The Effect of Amount Variation of Dental Polyethylene Fiber on Flexural Strength of Fiber Reinforced Composite

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Abstract

Fiber-reinforced composites (FRCs) are a relatively new group of materials among those that have been investigated in dental or medical applications over the last 40 years. Their use is growing in many dental applications, including dental implant-supported prostheses. With recent advancements in adhesive technology, new and stronger composite materials, and the development of bondable polyethylene fiber, then it is possible to create a conservative, highly esthetic prosthesis that is bonded directly to the teeth on either side of the missing teeth. Therefore, this study aimed to investigate the effect of the amount variation of polyethylene fiber on the flexural strength of the reinforced composite. Eight samples of polyethylene fiber-reinforced composites (FRCs), which were divided into 2 groups: Group I, which includes 4 specimens of 1 strip polyethylene fiber, and Group II, which includes 4 specimens of 2 strips of polyethylene fiber. Also, each specimen was subjected to a 3-point bend test of flexural strength on a universal testing machine at a crosshead speed of 1 mm/minute, with loading until failure. The results were analyzed by T-Test. The results show that there were significant differences according to the amount which show discloses the P-value (0.001), which less than 0.05 (P<0.05). Thus, that leads to there is significant differences in the level of samples among polyethylene fiber 1 strip (1S) and polyethylene fibers 2 strips (2S). It can be concluded that there is an effect of amount variations of polyethylene fiber-reinforced composite on the flexural strength.

Keywords: Composites, Polyethylene Fiber, Amount Variation, Flexural Strength, Bite Force.

Introduction

Various options are currently available in clinical practice for the replacement of a single missing tooth, ranging from conventional fixed or removable dental prostheses to a single implant-supported crown. Dentists will give treatment depend on their patient's conditions,
included indication and contraindication of the treatment based on oral and systemic conditions of their patients (Zarow et al., 2010; Nurcan et al., 2011). Bridges can be fabricated by using such materials as composite resin. Fiber-reinforced composite resin (FRC) was suggested as an alternative material for the construction of resin-bonded fixed partial dentures (FPDs) (Steven et al., 2004), and its use in the past decade increased markedly. It has several potential advantages compared with a metal framework, such as improving adhesion of the resin, agent to the framework, esthetics, and physiologic stiffness of the framework material (Schutt et al., 2004; Mallick et al., 2008).

Composites consist of two materials in which one of the materials called the reinforcing phase is in the form of fibers or particles, and is embedded in the other material called the matrix phase (Monaco et al., 2003), the role of the reinforcement in a composite material is to increase the mechanical properties of the neat resin system, while the resin combines the fibers and protects the fibers from the external environment moisture (Callaghan et al., 2006).

The curing light is a piece of dental equipment that is used for polymerization of light cure resin-based composites it can be used on servable different fiber-reinforced composite that is cured by light. The light used falls under the visible blue light spectrum, is also delivered over a range of wavelengths, and varies for every type of device (Sherwood and Anand 2010). Fiber-reinforced composites (FRCs) are relatively new materials among those that have been investigated in dental applications over the last 40 years. Their use is growing in many dental applications, including implant-supported prostheses (Freilich et al., 2000), every different fiber used in composites has different properties and then affects the properties of the composite in different ways. It is also required to specify the geometry of the reinforcement, its concentration, distribution, and orientation (Taylor et al., 2007; Behr et al., 2001).

Fiber-reinforced composite is a combination of fibers and resin matrix. The effectiveness of fiber reinforcement is depending on many variables including the fiber volume fraction (Callaghan et al., 2006), the position of Fibers, the direction of fibers, adhesion of fibers to the polymer matrix, and the impregnation of fibers with resin (Mohammed et al., 2007).

Flexural strength is also known as transverse strength, bending strength is a measure of stress required to fracture a material. This stress is produced by bending force or bending moment (flexure) in a material (Powers and Wataha, 2008; Anusavice, 2009). Reinforcement has been advocated as a means to improve the strength and durability of the resin. There are reports about using fibrous reinforcing materials such as carbon aramid glass and high-performance polyethylene (HPPE) to improve the mechanical properties of resins and know the bite force (Monaco et al., 2003).

With modern advancements in adhesive technology, new and stronger composite materials, and the development of bondable polyethylene fiber, it is possible to create a conservative, highly esthetic prosthesis that is bonded immediately to the teeth on either side of the missing teeth (Beill and Zer, 2000), ribbon (Ribbond, Inc Seattle, Wash) is an ultrahigh molecular weight polyethylene fiber that is woven into a porous ribbon. It is biocompatible, inert, colorless, pliable, and compliant; these properties make it attractive for use in both direct and indirect restorations (Anusavice, 2003).

Many reasons lead to fracture of the dental bridge. The bite force becomes the main reason because it is the main force in the mouth, which affects the dental bridge (Taylor et al., 2007), for anterior FPDs the connector area is relatively thin compared to the connector area in posterior FPDs. Moreover, loading of posterior bridges is expected to be of vertical a gulation with the lower change of rotation forces compared to anterior bridges. Given the volume difference, the anterior bridge has a lower opportunity to withstand these occlusal loading forces (Heumen et al., 2010).
Measuring biting forces is quite easy. A measuring device, basically a force transducer, is directed to a specific place, a bite point source of a specific tooth as well as a general bite force over the full dentition (Houston, 2003), the bite forces at the anterior teeth, are lower with less action of the jaw muscles. A powerful bite force in humans is expecting due to the shorter jaw, and the point force of the bite is located on the molars and premolars. The bite forces range from 55 pounds (lbs) to 280 lbs, averaging 162 lbs (237.169 MPa), the force of the incisors is 34 lbs (132.74 MPa) (Houston, 2003; Radoslav et al., 2010).

Kamble et al (2012) were compared the flexural strength of poly-methyl methacrylate (PMMA) and bis-acryl composite resin reinforced with polyethylene and glass fiber. The study showed that of two fiber-reinforcement methods evaluated, glass fiber reinforced for the PMMA resin and bis-acrylic composite resin materials produced the highest flexural strength.

Callaghan et al (2006); and Behr et al (2000) were studied three kinds of fiber-reinforced composite molar crowns were tested on their fracture resistance and marginal adaptation under simulated oral stress conditions, and fondue resistance of molar crowns made of the glass fiber-reinforced composite was higher than those of polyethylene fiber-reinforced composite crowns. Based on the background, this study aimed to determine the effect of amount variation polyethylene fiber-reinforced composite on the flexural strength.

Materials and Method

The study is an experimental laboratory study conducted at the Faculty of Engineering-Tripoli University and Higher Institute of Medical Professional- Msallath, Libya. The sampling technique (sample size) was based on Daniel’s formula (1991). The study used 8 samples divided into 2 groups each group involved 4 samples.

Study Procedure:
Preparation of Specimens

Eight rectangular strip specimens of the material, measuring 25 × 2 × 2 mm, were prepared by filling a metal mold, placing and clamping a glass lid over the mold, and curing for 30 seconds in the quartz tungsten halogen (QTH) light curing (Litex 660, Dentamerica, USA) at room temperature. After polymerization, 8 strip specimens of the material were stored in distilled water at an incubator (Sanyo MIR-162, USA) at 37°C for 24 hours (American Dental Association, 1993). After 24 hours of the storage at 37°C, the specimens were taken out from the water and dried with tissues, before loading the height and width were measured by a digital micrometer with an accuracy of 0.01 mm (Black and Garth, 1998).

Determination of Fiber Volume Fraction

The fiber volume fraction was calculated using the following formula:

\[ \text{Volume Fraction} = \frac{a}{b} \times 100 \]

where the; (a) the volume fraction of the fiber. (b) the volume of the mold.

Grouping

The total numbers of samples were 8 samples, which were divided into 2 groups:

a) Group I: 04 specimens of 1 strip polyethylene fiber positioned vertically in the mold with fiber dimensions of 25 mm length, 0.7 mm wide, and 2 mm height.

b) Group II: 04 specimens of 2 strips polyethylene fiber with same the specifications mentioned in group I.
The Effect of Amount Variation of Dental Polyethylene Fiber Reinforced Composite on the Flexural Strength

Fig 1. After storing in the incubator the specimens of polyethylene fiber are ready for flexural strength testing

Flexural Strength Test

The flexural strength test was performed by the three-point bending test using a universal testing machine (Tokyo Testing Machine, Japan) at a crosshead speed of 1 mm/minute; the length of the specimens was 40 mm; the support span was 30 mm; with loading until failure. The maximum load was recorded at the time of failure and captured electronically. Flexural strength \( \sigma \) (with mega Pascal’s) was calculated using the following formula:

\[
\sigma = \frac{3FL}{2bd^2}
\]

\( \sigma \) is the flexural strength (MPa)

\( F \) is the load (force) at the fracture point (N)

\( L \) is the length of the support span (mm)

\( b \) is the width of the specimen (mm)

\( d \) is the thickness of specimen (mm)

Statistical Analysis

The data had been tested by normality test of using Shapiro-Wilk test which was used with small samples (less than 100). The data of flexural strength was analyzed by using statistical software (SPSS19.0, SPSS Inc). T-test has been done to evaluate the difference between sample groups (1 strip polyethylene fiber & 2 strips polyethylene fiber).

Results

Research was done on eight polyethylene fiber-reinforced composites specimens. The average flexural strength of FRC groups is based on the strips as shown in Table (01). It was shown that 2 strip fibers gave higher flexural strength than 1 strip fiber (Figure 2).

Table 1. Mean and Standard deviation (SD) of (1 strip polyethylene fiber & 2 strips polyethylene fiber).

<table>
<thead>
<tr>
<th>Variables</th>
<th>Mean</th>
<th>N</th>
<th>Std. Deviation</th>
<th>Std. Error Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>PE1S</td>
<td>201.125</td>
<td>04</td>
<td>13.91100</td>
<td>6.95550</td>
</tr>
<tr>
<td>PE2S</td>
<td>328.275</td>
<td>04</td>
<td>11.12066</td>
<td>5.56033</td>
</tr>
</tbody>
</table>
The result of the T-test showed there were significant differences according to the amount which show discloses the P-value (0.001), which less than 0.05 (P < 0.05). Thus, there is a significant difference in the level of samples among polyethylene fiber 1 strip (PE1S) and polyethylene fibers 2 strips (PE2S), the effects of amount on flexural strength for all groups Table (2).

### Discussion

The results indicated that the amount of fiber in FRC gives a significant difference in flexural strength. The flexural strength of the 2 strips was higher than 1 strip. Thus, some factors influence the strength of the fiber-reinforced composite, i.e. the fiber volume fraction. From the data of this research, it can be calculated from the fiber volume fraction:

- a) 1 strip polyethylene fiber, 35%.
- b) 2 strips polyethylene fiber, 70%.

By this finding, it was seen that the polyethylene fiber 1 strip has a volume fraction <65%, and polyethylene fiber 2 strips have a volume fraction >65%. It was stated by Callaghan et al (2006) that the fiber volume fraction more than 65% gave more strong in the construction of FPD significantly. Thus, from this finding, it can be said that the 2 strip fibers give a significant difference in flexural strength to 1 strip fiber. This condition is supported by the previous study in the tensile strength by Vakiparta et al (2004), studied the flexural strength of polyethylene fiber with different amount of one and two bundles of fiber, and showed that the polyethylene fiber two bundles gave the highest flexural strength than the polyethylene one bundle.

Many studies support the present study. According to Vallittu (1998), that comparing between three different amount of glass fibers (one, two, and three bundles), the increase of the amount of glass fibers in the FPD restoration caused the high fracture resistance of the FPD, and the result showed the glass fiber with three bundles are more strength than the other bundles.
Based on the Li et al. (2003) study, when comparing the dental bridge with non-fiber and one, and two bundle fibers reinforced, the results showed the dental bridge with two bundles gave the highest flexural strength values followed by one bundle and non-fiber. In the investigations by Prejmerean et al (2007), it can be noticed that the flexural strength of FRC which contained two bundles of fibers was about 1.5 up to 2 times higher than that of FRC with the same resin matrix and one bundle fibers. The investigations by Vakiparta et al (2004), studied the flexural strength of E-glass fiber with different amounts of one and two bundles of fiber, showed that the E-glass fiber gave the highest flexural strength than the E-glass one bundle.

For a practical condition as an apostate in the background that the bite force of anterior teeth is 34 Lbs (132.748 MPa) and for the posterior teeth is 162 Lbs (237.169 MPa) by (Houston 2003). By this research, it was known the flexural strength of 1 strip of polyethylene fiber was 135MPa, and for 2 strips of polyethylene fiber was 223.59 MPa. Therefore, it can be recommended that the anterior teeth need a minimum of 1 strip of polyethylene fiber and for posterior teeth minimum 2 strip polyethylene fiber.

Conclusion

Based on the results, there are significant differences in the level of samples among polyethylene fiber 1 strip (1S) and polyethylene fibers 2 strips (2S). There is an effect of amount variations of polyethylene fiber-reinforced composite on the flexural strength. Thus, the two strips of polyethylene fiber are stronger than one strip of polyethylene fiber.

References

Kamble B., Campo EA; (2012), Selection of polyethylene materials: how to select design properties from different standards. Willian Andrew inc, NY.
Li D., Ellakwa S., Marquis C; (2003), Influence of different techniques of laboratory construction on the fracture resistance of fiber reinforced composite bridge, The Journal Contemporary Dental, 54-001-013.
Nurcan L., Nilgun Seven; (2011), the influence of different fiber-reinforced composites on shear bond Strengths when bonded to enamel and dentin structures, Journal of Dental Sciences, Turkey.
تأثير الكميات المختلفة من ألياف البولي إيثيلين السني على قوة الكسر للكمبزت المدعم

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ملخص البحث:
إن مواد الكمبوزت المدعم بالألياف تعتبر مجموعة جديدة نسبيا من بين تلك المواد التي تم فحصها في تطبيقات طب الأسنان والتطبيقات الطبية خلال الأربعين سنة الماضية، ويتزايد استخدامها في العديد من تطبيقات طب الأسنان، بما في ذلك التعويضات التي تم زراعة الأسنان. والتقدم الحديث في التقنية اللاصقة لمواد الكمبوزت السني، وتطوير ألياف البولي إيثيلين القابلة للربط يمكننا من عمل تعويضات سنية بديلة ذات مظهر جمالي عالي ترتبط مباشرة بالأسنان على جانبي الأسنان المفقودة. لذلك، كان الهدف من هذه الدراسة هو معرفة تأثير الكميات المختلفة من ألياف البولي إيثيلين على قوة الكسر للكمبزت المدعم. استُخلصت هذه الدراسة على 8 عينات من الكمبزت المدعم بالفوابالي إيثيلين والتي تم تقسيمها إلى مجموعتين: المجموعة الأولى، وتشمل 4 عينات مدعمة بشريط واحد من ألياف البولي إيثيلين والمجموعة الثانية، وتشمل 4 عينات مدعمة بشرتيين من ألياف البولي إيثيلين. بالإضافة إلى ذلك، خضعت جميع العينات لاختبار قوة الكسر (اختبار الثلاث نقاط) عند سرعة تفاعل 1 مم/دقيقة على جهاز اختبار الميكانيكي مع التحميل حتى حدوث الكسر. النتائج المتحصل عليها تم تحليلها بواسطة اختبار (T-test) وأظهرت النتائج وجود فروق ذات دلالة إحصائية هامة بين الفئتين (P < 0.05) وهذا يقودنا إلى أن هناك اختلاف هام بين العينات المدعمة بشرتيين واحد من ألياف البولي إيثيلين والعينات المدعمة بشريتين من ألياف البولي إيثيلين. ومن هنا يمكن الاستنتاج بأنه هناك تأثير إيجابي عند اختلاف كمية ألياف البولي إيثيلين المدعم للكمبزت على قوة الكسر.

الكلمات المفتاحية: الكمبزت، ألياف البولي إيثيلين، اختلاف الكمية، خاصية قوة الصلابة، قوة العضة.