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The Effect of Combination of E-glass and Polyethylene Fiber-Reinforced Composites on Flexural Strength

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Keywords:
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ABSTRACT

The Fiber-reinforced Composites (FRCs) is a combination of fibers and a resinous matrix. The mechanical properties of (FRCs) materials are primarily dependent upon fiber type (glass, carbon, aramid, or polyethylene). The aim of this study was to evaluate the effect of combination of E-glass and Polyethylene (FRCs) on flexural strength. Materials and Method: This research was an experimental study and using braided Polyethylene (pre-Silanated) fiber (Construct, KerrLab, Corporation, West, Collins Orange, CA, USA), unidirectional E-Glass fiber (everStick C& B, Stick Tech Ltd, Turku, Finland), Resin matrix (Construct Resin), (Construct, KerrLab, West, Collins Orange, CA, USA) and Coupling agent 3-(Trimethoxysilyl) propyl methacrylate (γ-MPS) 98% Purity (Acros organics Pittsburgh USA). This study was conducted with sixteen specimens which were prepared in a metallic mold (25 x 2 x 2 mm). The specimens were divided into four groups according to the type of the Fiber and combination of fibers. (N = 4): G1 - Two layers of (PE-EG-FRCs); G2 - Two layers of (PE-PE-FRCs); G3 - Two layers of (EG-EG-FRCs); G4 - Two layers of (EG-PE FRCs). Measurement of flexural strength used the universal testing machine. The result was analyzed with one way Anova. Result: The result of the study showed that the flexural strength for PE-EG fiber was 240.47±3.78 MPa and 179.25 ±42.47 MPa for EG-PE, 175.13±22.56 MPa for EG-EG, and 154.69 ±16.91MPa for PE-PE. The result of one way Anova test shows there were significant differences among groups in the effects on flexural strength because the value of ($F = 8.377$, p value < 0.01). For each group, values for flexural strength were obtained. PE-EG fiber was the highest flexural strength ($p < 0.05$), when compared to other evaluated combinations. Two layers of PE-EG appear to be more resistant than other combination of (FRCs).

تأثير الجمع بين المركبات المقواة بألياف الزجاجية و ألياف البولي إيثيلين (FRCs) على قوة الانحناء

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الكلمات المفتاحية:
المركبات المقواة بالألياف
ألياف البولي إيثيلين
ألياف الزجاج الإلكتروني

الملخص

المركبات المقواة بالألياف (FRCs) هي مزيج من الألياف ومركبات راتينجية والتي خواصها الميكانيكية تعتمد بشكل أساسي على نوع الألياف المستخدمة (زجاج ، كربون ، أراميد ، أو بولي إيثيلين)، وكان الهدف من هذه الدراسة تقييم تأثير الجمع بين المركبات المقواة بألياف الزجاجية و ألياف البولي إيثيلين (FRCs) على قوة الانحناء. **المواد والطريقة:** هذا البحث عبارة عن دراسة معملية تجريبية بإستخدام ألياف مادة البولي إيثيلين

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المجدول (Construct (pre-Silanated) ، KerrLab، Corporation، West، Collins
Orange، CA، الولايات المتحدة الأمريكية (و الألياف الزجاجية الإلكترونية أحادية الاتجاه
(everStick C& B, Stick Tech Ltd, Turku, Finland)و مصفوفة الراتنج (بناء الراتنج)
(Construct, KerrLab, West, Collins Orange, CA, USA)و عامل اقتران 3-
(Trimethoxysilyl) Propyl methacrylate (γ-MPS) 98% Purity (Acros organics
Pittsburgh USA). أجريت هذه الدراسة على ستة عشر عينة تم تحضيرها في قالب معدني (25 × 2 × 2
مم) وتم تقسيم العينات إلى أربع مجموعات حسب نوع الألياف. المجموعة الاولى (G1) تحتوي على 4 عينات
(N=4)كل عينة مكونة من طبقتان من(PE-EG-FRCs) ؛ المجموعة الثانية- (G2) طبقتان من-(PE-
PE-FRCs)؛ والمجموعة الثالثة - (G3) طبقتان من (EG-EG-FRCs) ؛المجموعة الرابعة –(G4)
طبقتان من .(EG-PE FRCs) استخدمت الة الاختبار الهيدروليكية الشاملة (UTM) لقياسات قوة
الانحناء. **النتيجة:** تم تحليل النتائج بإستخدام (One way Anova)، أظهرت نتائج الدراسة أن قوة
الانحناء لألياف (PE-EG) كانت 240.47 ± 3.78 MPa و 179.25± 42.47 MPa لـ (EG-PE)،
175.13 ± 22.56 MPa لـ(EG-EG) ، و 154.69 ± 16.91 MPa لـ (PE-PE). (One way
Anova) اظهرت وجود فروق ذات دلالة إحصائية بين المجموعات في التأثيرات على قوة الانحناء لأن قيمة (F
= 8.377, p value < 0.01).. تم الحصول على قيم قوة الانحناء لكل مجموعة حيث كانت ألياف (PE-
EG) أعلى مقاومة للانحناء (p < 0. 05) ، عند مقارنتها بالتركيبات المقيمة الأخرى. اظهرت طبقتان من عينات
(PE-EG) انهما اكثر مقاومة من باقي الطبقات بالعينات الاخرى من (FRCs).

Introduction

Fiber reinforced composite materials (FRCs) are the fibers and a matrix. The matrix acts as a binder and other constituents that may also be found include coupling agents, coatings, and fillers. The coupling agents and coatings are used to improve their wettability promote bonding across the fiber matrix interface (Wibowo et al., 2018). Both are promoted a better load transfer between the fibers and the matrix. Some polymeric matrices contain fillers, which are used to improve dimensional stability and reduce costs (Faizah et al. 2016). The mechanical properties of FRC materials are primarily dependent upon fiber type (glass, carbon, aramid, or polyethylene), quantity of fibers in the matrix resin, fiber architecture (unidirectional, woven, or braided), and quality of impregnation of fiber with resin (Garoushi et al., 2006).

FRCs prostheses offer the advantages of good aesthetics, minimal invasive treatment, and an ability to bond to the abutment teeth, thereby compensating for less-than-optimal abutment tooth retention and resistance form. These prostheses are composed of two types of composite materials; fiber composites to build the framework and hybrid or microfill particulate composites to create the external veneer surface (Niloofar Bahramian et al., 2015).

The use of fiber in dental materials has several functions including increasing strength and stiffness, increasing the resistance of the material to fracture, and reducing shrinkage (Septommy, et al., 2014). Fibers commonly used in dentistry are Ultra-high-molecular weight polyethylene (UHMWPE) fiber and glass fiber.

UHMWPE fibers have poor adhesion to polymer matrix; meanwhile, glass fibers have enhanced adhesion to the polymer matrix with better esthetics and biocompatibility, compression strength, and safety for patients with allergy (Maulida et al., 2019; Engie et al., 2021).

(FRCs) have been used for variety of dental applications, such as bridges, splints, posts, space-maintainers, orthodontic retainers, denture bases, clasps and connectors, and implant prostheses. In general, in a FRC, fibers are the main load-carrying members, while the surrounding matrix acts as a load transfer medium and protects the fibers from outside environment. (Niloofar Bahramian et al., 2015).

There are many problems associated with FRC prostheses. For instance, loss of surface shining on the particulate veneering composite; excessive translucency in pontic areas; fracture or chipping of the particulate composite veneer and debonding of the retainer (Garoushi et al., 2006). Many studies have done to outcome these problems; Dental reconstructions are during clinical function subjected to biting and chewing forces. Functional rehabilitation of the dentition is the main purpose of a dental prosthesis. A fixed dental prosthesis (FDP) is considered as treatment of choice for replacing missing teeth. Since conventional and implant-retained FDPs are invasive, time consuming, and expensive the dental profession continues the search for alternatives. One such alternative is a FRCs fixed dental prosthesis (FRC-FDP). FRC-FDPs are basically made of FRC framework acting as a stress dissipater and are veneered with particulate filler composite (PFC). Following the introduction of glass FRCs in the early 1990s (Goldberg et al., 1992), their use increased enormously over the last years (Freilich and Meiers, 2004).

Limited information is available on their longevity and clinical behavior, but the available clinical research showed that FRC-FDPs are able to function acceptably for up to five years (Behr et al., 2003; Freilich et al., 2002; Gohring et al., 2005; Vallittu et al., 2004), with reported five year-survival rates between 73% (Gohring and Roos, 2005) and 93% (Vallittu et al., 2004). Regardless of the promising results, typical kinds of failures, like delaminating and chipping of veneering composite, were encountered during clinical function (Behr et al., 2003; Freilich et al., 2002; Gohring and Roos, 2005; Monaco et al., 2003). For that reason a FRC-FDP should be capable to withstand up to 500 N in the premolar region and 500-900 N in the molar region (Behr et al.,2002; Ozcan et al.,2005). Prior to in-vitro studies on framework designs indicated final failures after mechanical loading, along with detailed evaluation of failure patterns (Tacir et al., 2018). Final failure loads were reported to be 27% to 46% higher than the values obtained from initial failure and often surpassed the physiological masticatory forces (Yee ANG et al., 2021).

(Pasi Alander et al., 2021) stated that in order to withstand chewing forces, resin-based FDPs are strengthened with the addition of FRC reinforcement. In these types of restorations, the FRC framework distributes the stress, maintaining the integrity and increasing the longevity of the prosthetic device. The mechanical properties of FRCs restorations range from isotropic to anisotropic and are greatly influenced by the type, volume, location and direction of the fibers. Long continuous fibers have shown outstanding performance on the reinforcement of PFC when located at the tensile side of restorative appliances. The thickness of the material, the design of the preparation, as well as the properties of the luting agent are the factors that have a direct influence on the strength of (FRC-FDPs).

Previous research stated that FRC- FDPs with a conventional design and even some with a modified design (FRC) may be not indicated for use in the molar region. These studies were focussed on the correct design of the FRC framework and the use of high quality pre-impregnated glass fibers in optimum quantity to reduce the possibility of framework fractures. Veneering composite chipping can be avoided by using thicker layer (1-2 mm) of composite resin on the surface of FRC framework (Garoushi et al., 2006). Framework design with a perpendicularly placed additional FRC reinforcement for cuspal support is crucial in fabricating a successful posterior FRC bridge (Yee ANG et al., 2021).

The preference for FRC in the construction of dental bridges gained popularity as it adopts the principle of minimally invasive dentistry and excellent esthetics. The clinical performance of an FRC bridge seems to be satisfactory with a success rate of 97% at 4.7 years, and the commonly observed failure involves fracture of the veneering material or delamination at the pontic area (Ahmed KE et al., 2017; Garoushi et al., 2018). The leading factor causing such failure is the lack of a substructure support that can be reinforced by placing additional FRCs within the framework. Therefore, various modified framework designs were proposed with their respective ideologies; in the latest review, a design with a combination approach was recommended to reinforce the pontic area (Perea-Lowery et al., 2018).

The framework design should be modified to support the veneering composite, and the amount of fibers should be increased to improve the rigidity of the FDP (Freilich et al., 2002). The most frequently used FRC framework consists of a bundle of unidirectional FRC placed in the central part of a FDP. It seems that the amount of FRC included in such conventional framework is too little to provide the necessary support and rigidity. A high-volume anatomically shaped FRC framework should be able to deal with these shortcomings. Clinical reports demonstrated an improved resistance against veneering composite fractures of a larger substructure volume at the pontic area by using a wraparound design, or a bundle of fibers oriented perpendicularly towards longitudinal fibers (Monaco et al., 2003, Freilich et al., 2002, Xie et al., 2007).

There are numerous studies, in dental literature available with an evidence of comparing different framework designs of FRC-FPDs. A study by (Behr et al.2005), evaluated different forms of frameworks, the authors tested Simulated three-unit FRC-FDPs with one anatomical framework and two traditional framework design FRC-FPDs. They demonstrated a significant higher fracture resistance for an anatomically shaped framework (902N) when compared to one anatomical and two traditional frameworks (694 and 737N). Also Xie et al. (2007), tested the fracture resistance of inlay-retained FRC-FDPs with different framework designs. A framework which supported the pontic area in buccolingual direction showed significant higher fracture resistance compared to conventional framework design and high-volume designs. (Freilich et al. 2002). Therefore, a high-volume design, which was more rigid and offered more support for the veneering composite, was introduced. The high-volume design showed a 95% survival rate instead 62% for the low volume design after a mean observation time of 3.75 years. (Monaco et al. 2003), investigated the clinical behavior of inlay- retained FRC-FDPs with conventional and modified framework designs over a period of 12–48 months. The conventional framework design showed a higher failure rate than the modified framework design. In the group of FDPs with a conventional framework design delamination occurred in three cases (16%), while in the modified framework group only one FDP (5%). In the search for the optimum framework design for a posterior FRC bridge, many researchers proposed a combination approach with multiple FRCs (Yee ANG et al., 2021).

According to these problems that may happen after ageing of FRCs, FPD and looking for suitable solutions to avoid all these problems, this study proposes new modification of framework designs of FRCs, FPD by the combination of E-glass fiber-reinforced (EG-FRCs) and Polyethylene fiber-Reinforced composites (UHMWPE-FRCs) to improve of mechanical properties of fiber-reinforced composites.

The aim of this study is to determine the effect of combination of EG-FRCs and UHMWPE-FRCs on flexural strength of FRCs system. Research Benefits include Scientific information of the effect of combination of E-glass and Polyethylene fiber-Reinforced composites on flexural strength, and practical benefit is improving of mechanical features of FRCs, FPD. This study hypothesis that, the combination of E-glass fiber and polyethylene fiber-reinforced composite increase the flexural strength of FRCs system

MATERIAL AND METHODS

1. MATERIAL:

a. Braided Polyethylene (pre-Silanated) fiber system (Construct, KerrLab, Corporation, product number; 30869, 2 mm wide, a mount of fibers bundles 800, West, Collins Orange, CA, USA), and Unidirectional E-Glass fiber system, product number; 100230, 1.5 mm wide, a mount of fiber bundles 4000, (everStick C& B, Stick Tech Ltd, Turku, Finland).
b. Construct Resin; Light color, 3.5 g Syringe, (Construct, Kerr Lab, West, Collins Orange, CA, USA).
C. Silane coupling agent 3-(Trimethoxysilyl) propyl methacrylate (γ-MPS) 98% Purity (Acros organics Pittsburgh USA).

2. Preparation of specimens

Metallic mold measuring (25 x 2 x 2 mm), according to the ISO 10477: 92, is prepared for fabrication of specimens. Then, measure the length of fiber to make sure of the required appropriate length of ribbon (strip) E-glass and PE- fiber to accommodate for the adaptation into metallic mold. Silanization of UHMWPE fibers with the chemical surface modification or treatment was carried out using 2 (wt/vol) % γ-MPS in ethanol/distilled-water (70/30 wt/wt, pH adjusted at 3.8 using acetic acid). Having the silane prehydrolyzed for 1 h, the fibers were immersed in the solution and left for 1 week at room temperature to dry. Then, a thin layer of hybrid/flowable composite is applied into metallic mold then, the E-glass fiber ribbon sink into the layer of composite and adaptation and a thin layer of composite reapply along metallic mold until full cover of E-glass fiber strip then the PE-fiber ribbon is sinking into layer of composite and adaptation. Reapplying again the composite is along metallic mold until full cover of PE-fiber strip. Then, the composite is light cured with Quartz tungsten halogen (QTH) light curing unit (Litex 660, Dentamerica, USA) on both sides of specimens for 3x 40s according to manufacturer direction. Then, the cured specimens be removed from metallic mold and all of specimens store in water on 37 C° for 24 hours, the specimen's dimension are measured by Vernier caliper. After that, the specimens are ready for flexural strength measurement.

3. Grouping

Table 1. The total number of samples is 16 samples, which divided into four groups.

Group	Number of samples	Fiber	Number of layers
I	4	PE-EG	Two layers
II	4	PE-PE	Two layers
III	4	EG-EG	Two layers
IIIV	4	EG-PE	Two layers

4. Flexural strength test.

The distance between supports is set to 20 mm. Three-point bending test is carried out using universal testing machine (Tokyo Testing Machine, Japan), applying a load to the specimen at cross-head speed of 1mm/min until the specimen fractures.

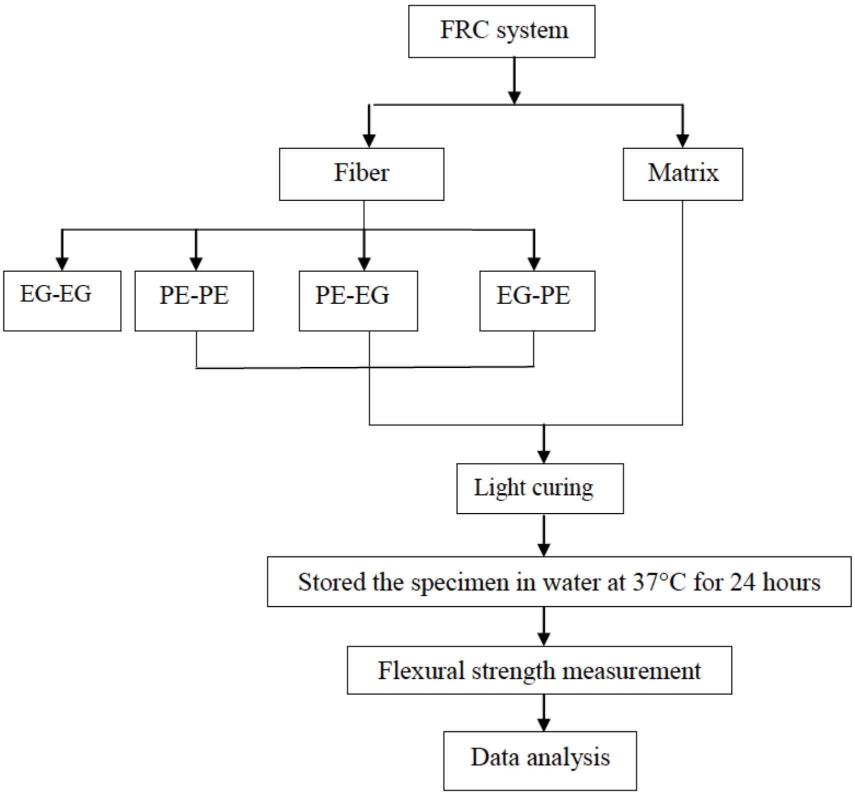
The maximum load exerted on the specimen is recorded.

Flexural strength is calculated according to following equation:

$$\sigma = \frac{3FL}{2bd^2}$$

Where
σ is the flexural strength (MPa)
F is the load 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 depth or thickness of the specimen (mm)

G. Flow of Research



Statistical Analysis

Calculated value for the test parameters were statistically analyzed using IBM SPSS Statistics version 19.0 software (IBM Corporation, Armonk, NY, USA). Furthermore, the Shapiro Wilk test was used to determine whether the distributions of continuous variables were normal. Then, the homogeneity of variance F-test (one-way Anova) to examine the differences between group and within group on flexural strength.

RESULT AND DISCUSSION

RESULT:

Research had been done on sixteen of combinations fibers-reinforced composites specimens. All specimens were prepared in Integrated Research Laboratory at Faculty of Dentistry of Gadjah Mada University. Flexural Strength measurements were carried out with 3-point universal testing machine (Tokyo Testing Machine, Japan) in Material Laboratory of Faculty of Mechanical and Industry Engineering Technology of Gadjah Mada University.

The Study Findings:

The Results of Study's Hypothesis:

The current study includes one major hypothesis, which is:
“The combination of E-glass fiber and polyethylene fiber-Reinforced composites increase the flexural strength of FRCs system”.

To examine this hypothesis, the researchers used means and standard deviations, for all groups in the current study, and then, the researchers checked the normality of scores by using (Shapiro Wilk) test which is used with small samples (less than 100), to determine the suitable statistical method to analyze the current data, in details; when the data belong to normal distribution it is appropriate to use parametric tests, while if the data do not belong to normal distribution it is appropriate to use parametric tests.

Table.2, Means, Standard Deviations, and Test of Normality

Variables	Mean	S.D.	Shapiro Wilk value	df	Sig.
PE-PE	154.69	16.91	0.965	4	0.812
EG-EG	175.13	22.56	0.963	4	0.798
EG-PE	179.25	42.47	0.855	4	0.243
PE-EG	240.47	3.78	0.948	4	0.701

Table (2) shows the means of all groups with standard deviations, and the data in this variables distributed normally because the values of Shapiro Wilk statistic are not significant ($p > 0.05$). So to check the hypothesis, the current study will use parametric test.

To examine this hypothesis, the researchers used F-test (one-way Anova), to examine the effects of groups (combination) on flexural strength, and the results are shown in the following tables.

Table. 3, the Result of One Way Anova Test (The Effects of Groups on Flexural Strength)

Source of variance	Sum of Squares	Df	Mean Square	F	Sig
Between Groups	16413.987	3	5471.329		
Within Groups	7837.840	12	653.153	8.377	0.003
Total	24251.827	15			

The result of one way Anova test shows there were significant differences among groups in the effects on flexural strength because the value of ($F = 8.377$, p value < 0.01), in addition according to table (2) the group PE-EG obtained the first rank in flexural strength with mean and standard deviation (240.47& 3.78), the group which got the second rank was EG-PE with mean and standard deviation (179.25 & 42.47), then group EG-EG with mean and standard deviation (175.13& 22.56), and the last group was PE-PE with mean and standard deviation (154.69 & 16.91), so to check the nature of these differences the researcher used one of Post Hoc test (Scheffe test), and the result is in as shown in the table below.

Table.4. The Result of Post Hoc Test (Scheffe Test) to check the differences Among Groups

Groups	EG-EG	EG-PE	PE-EG
PE-PE	- 20.44	- 24.56	- 85.78*
EG-EG	----	- 4.13	- 65.34*
EG-PE	----	----	- 61.22

Table (4) shows the differences between all groups that are insignificant, so we can say the effects of these groups in flexural strength are similar, except between PE-PE and PE-EG in favor to PE-EG and between EG-EG and PE-EG in favor to PE-EG. Thus we can arrange these groups ascending according to their means as the following.

1. Group (PE-PE) the effect in flexural strength in the least.
2. Group (EG-EG) the effect in flexural strength is more than group (PE-PE) but not significant.
3. Group (EG-PE) the effect in flexural strength is more than groups (EG-EG & PE-PE) with insignificant differences.
4. Group (PE-EG) the effect in flexural strength is more than group (EG-PE) with significant differences.

DISCUSSION

Previous reports have shown that positioning the framework at the site of the tensile stress, in addition to orienting the fibers along the direction of the stress increases the stiffness and fracture strength of a dental prosthesis. FRC design should include the fibers oriented in the same direction as the maximum principal stress, which enhances the fracture strength of the FDP and avoids fractures (Pasi Alander et al., 2021)

In the present study, the combination of FRC had a significant influence on the flexural strength of the FRC. The more FRC was used with different types, the higher the load-bearing capacity became. Based on the result of study in (Tables 2, 3, 4), the flexural strength values of specimens reinforced, showed statistical differences. The flexural strength of the combination of braided polyethylene (UHMWPE) fiber and unidirectional glass fiber reinforced composites (PE-EG-FRCs) showed significantly increased values compared to the other samples of (PE- PE), (EG-EG) and (EG- PE-FRCs).

A variety of factors have an influence on the physical properties of dental FRCs, some of them are: tensile strength and elongation of fiber and polymer matrix, surface treatment and type of fibers, orientation and length of fibers, number and diameter of fibers as well as location of the FRC in the dental reconstruction. The mechanical properties of an FRC framework can be altered by changing the orientation of fibers, their content and geometry, which is known as cross-sectional design (Vallittu P et al., 2017).

Many studies stated that the mechanical properties of (FRCs) are dependent on many factors, including the mechanical properties of resins and fiber type glass, carbon, aramid, or polyethylene (Vazquez et al., 1998). The quantity of fibers in the resin matrix (Vallittu et al, 1994) the length of fibers, the orientation of fibers, the fiber architecture (unidirectional, woven, or braided), the adhesion of fibers to the polymer matrix, and the impregnation of fibers with the resin (Vallittu et al., 1994 and Stipho et al., 1998).

An improved flexural strength of the FRCs can be obtained by a good wettability and adhesion of polymer to the fiber. Surface treatments by silanation of glass fiber and polyethylene fiber (Vallittu et al., 2017 and, Marei et al., 1999), PMMA impregnation can enhance the adhesion between fiber and polymer and increase the mechanical properties (Vallittu et al., 1999) or the combination of polyethylene fiber and E-glass fiber-Reinforced composites.

The combination of braided Ultra-high-molecular-weight polyethylene (UHMWPE) fiber and unidirectional glass fibers reinforced composites (PE-EG-FRCs) showed higher mechanical properties than the combination of unidirectional glass and braided polyethylene fibers (EG-PE-FRCs) and also higher than the combination of unidirectional glass and unidirectional glass fibers (EG-EG-FRCs). (Maulida, et al., 2019) has evaluated the flexural strength and modulus of elasticity of two systems of reinforcement fibers. In addition, the influence of thermocycling and the number of employed layers of fibers on mechanical features and stated that the pre-impregnated polyethylene fiber had better flexural strength in comparison to the pre-impregnated glass fiber. Therefore, Ultra-high-molecular-weight polyethylene (UHMWPE) fibers in a double layer had a higher flexural strength in comparison to all the other combinations tested. In contrast, the glass fibers did not demonstrate the same results, and the mechanical properties were similar both in single or double layers.

This could be explained by the differences of fiber types and direction of orientation (unidirectional, woven, or braided), position of fibers and water sorption. Because of UHMWPE fiber is very resistant to water, moisturous than EG fiber and other types of fibers. So, when parallel position of braided UHMWPE fiber layer is above or cover unidirectional EG layer fiber, that could reduce the water sorption into the fiber reinforced composites. As a result, the chemical bonds between fibers and matrix are less affected by water because of UHMWPE fiber is resistant to water sorption into composite. Therefore, no water sorption in fiber- reinforced composite could reduce the degradation of adhesion between polymer matrix and fibers. Generally, (Al-Mulla et al., 1989) stated that water has the main effect on degradation of dental polymers and dental composites. However, the structure of the FRCs material is more complicated, (Latour et al., 1992) has stated that the interface between the polymer matrix and the fibers could be affected by an aqueous environment in the long term. Chemical factors such as competition for polar bonding sites at the interface may be primarily responsible for saliva induced degradation of adhesion between polymer matrix and fibers.

The high water sorption of the polymer matrix, caused plasticization of the polymer. The primary mechanism for the ingress of water is diffusion and some absorption is facilitated by the polarity of polymer chains. Water molecules penetrate into the spaces between polymer chains and occupy positions between the chains, and thus, the polymer chains are forced apart. Water molecules act as a plasticizer and the polymer chains generally become more mobile and as a result, the flexural modulus and strength are reduced (Anusavice, 1996).

The effect of Ulra-high-molecular-weight polyethylene (UHMWPE-EG) on the fracture resistance was considerable. This was probably due to the position of the braided polyethylene fibers positioned at the compression side of UHMWPE-EG is higher fracture strength than the unidirectional glass fibers at the compression side. And also, the position of unidirectional glass fiber reinforcement, which was at the tension side of (UHMWPE-EG) in higher fracture strength than braided polyethylene fibers at the tension side. Therefore, (UHMWPE-EG) will result higher flexural strength than EG-UHMWPE.

Conversely, (Vallittu, 1998) found that when E-glass fiber was positioned at the compression side of the FPD resulted in higher fracture strength than the aramid fibers at the compression side or the polyethylene fibers positioned in the ideal region at the side of the highest tensile stress in the FPD. This suggests that the use of glass fibers, which bond adequately to the polymers, might be more suitable than the use of polyethylene ribbon and aramid fibers as reinforcement of polymers in temporary restorations. Thus, (Vallittu et al., 2002) has stated that the position of the fibers greatly influenced the mechanical properties. Therefore, to improve the reinforcing effect by fibers, the fibers should be placed at tension side of the specimen during the loading process.

For our samples, the highest flexural strength of the composites reinforced with (braided and unidirectional) fibers was obtained for the (PE-EG) samples by 240.47 MPa ($p < 0.05$). For instance, the flexural strength of the PE-PE samples was lower than the EG-EG samples by 154.69 MPa ($p > 0.05$), and also, EG-EG samples was lower than the EP-EG samples by 175.125 MPa ($p > 0.05$).

The exception is when EG-PE fibers showed a slightly higher value than PE-PE, but not significantly different ($p > 0.05$). The highest reinforcement for unidirectional E-glass fiber composites was obtained for EG-EG fiber samples; for (braided) Polyethylene fiber composites, the highest value was for PE-PE fibers samples. The reinforcement for EG-EG and EG-PE was very similar, except between PE-PE and PE-EG in favor of PE-EG, and between EG-EG and PE-PE in favor of PE-EG.

In our case, PE-EG had higher strength than EG-PE. The combination of unidirectional E-glass fiber and braided polyethylene fiber (as in the EG-PE composites) led to mechanical properties lower than in the PE-EG composites but higher than PE-PE. This implies that the increase in fiber reinforcement in the EG-EG and EG-PE samples were not sufficient for increasing the flexural strength above the value obtained for the PE-EG samples. One possible explanation for this behavior could be a poor impregnation of braided polyethylene fiber bands with the polymer matrix (Vallittu, et al 2003 and Freilich, 2000). A poorer monomer impregnation in the structure of braided polyethylene fiber than in the unidirectional E-glass fibers could be one of the reasons for lower mechanical properties in the case of braided FRC. Braided polyethylene fiber is flexible during impregnation with monomers and for a good impregnation, we press and relax the fiber with composite. This means that sometimes samples could have air bubbles included inside

In our study, the damages of the combinations of fibers are seen on the tested of FRC, may be classified into three categories: matrix cracks, delamination and fiber breakage from polymer matrix. These defects can significantly reduce the stiffness of composite materials, and also mentioned in other studies (Kono, et al 2009, Kanie., et al 2000 and Lee and Zahuts, 1991) A good adhesion of the fibers to the polymer matrix offers a possibility to transfer stress from the polymer matrix to the fibers. The same behavior of lower monomer impregnation of the fibers that caused a reduction in transverse strength of the denture-base polymer with glass fibers and a lack of the adsorbed monomer liquid in the fiber bundle before polymerization was observed by (Vallittu., et al 1995) An inappropriate degree of polymer impregnation of the fibers and the presence of air bubbles in fiber-reinforced composites will allow staining of the restoration by water, oral microbes, and food (Vallittu., et al 1999). The authors suggest future studies researchers to use this study as a reference to study deeply about the effect of combination of E-glass and Polyethylene (FRCs) on flexural strength.

CONCLUSION

Based on the results of research that has been done, it can be concluded that:

1. The combination of PE-EG fibers had a higher flexural strength in comparison to all other combinations tested.
2. A combination of braided polyethylene fiber with unidirectional E-glass fiber could be alternative and an advantage for improving mechanical properties of FRC used for dental applications.
3. The combinations of the same type of fiber (PE-PE and EG-EG fibers) did not demonstrate the same results with the combination of different types of fiber (PE-EG and EG-PE) on flexural strength.
4. The mechanical properties of the combination of the same types of fiber were similar both in one or two layers.

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