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The Effect of Adding Glass and Polyethylene Fibers on Flexural Strength of Three Types of Glass-Ionomer Cements

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Abstract: This study was to compare the flexural strength of three types of glass-ionomer cement combined with two types of fibers. About 90 specimens were prepared in a split mold. Glass and polyethylene fibers measuring 1 mm in length were added to the powder of Conventional Glass-Ionomer cement (CGIc), a Resin-Modified Glass-Ionomer Cement (RMGIc) and cermet (miracle mix). The specimens were divided into 9 groups according to the type of glass-ionomer cements and the fibers (n = 10): Group 1: CGIc; group 2: RMGIc; group 3: Cermet (MM); group 4: CGIc + glass fiber; group 5: RMGIc + glass fiber; group 6: MM + glass fiber; group 7: CGIc + polyethylene fiber; group 8: RMGIc + polyethylene fiber; group 9: MM + polyethylene fiber. The mean flexural strength (MPa) values were determined in a 3-point bending test at a crosshead speed of 0.5 mm min^{-1} by a universal testing machine. The results were analyzed using two-way ANOVA and a post hoc Tukey test ($p<0.001$). Flexural strength increased significantly after adding 8 glass or polyethylene fibers to GI cements ($p<0.001$) except when glass fibers were added to cermet ($p>0.001$). In addition, flexural strength of polyethylene fibers increased more than that of glass 3 fibers in all the groups ($p<0.001$). Adding fibers, especially polyethylene fibers can increase flexural strength of glass-ionomer cements.

Key words: Flexural strength, glass-ionomer cements, glass fiber, polyethylene fiber

INTRODUCTION

Glass-ionomer cements are water-based, self-adhesive materials usually used in low stress-bearing areas (Sakaguchi and Powers, 2011; Zoergiebel and Ilie, 2013). Conventional resin-modified and metal-reinforced versions are three main types of glass-ionomers (Sakaguchi and Powers, 2011). In comparison with composite resin, glass-ionomer cements have some advantages, such as chemical adhesion to tooth structure, long-term fluoride release, ability to absorb fluoride and lower coefficient of thermal expansion (Carvalho *et al*., 2012; Markovic *et al*., 2008). However, they have lower fracture resistance and higher occlusal wear rate (Bonifacio *et al*., 2009; Hammouda, 2009).

These cements have their own drawbacks, such as lack of toughness, early water sensitivity, poor surface polish, solubility and erosion in the oral environment and low diametral tensile strength (Hammouda, 2009). Some materials, such as metal particles or alumina, zirconia or glass fibers have been added to glass-ionomer cements to improve their flexural strength and fracture resistance (Lohbauer *et al*., 2004). Several types of fibers have been added to dental composite resins to improve their physical and mechanical properties (Sharafeddin *et al*., 2011, 2012; Sharafeddin and Bahrani, 2011). Adding short fibers to composite resins has led to higher performance of flexural strength and compressive load-bearing capacity (Garoushi *et al*., 2007). Short fibers can act as reinforcing agents for glass-ionomer cements, especially when their composition is similar to that of the fluoro-alumino-silicate glass of the powder in the cement (Kobayashi *et al*., 2000). Glass fibers measuring 0.01-12 mm in length can reinforce polypropylene and composite resin materials (Callaghan *et al*., 2006). Furthermore, fiber glass can increase toughness of resin-modified glass-ionomer cements and improve diametral tensile strength, hardness, flexural strength, flexural modulus and fracture resistance of conventional glass-ionomer restorative materials (Callaghan *et al*., 2006; Hammouda, 2009).

It was reported that reinforcement of composite resins with 22.5 wt.% of short E-glass fiber reduces polymerization shrinkage stress and microleakage compared to conventional restorative composite resins (Garoushi *et al*., 2008). Improving mechanical and physical properties of glass-ionomer cements can result in better clinical outcomes. The aim of this study was to evaluate the effect of adding glass and polyethylene fibers to conventional, resin-modified and metal-reinforced glass-ionomer cements on their flexural strength.

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MATERIALS AND METHODS

In this experimental study, 90 specimens were prepared in 9 groups (n = 10). Metal split molds with a slot measuring (2×2×25) mm (Fig. 1) were used for preparation.

In group 1, conventional glass-ionomer (Fuji II GC America, Chicago, IL, USA) powder and liquid were mixed according to manufacturer's instructions and packed into the mold. In group 2, the powder and liquid of Resin-Modified Glass-ionomer Cement (RMGIC) (Fuji II LC, GC America, Chicago, IL, USA) were mixed and then were packed into the mold and cured with an LED unit (Elipar Freelight II, 3M ESPE, Seefeld, Germany) with light intensity of 890 mW cm^{-2} for 20 sec in three points. In group 3, Miracle Mix (MM) (GC America, Chicago, IL, USA) powder and liquid were mixed and packed into the molds.

In groups 4-6, glass fibers (Henan Jiyuan Glass Fiber Co., Ltd.) which measured 1 mm in length and were cut by special scissors were added to the powder of CGIc, RMGIc and MMc in 5 wt.% (Hammouda, 2009) before mixing with the liquid. Weight adjustment was carried out with an electronic scale (Precision Health Scale, A&D company, Tokyo, Japan). All the mixing procedures were carried out according to manufacturer's instructions. The mixed materials were packed into the molds.

In order to achieve an even distribution of fiber, the mixture of powder and fiber of each sample was placed in an amalgamator (Duomat Amalgamator, Essen, Germany) in an empty amalgam capsule to triturate for 20 sec. The specimens in groups 4-6 were prepared with the same procedure used in groups 1-3, respectively.

In groups 7-9, polyethylene fibers (Fiber-Braid, NSI, Dental Pty. Ltd., New South Wells, Australia) were prepared and mixed with the powder and the specimens were prepared similar to that in previous groups in which glass fibers were used.

After setting, the specimens were removed from their molds and polished using 600 grit silicon carbide paper. The specimens were thermocycled (Rika-kogyo, Hachioji, Japan) for 1000 cycles in water at 5/55°C with a dwell time of 30 sec after 24 h of storage in deionized water.

Flexural strength was quantified by a three-point bending test (Zwick/Roell ZO20, Germany) at a crosshead speed of 0.5 mm min^{-1}. The flexural strength was calculated in MPa. The results were subjected to two-way Analysis of Variance (ANOVA) and post hoc Tukey tests.

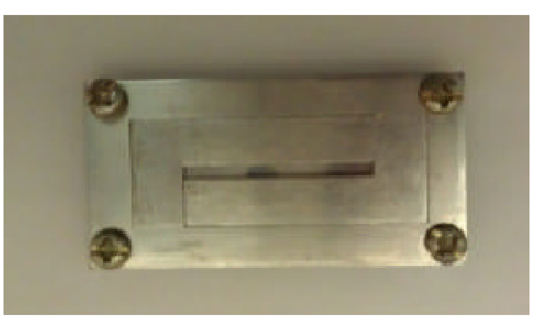

Fig. 1: Metal split molds

RESULTS

The two-way ANOVA showed a significant interaction effect between the three types of glass-ionomer cements and two types of fibers ($p<0.001$). Post hoc Tukey tests revealed that flexural strength increased significantly after adding either glass or polyethylene fibers to glass-ionomer cements ($p<0.001$) except when glass fibers were added to cermet ($p>0.001$) (Fig. 2). Flexural strength of cermet, CGIc, RMGIc increased significantly, respectively ($p<0.001$) (Table 1).

Table 1: Flexural strength values (MPa) of all the groups

Materials	Fibers	Mean	SD (log)	N
Conventional glass ionomer	Control	5.1811	0.29019	10
	Glass	10.7020	0.25633	10
	Poly ethylene	22.9920	0.12278	10
	Total	13.2017	0.66428	30
Resin modified glass ionomer	Control	13.7480	0.25455	10
	Glass	22.6900	0.18758	10
	Poly ethylene	47.6700	0.13010	10
	Total	28.0360	0.56231	30
Cermet	Control	6.6170	0.43116	10
	Glass	10.3570	0.15614	10
	Poly ethylene	15.6000	0.51509	10
	Total	10.8580	0.41391	30
Total	Control	8.6303	0.51793	30
	Glass	14.5830	0.41978	30
	Poly ethylene	28.7300	0.64775	30
	Total	17.4120	0.67949	90

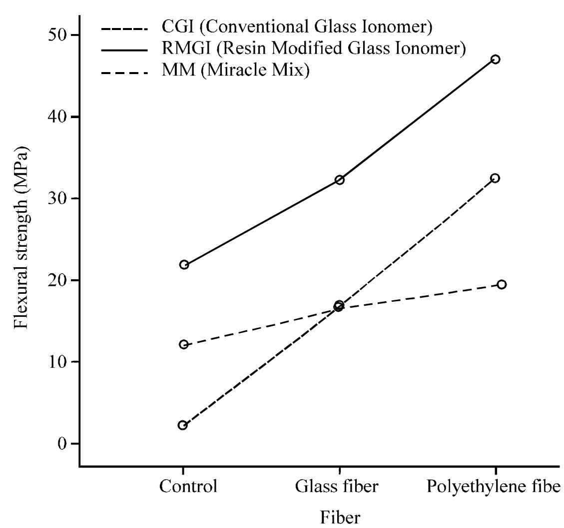

Fig. 2: Increase of fluxural strength of fibers

Furthermore, flexural strength of polyethylene fibers increased more than those of glass fibers in all the groups ($p<0.001$).

DISCUSSION

Conventional glass-ionomers are not very strong mechanically in comparison with other restorative materials (Garoushi *et al*., 2007). Therefore, there are some limitations in their clinical use and they are not suitable for high-stress areas (Zoergiebel and Ilie, 2013). Resin-modified and metal-reinforced glass-ionomers (cermet) were developed to improve low strength of conventional glass-ionomer cements (Lucksanasombool *et al*., 2002; Yli-Urpo *et al*., 2005). However, their use in posterior occlusal load-bearing areas is questionable (Sidhu, 2010).

Moreover, fibrous reinforcements, e.g., glass fibers have been tried due to their strengthening effect (Hammouda, 2009; Lohbauer *et al*., 2004; Sharafeddin *et al*., 2012b). Hydroxyapatite (HA) whiskers also have been used as strengthening materials for glass-ionomer cements (Arita and Okada, 2001). Addition of HA improved fracture resistance of glass-ionomer cements (Lucas *et al*., 2003).

Addition of fibers to composite resin materials has improved their physical and mechanical properties (Garoushi *et al*., 2008; Oshagh *et al*., 2009; Sharafeddin *et al*., 2012a). It has been reported that fibers exert such an effect on glass-ionomer cements (Hammouda, 2009).

Therefore in the present study, polyethylene and glass fibers were added to conventional resin-modified and metal-reinforced (cermet) glass-ionomers which are used in dental clinics as restorative materials. There are no studies available on polyethylene fibers as reinforcing agent for glass-ionomer cements.

The similarity in composition of glass fibers and fluro-alumino-silicate glass of the powder in the glass-ionomer cement may lead to the improvement of mechanical properties (Hammouda, 2009). It was shown in the present study that polyethylene fibers not only increased the flexural strength more than glass fibers, they also reinforced resin-modified glass-ionomer >2 other cements.

Resin-modified glass-ionomers are known as a hybrid between conventional composite resins and glass-ionomer cements (Lawson *et al*., 2012). These materials have methacrylate monomers in their composition as well as composite resins, leading to the improvement of mechanical properties, such as flexural strength, compared to conventional glass-ionomer and cermet (Lawson *et al*., 2012; Sakaguchi and Powers, 2011) which might explain higher flexural strength of RMGIc in comparison with two other glass-ionomer cements in this study.

It has been reported that glass fibers with an average length of 430 μm and 20 vol.% could act as reinforcing agents for resin-modified glass-ionomers (Lohbauer *et al*., 2004). It has been concluded that increasing the length and concentration of fibers increases the impact strength and wear resistance of resin materials (Callaghan *et al*., 2006). In the present study, it seems that polyethylene fibers reinforced RMGI more than the two other cements due to their resin base.

Polyethylene fibers are more flexible in comparison with glass fibers which are too rigid and brittle (Keshtkar *et al*., 2009). This can explain the higher reinforcement produced by polyethylene fibers than glass fibers in this study.

No studies are available on adding fibers to metal-reinforced glass-ionomer cements (cermet) at present. The results of this study showed that flexural strength of cermet was slightly affected by addition of both fibers. It may relate to metal particles in the cermet powder which could not contribute to an even distribution of the powder and fiber like conventional and resin-modified glass-ionomers. It appears adding two reinforcing agents to glass-ionomer which were metal particles and fibers, in these samples did not improve glass-ionomer flexural strength.

In general fibers interfere with crack propagation and act as crack bridges, resulting in an increase in mechanical properties (Lohbauer *et al*., 2004). Fibers adhere to the matrix of glass-ionomer cements and modify the nature of load stress and thus increase the flexural strength of glass-ionomer cements. The concentration of fiber affects mechanical properties of glass-ionomer cements. The nature of local stress and the connectivity of the yielded microzones adjacent to neighboring fibers can be modified by an enhanced matrix-fiber adhesion (Hammouda, 2009). Therefore in the present study, 5 wt.% fiber loading was used which yielded better results compared to lower concentrations in previous studies (Hammouda, 2009).

The flexural strength of the specimens was evaluated after 24 h of storage in deionized water. Duration of storage can affect the mechanical properties of glass-ionomer cements and increase their strength and hardness by increasing storage time from 24 h to 1 week (Hammouda, 2009; Lohbauer *et al*., 2003; Sharafeddin *et al*., 2011). Formation of aluminum polycarboxylate improves the mechanical properties of glass-ionomer cements, rendering them more stable which can lead to increased setting reaction of glass-ionomer cements (Cefaly *et al*., 2001). The samples of the present study were thermocycled for 1000 cycles to achieve desirable aging and simulate clinical thermal stress conditions during flexural strength of glass-ionomer cements.

The results of the present study showed that reinforced glass-ionomer cements improved performance of glass-ionomer due to their improved physical properties. Furthermore, the advantage of fluoride release from these fiber-reinforced cements in comparison with composite resin materials might make them suitable as a foundation for a crown in patients with poor oral hygiene or higher caries activity. Different media, such as bleaching agent affect the physical properties of composite resins (Sharafeddin and Jamalipour, 2010) which may have the same effect on GIc with different ratio of fiber that can be investigated in future studies.

CONCLUSION

It can be concluded that the type of the fiber has a great influence on the flexural strength of glass-ionomer cements. Also, the use of polyethylene fiber can directly enhance flexural strength more than glass fiber. Polyethylene fiber-RMGIc combination has the highest flexural strength.

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