical bond. However, after enamel etching, the RMGIC's bond is both micromechanical and chemical.[27,28] On the other hand, RMGIC is a dual-cured adhesive, and more complete curing may be achieved in comparison to light cured TF. These factors can be the reasons for the higher RMGIC's bond strength compared to TF. As the difference between FRC and TF regarding the thermal expansion coefficient is more than that of FRC and RMGIC, during water absorption, the hygroscopic expansion of two materials would differ and the bond between TF and FRC would become weaker.

The basic advantage of RMGIC, compared to TF, is the possibility of the charge and release of fluoride ions.[42] This leads to a decrease in decalcification and white spots around orthodontic appliances. FRC retainers are bonded to the lingual surface of the anterior teeth for long duration or permanently and consequently, RMGIC is appropriate for FRC bonding.

In debonding of FRCs from the tooth surface, most failures were cohesive. In general, 5.2% of the failures were adhesive, and 94.8% of the failures were cohesive. In all groups, failure patterns were similar, and there were no differences among them. Matasa showed that when the bond failure was cohesive, the bond strength was higher compared to adhesive bond failure[43] and moreover, bond failure within the adhesive, or at the bracket-resin interface is more desirable than at resin-enamel interface.[44,45] Possible limitations of the present study can include the difficulty in standardization of procedure to assess the ARI, as it is mainly used for debonding brackets not bonded retainers, as well as the fact, that using the ARI did not allow microscopical assessment of the enamel surfaces of teeth and investigating the underlying mechanism for observed differences between TF and RMGIC groups. The use of scanning electron microscope can be incorporated in future studies. It should be noted that this study could not completely simulate the clinical procedures of composite coverage of the FRC in the interproximal spaces, and further clinical studies are necessary for further details.

CONCLUSIONS

Our findings showed no significant differences between SBS of FRC bars with and without covering by RMGIC. Not covering the surface of FRC can result in less bulky constructions that may reduce plaque accumulation and irritation of the tongue. Our results showed that when using RMGIC as an adhesive material, covering of FRC bars seems unnecessary.

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Conflicts of Interest

There are no conflicts of interest.

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