Al-Rafidain Dental Journal

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Evaluation the Effect of Fiber Reinforcement Materials on Flexural Strength of Heat Cured Denture Based Resin Materials.

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Article information

Received: 26 February 2023
Accepted: 7 March 2023
Available online:5 September 2024

Keywords
Fiber reinforcement materials,
Flexural strength,
Heat-cured PMMA denture base resin.

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Abstract

Aims: To assess the effect of fiber reinforcement materials on the flexural strength of heat-cured denture-based resin. **Materials and Methods:** A sample of heat-cured acrylic resin was created and divided into a control group (heat-cured with no fiber addition) and two experimental groups (with fiber additive). The flexural strength was evaluated, and calculated, and the information was statistically analyzed using descriptive statistics, an analysis of variance (ANOVA), and Duncan multiple range tests with $p \leq 0.01$ in SPSS Version 19. **Results:** The result showed a highly significant increase in flexural strength, untreated polypropylene fibers showed the highest flexural strength followed by untreated glass fibers. **Conclusion**: Reinforcement with fibers was an efficient approach for the improvement of flexural strength of heat-cured PMMA denture base resin.

تقييم تأثير تقوية الألياف على قوة الانحناء لمواد الراتنج المعتمدة على أطقم الأسنان المعالجة بالحرارة

الملخص

الأهداف: لتقييم تأثير مواد تقوية الألياف على قوة الانحناء للراتنج المعتمد على طقم الأسنان المعالج بالحرارة.
المواد وطرائق العمل: تم إنشاء عينات من راتنج الأكريليك المعالج بالحرارة وقسمت إلى: مجموعة تحكم (تمت معالجتها بالحرارة بدون إضافة ألياف) ومجموعتين تجريبيتين (مع ألياف مضافة). تم تقييم قوة الانحناء وحسابها وتحليلها إحصائيًا باستخدام الإحصاء الوصفي وتحليل التباين (ANOVA) واختبارات Duncan متعددة النطاق مع p ≤ 0.01 في SPSS الإصدار 19. **النتائج**: أظهرت النتائج زيادة معنوية في مقاومة الانحناء، وأظهرت ألياف البولي بروبلين غير المعالجة أعلى مقاومة للثني تليها الألياف الزجاجية غير المعالجة. **الاستنتاجات:** كان التعزيز بالألياف أسلوبًا فعالاً لتحسين قوة الانحناء لراتنج قاعدة طقم أسنان PMMA المعالج بالحرارة.

DOI: 10.33899/rdenj.2023.138002.1194,

INTRODUCTION

The most frequently used material to make removable prostheses is polymethyl methacrylate (PMMA) denture base resin. This material is not perfect in every way, and its use and popularity are due to a combination of virtues rather than a single desirable quality. Despite meeting aesthetic requirements, it falls short in terms of meeting the mechanical needs of prostheses.; PMMA's lack of strength, especially under fatigue failure from biting force inside the mouth and impact failure from dropping the dentures outside the mouth, is the main issue with this material used to make dentures [(1)].

Many attempts have been made to improve the PMMA denture foundation, including inserting metal wire; nonetheless, the main issue with employing metal wire is that it adheres poorly to the acrylic resin matrix [(2)]. The alternative strategy involves adding fibers like glass, carbon, aramide, nylon, and polyethylene to the PMMA denture base resin to strengthen it [(3)]. Fiber-reinforced polymer composites (FRPCs) have generated a lot of attention in a variety of technical fields due to their elevated specific strength, elevated modulus, improved wear resistance, and low density [(4)].

MATERIALS AND METHODS

The materials utilized in this study were heat-cured acrylic resin (SR Triplex® Hot, Ivoclar Vivadent), glass fiber, polypropylene fiber. Thirty samples were prepared from heat-cured acrylic resin to evaluate the transverse strength. The samples were divided into three groups (10 samples) for each group: Group I: the control group (heat-cured alone without additives) and two experimental groups (with additive); (group II, heat cured 2.5% glass fiber group, and group III, heat cured 2.5% polypropylene fiber group).

Specimens Grouping of Study

1. Group (I): Control group (acrylic resin samples devoid of fibers).
2. Group (II): Reinforced group with glass fiber (specimens of acrylic resin with glass fibers).
3. Group (III): Reinforced group with polypropylene fiber (specimens of acrylic resin with polypropylene fibers).

A: Method of Glass and Polypropylene fibers Addition:

The addition of glass and polypropylene fibers was carried out by adding the fiber at a percentage of (2.5% by weight) to the powder and mixing it at random for five minutes with a mortar and pestle until a uniform mixture was achieved. [(5)] 2.5% of the glass and polypropylene fibers (7 mm in length) in groups B and C that were reinforced with fibers that had been impregnated with monomer were placed in a Petri plate and soaked in monomer for ten minutes to improve the bonding of the fibers with PMMA resin [(6)]. The excess liquid was left to dry after the fibers and monomer were separated, and then the fibers and polymer powder were fully combined.

In accordance with the manufacturer's recommendations (SR Triplex® Hot, Ivoclar Vivadent), the monomer was incorporated into the polymer that included the randomly arranged fibers in a 2:1 by-weight ratio. It was mixed to make sure that every fiber in the dough mixture had been thoroughly saturated with monomer and distributed uniformly.

B- Curing cycles: Using a thermostatically controlled water bath, a short curing cycle was performed, which involved heating it to 100°C for 90 minutes and letting it boil for 45 minutes. The flask was taken out of the water bath after the curing cycle and placed on a bench to cool.

C- Flexural Strength Measurement Test

With dimensions of (64 × 10× 3.3 ±0.2 mm), thirty specimens, ten samples for every category, were created according to ADA specification No.12 (2002) [7]. All samples were kept in deionized distilled water at 37 °C for (48) hours prior to testing for residual monomer elimination [8].

As shown in figure (1), the test was performed using a three-point bending test (universal testing machine) (GESTER Total Test Solution Machine, China) in the College of Dentistry/ University of Mosul.

The test was conducted at a crosshead speed of 5mm/min, and the apparatus had two supports spaced 50mm apart and a central loading press. The test sample was positioned at the ends of the two struts with the loading head applied in the middle of the struts, and it deflected until it broke as shown in figure (1). Using the formula, the flexural strength was determined.

$S = 3PI/ 2bd2$

S =transverse strength (N/mm2), P= greatest force applied to the specimen (N), I=distance between supports (mm), b= he specimen's width (mm)

d= the specimen's depth.

Figure (1) A- Transverse Gester machine, B- Transverse Testing Specimen on GESTER Machine

RESULTS

Transverse (Flexural) Strength of Untreated Glass and Polypropylene Fibers

The statistical study was performed using the spss program version and included descriptive statistics, the test of normality, and inference statistics (ANOVA and Duncan's test). Because the Shapero test findings for the test of normality were not significant with a normal distribution at (P0.05), we can employ parametric testing instead.

The statistical analysis (mean and standard deviation) is displayed in Table (1). For the transverse (flexural) strength of untreated glass and polypropylene fibers, with the control group having the lowest value and untreated polypropylene fibers having the greatest value, with untreated glass fiber falling in between them.

Analysis of variance (ANOVA) revealed that untreated glass and polypropylene fibers differed significantly from the control group at a level of significance P value 0.01 as shown in the Table (2).

According to Duncan's multiple range test (Figure 2), the addition of untreated glass fibers had no statistically significant effect on the control group, but the addition of untreated polypropylene reinforced fibers resulted in a highly significant increase in the transverse strength of the resin relative to the control group, with a significance level of P 0.01.

Table (1) Descriptive Data of Transverse (Flexural) Strength of Untreated Reinforced Resin Groups.

Group	N.	Mean	SD.
Control	10	74.6100	2.74892
Untreated Glass fibers	10	76.5600	1.47513
Untreated Polypropylene fibers	10	82.9800	2.68403

Table (2): ANOVA for Transverse (Flexural) Strength of Untreated Fibers Reinforced Resin.

Untreated Fibers Group	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	383.586	2	191.793	33.973	0.000*
Within Groups	152.429	27	5.646		
Total	536.015	29			

SD= standard deviation, N= number of samples.

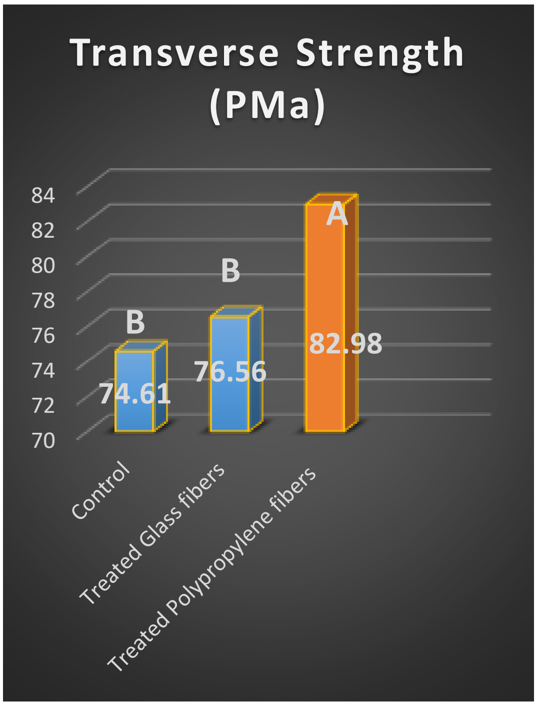

Figure (2): Duncan's Multiple Range Test for Transverse Strength of Untreated Fibers Reinforced Resin

DISCUSSION

A: Transverse (flexural) Strength of Glass Fibers Reinforced group:

The present result demonstrated that the untreated glass-reinforced fibers group showed an increase in the flexural (transverse) strength mean value compared with the control groups, but this slight increase was not statistically significant. This agreed with Chen et al. [9] who did not notice a notable difference in flexural strength when polyester, glass, and aramid fibers were used and were used in varying lengths or concentrations. Despite the fact that there was no evidence of a statistically significant difference between the flexural strength values of glass-reinforced specimens and those of other specimens; E-glass fibers had a high alumina content and a low alkali and borosilicate concentration (55 percent SiO2, 22 percent CaO, 15 percent Al2O3, 6 percent B2O3, 0.5 percent MgO, and 1.0% Fe + Na + K) (manufacturer's information), may have contributed to the increase in the flexural (transverse) strength after adding untreated glass fibers [10]. In addition, the majority of stresses were absorbed by the glass fibers without deforming because of their extremely high elasticity modulus [11]. This outcome was consistent with research by AL-Omari [12], who demonstrated how random glass fiber reinforcement boosted the flexural strength of the PMMA denture base material.

There may be further reasons for the improvement in the transverse strength of dental polymers following reinforcement with untreated glass fiber, such as proper impregnation of the fibers with the PMMA denture base material's monomer [13]. This was supported by Jaikumar et al. [14], who demonstrated that glass fiber-reinforced polymethyl methacrylate (PMMA) had the highest flexural strength value.

The present study agreed with a study by Asghar and Kaleem [15] discovered that adding woven E-glass fibers to heat-cured PMMA denture base materials significantly improve the material's flexural strength. While disagree with Hachim et al. [16] who noticed that reinforcement with polyester fibers showed that flexural strength decreased as compared to the control group, and this decline in flexural strength may be explained by the fibers' random orientation.; Another point of contention was addressed by Hamad [17], who discovered that adding glass fibers and (nano) Al_2O_3 particles to PMMA composite materials for prosthetic denture base materials reduced their flexural strength. This decrease might be caused by the fact that PMMA matrix and random woven glass fiber have higher flexural strengths than (nano-Al_2O_3) particles.

B: Transverse (flexural) Strength of Polypropylene Fibers Reinforced group:

According to the results, untreated polypropylene fibers significantly enhance the mean transverse strength value when compared to the control group. This increase was caused by the resin's inclusion of fibers, which ensured that loads were transferred from the matrix to the fiber and also prevented cracks, increasing the resin's strength and enabling it to withstand the applied load more than when the specimens had no fiber in their structure. In composites made of polymer and fiber, the fibers are bound by the polymer matrix, which creates a continuous phase around the fibers [(18)]. This outcome was consistent with Khalaf's findings [(6)], who discovered that the transverse (flexural) strength of heat-cured acrylic reinforced by randomly oriented polypropylene fibers (12mm, 2%) was much higher than the control group.

Another agreement was with Aarthy's [(19)] study findings, which showed that adding glass fiber, polypropylene fiber, and carbon fiber to acrylic resin samples improved their flexural strength.

The results of the current study contradict with those of Kumar et al. [(20)], who investigated the transverse strength of conventional denture base resin and denture base resin reinforced with 1wt% and 2wt% polypropylene fibers and discovered that specimens containing 2wt% polypropylene fibers had the lowest values, while incorporation of 1wt% polypropylene fibers had no discernible effect on the transverse strength.

Another point of contention was with Deepan *et al*. [(21)] 's study, which revealed that polypropylene fiber reinforcing had a negligible effect on the mean transverse strength of Trevalon denture base resin. In comparison to the controls utilized in the study, the modulus of elasticity of Trevalon Hi has dramatically risen after fiber reinforcing.

CONCLUSION

When flexural strength values were compared between conventional denture base resin that had been reinforced with glass and polypropylene fibers and unreinforced denture base resin, the results were statistically significant (control group). Glass fibers bonded with traditional heat-cure denture base resin after being prepared with monomer liquid increased the flexural strength. Also, polypropylene fibers pretreated with monomer liquid reinforced with traditional heat cure resin also displayed improved flexural strength values. The flexural strength of conventional heat-cured resins used for denture bases can be increased by using glass and polypropylene fiber reinforcement.

Conflict of Interest

The authors declare that there are no conflicts of interest regarding the publication and/or funding of this manuscript.

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