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A Comparison between Fiber Reinforced and Hybrid Composite

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Abstract. The problem of fracture of composite resin under flexure and shear loads has regularly been encountered. Few studies claimed that the addition of fiber improves the mechanical properties of dental composite. The aim of this study was to evaluate the effect of the addition of polyethylene fiber to hybrid composite on the following properties; water sorption, compressive strength, flexural strength, shear bond strength to enamel, and shear bond strength to dentin. A total number of 100 specimens were used to conduct this study. The results were collected, tabulated and statistically analyzed using ANOVA and "student's" *t* test. It was found that the addition of polyethylene fiber resulted in a significant increase in the water sorption and in the flexure strength properties of hybrid composite ($p < 0.05$). It was concluded that the addition of polyethylene fiber does not significantly improve the properties of hybrid composite, and further studies are required to evaluate the effectiveness of adding fiber to hybrid composite.

Keywords: Composite resin, Fiber reinforced composite, Mechanical properties, Water sorption.

Introduction

Patients are asking for nonmetallic restoration for esthetic reasons and because of the supposed mercury toxicity. Composite with good

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mechanical properties was recommended for posterior use. During the last decade, new formulation of nano-composite has been presented, which can achieve high wear resistance, low thermal conductivity and easy handling[1].

Fiber-reinforced composite improves the mechanical properties. Examples of reinforcing fiber are carbon, glass fibers or polyethylene fiber. Polymeric reinforcements such as polyethylene are often used for chair side application[2]. The interaction between the fibers and polymer matrix plays a vital role for transferring load from the matrix to the fibers[3,4].

The fiber-reinforcing principle can be used in dentistry on the removable appliances[5], temporary resin bridge work and splinting of traumatized. Additionally, on periodontally involved teeth in the implant prosthodontics, and as post and core[6]. Glass, polyaramid, carbon fiber and polyethylene fiber can be used to reinforce resins[7,8].

The reinforcing efficiency of fibers depends on the component of fiber, fiber orientation, the ratio of fiber to resin, and the adhesion between fiber and resin. Silane coupling agent has been used to improve adhesion between polymer matrix and the fibers. It was reported that silane coupling agent significantly increases the flexural strength of resin[9]

Ellakwa *et al*.[10] found that the placement of fiber at the tensile side of heat polymerized acrylic resin specimens had improved their flexural strength property. Unidirectional glass fibers were effective in improving the flexural strength and elastic modulus of the resin composite[11].

The shear bond strength is influenced by the concentrations of defects at the interface[12]. The flow ability of composite at the adhesive inter phase did not improve the bond strength value[13]. Failure occurs as a result of complex shear and tensile stress within the sample[14]. This may be attributed to the dump under compressive loading, and thus, act as inclusion bodies that lead to break up of the composite resin matrix[15].

Water sorption of the material represents the amount of water adsorbed on the surface, and absorbed into the body of material during fabrication and during service[12].

Composite degradation results from the diffusion of water into the material[16,17]. Penetration of water enhances the surface deterioration of polymer matrix, plasticization of polymatrix and erosion of filler bonding. This erosion results in a mass loss of composite material[18]. Fiber reinforced composite is affected by the degree of impregnation of fibers within the resin[19].

The use of polyethylene fiber, over or under mesioocclusodistal (MOD) composite restorations, increased the fracture strength. However, when the fiber was placed on the occluscal surface of the restoration from buccal to lingual direction, a significantly higher fracture resistance was observed[20]. It was found that addition of polyethylene fiber to hybrid composites, contributed to the improvement of ultimate tensile strength, with reduction in the multiple cracking behaviors of hybrid fiber composites[21]. Incorporation of glass fiber enhanced tensile, flexural and impact strength. Furthermore, adding glass fiber improves the wear resistance of composite[22].

Aims and Objectives

The present study evaluates the effect of the addition of polyethylene fiber to the hybrid composite on the following properties:

1. Water sorption
2. Compressive strength
3. Flexural strength
4. Shear bond strength to enamel
5. Shear bond strength to dentin

Materials and Methods

Two types of composite materials were used. Hybrid composite (as a control) and polyethylene fiber reinforced composite (FRC) (Ribbond® bonded reinforcement ribbon, Ribbond, Seattle WA, USA). A total number of 100 specimens were divided equally into two groups: Group I (Hybrid) and Group II (FRC). Then, each group was subdivided equally into five subgroups according to the tests used in this study (Table 1).

Table 1. Groups and subgroups tested.

No.	Test	Hybrid (Control)	FRC	Total
1	Water sorption	10	10	20
2	Compressive strength	10	10	20
3	Flexural strength	10	10	20
4	Shear bond to enamel	10	10	20
5	Shear bon to dentin	10	10	20
Total		**50**	**50**	**100**

1. Water Sorption

A teflon mold was fabricated with 10 mm in diameter and 2 mm in thickness. The mold was placed over a glass slab and the composite filled the mold. Another glass slab was placed over the material and curing was done for 40 seconds according to manufacturer's instructions. The composite disc was removed and finished to remove flashes.

The discs were transferred to desiccators for 1 hour and then weighted using electric balance (dry weight) (Precisa 120A, PAG Oerlikon AG, Zurich, Switzerland). The specimens were immersed in water for 48 hrs. Then, they were removed from water, wiped off, waved in air for 15 second and weighted (wet weight). Afterwards, the water sorption was calculated using the following equation.

$$\textbf{Water sorption} = \frac{\text{wet weight} - \text{dry weight}}{\text{Dry weight}} \times 100$$

Lloyd materials testing machine were used to test materials properties. The loads were applied at a cross head speed of 0.5 mm/min. (Lloyd Instruments Ltd, Model LRY plus No. 01/2962. West Sussex, U.K.).

2. Compressive Strength

A split teflon mold 4 mm in diameter and 6 mm in height was fabricated according to Piwowarczyk *et al.*[28]. The compressive strength was calculated in megapascals (MPa) according to the following equation:

$$\textbf{Compressive strength} = \frac{F}{D^2}$$

Where F = Maximum force in Newton on the specimen
D = Diameter of specimen in millimeters

3. Flexural Strength

A split teflon molded with dimension of 25 mm in length 2 mm in breadth, and 2 mm in thickness. The flexural strength in MPa was calculated using the following equation:

$$\textbf{Flexural strength} = \frac{3pl}{2WT^2}$$

Where:

P = Maximum load in Newton
L = Length of specimens
W = Width
T = Height of the specimens in mm

4. Shear Bond Strength for Enamel & Dentin

Freshly extracted teeth were sectioned mesio-distally; the teeth, then embedded in self-curing acrylic resin using a mold. A split teflon ring of a 5 mm diameter and 3 mm in height was used.

The surfaces of enamel or dentin were finished using 600 fin grit sand paper. The composite was manipulated according to the manufacturer's instruction. The shear bond strength was calculated using the following equation:

$$\textbf{Shear bond strength} = \frac{\text{Maximum load in Newton}}{\text{Area in mm}^2}$$

The results were statistically analysed using ANOVA and "student's" *t* tests.

Results

1. Water Sorption

The fiber reinforced composite (FRC) recorded a higher mean water sorption than the hybrid composites, but statistically there was no significant difference ($p > 0.05$). There was a statistically significant increase ($p < 0.05$) in water sorption percentage after 7 days for hybrid and FRC composite (Table 2).

Table 2. Statistical analysis of water sorption for tested materials in mg.

Material	Hybrid Composite	FRC Composite	P – Value
Mean and SD (after 4 hours)	0.019	0.06 $\pm$ 0.05	0.152
Mean and SD (after 7 hours)	0.093	0.15 $\pm$ 0.09	0.045

2. Compressive Strength

Hybrid composite registered a higher mean compressive strength than the fiber reinforced composite, but no significant difference was statistically detected ($p > 0.05$) (Table 3).

Table 3. The statistical analysis of the compressive strength in MPaf the two tested materials.

Materials	Hybrid Composite	FRC Composite	p Value
Mean +SD	139.82 +12.02	130.94 +14.43	0.338

3. *Flexural Strength*

The FRC composite showed a higher mean flexural strength than hybrid composite (as a control). Statistical analysis showed a significant difference between the two groups ($p < 0.05$) (Table 4).

Table 4. The statistical analysis of the flexural strength in MPa the two tested materials.

Materials	Mean and SD	P-Value
Hybrid Composite	122 ± 15.63	p<0.05
Fiber reinforced composite	156.52 ± 18.15	

Significant at p < 0.05

4. *Shear Bond Strength*

Fiber reinforced composite showed a higher mean shear bond strength value than hybrid composite, but statistically there was no significant difference between the two tested material ($p > 0.05$) (Table 5), but a significant difference was statistically detected between bond to enamel and to dentin. The mean shear bond strength to enamel was higher than that to dentin in the two tested materials.

Table 5 The statistical analysis of the shear bond strength in MPa for the two tested materials to enamel and dentin.

Materials	Hybrid Composite Mean and SD	F.R.C Composite Mean and SD	P-Value
Enamel	18.89 + 1.6	20.12 +2.5	0.336
Dentin	12.38 +	14.65 + 2.4	

Significant at p ≤ 0.05

Discussion

This study evaluates the effect of the addition of fibers on the reinforcement of hybrid composite resin as regards to water sorption, compressive strength, flexural strength, and shear bond strength to enamel and dentin.

The water sorption increased by time of immersion for the two groups with more sorption in the FRC. The hybrid composite as the fiber may avail more matrix to water sorption, inducing more localized water entrapment resulting in more absorption of water in the FRC. Also, the environmental temperature may have an effect on the rate of diffusion of fluids into the polymer and increased water sorption[23].

Compressive strength was measured as it was considered important in the process of mastication. The result of this study showed that the mean compressive strength for hybrid composite was higher than that of FRC. This may be attributed to the anisotropic nature of FRC. The presence of fibers in the resin matrix led to its discontinuity in the resin, and initiated cracks that propagated under compressive loading. Ellakwa *et al.*[24] stated that the fibers may not affect the strain energy stored within the composition allowing initiation of cracks and failure.

Flexural strength was evaluated for composite resin as it was subjected to bending in clinical service. The results of this study showed that the flexural strength of FRC was significantly higher than the hybrid composite. These results are in agreement with the result of Karacaer *et al.*[25] and Hamza *et al.*[26]. While Rahamneh *et al.*[27] stated that the fibers may act as an area of stress concentration, which may actually weaken rather than strengthen the matrix.

In the present study, the shear bond strength of hybrid composite and FRC to the enamel and dentin were measured to each other. The results showed no statistically significance between them. This may have attributed to the fiber content as well as to the direction of fiber in FRC. Furthermore, the presence of fibers may create stresses at the resin-tooth interface that will initiate crack, and causes adhesive bonding failure in FRC less than that in hybrid composite. These results were in agreement with the results of Piwowarczyk *et al.*[28], Meiers *et al.*[29], and Tezvergil *et al.*[30]. The bond strength to enamel was higher than that of dentin, this may be related to hydrolytic pressure in dentinal tubule that interfere with penetration of composite into dentine irregularities. Voids may also be present at the composite dentin interface decreasing bond strength than that of enamel.

Conclusion and Recommendation

Within the limitation of this *in vitro* study, it concludes that polyethylene fiber has only a significant increase in the water sorption, storage time and flexural strength of hybrid composite. The results were not conclusive enough to find hybrid composite with polyethylene fiber as a material with superior properties than the regular hybrid composite. Further studies are needed to evaluate whether Polyethylene fiber is an effective modality in improving the properties of hybrid composite significantly.

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تأثير إضافة ألياف البولي إيثيلين على بعض خواص حشو كمبوزيت المهجن

معتز أحمد غلمان، و **محمد ثروت خليل**، و **عبدالغني إبراهيم ميره**[١] ،
و**غادة حسين نجيب**، و**عبيرمحمدالنويصر**
[١] قسم العلاج التحفظي، و [٢] قسم إعادة تأهيل الوجه والفم والفكين
و [٣] قسم علوم طب الأسنان الوقائـي
كلية طب الأسنان ، جامعة الملك عبد العزيز
جدة – المملكة العربية السعودية

المستخلص. في الآونة الأخيرة اتجهت الغالبية للمظهر، إن كمبوزيت الأسنان استخدم استخدامًا واسعًا ليس فقط للأسنان الأمامية بل يستخدم للأسنان الخلفية كطلب المريض، ولكن يكسر تحت تأثير قوة الثني. إن إضافة الألياف العديدة تحسن الخواص الميكانيكية كألياف الكربون، الأراميد والألياف الزجاجية. وحديثًا أضيفت ألياف البولي إيثيلين لتحسين الخواص وأيضًا تحقيق الناحية الجمالية. الكمبوزيت المهجن واسع الاستخدام في مجال طب الأسنان، ولكن تكسر بسهولة عند الثني، لذلك يهدف هذا البحث إلى اختبار تأثير إضافة الألياف الصناعية من البولي إثيلين لمادة الكمبوزيت المهجن على قوة الضغط وقوة الثني وقوة الربط القصيم مع طبقة المينا والعاج للسن الطبيعي تم تحضير العينات بعد عمل قالب من التيفلون لقياس قوة الضغط، وعمل قالب آخر لقياس قوة الثني. تم تجميع أسنان طبيعية، وتم فصل الجذور عن التاج، وأخذ التاج ويوضع في قالب ليب به إكريل بحيث يصبح طبقة خارجية من المينا أو العاج لقياس الربط

القصية وتم ذلك طبقًا لتوصيات الأيزو. وتم تجميع النتائج، وجدولتها ثم تحليلها إحصائيًا. وقد أوضحت النتائج أن الألياف قد تضعف قوة الضغط مع زيادة قوة الثني التي تزيد من قوة الربط القصية لكمبوزيت مع الأسنان.