Al-Rafidain Dental Journal

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Effect of Treated Fiber Reinforcement on the Flexural Strength of Heat-Cured Denture Base Resin Materials

Reem M. Arif * [1], Nagham H. Kassab [2], Ragheed kassab[3]

[1] Ministry of Health/ Nineveh Health Directorate / Iraq
[2] Department of Prosthodontics, College of Dentistry, Mosul University / Iraq
[3] Toowoomba Hospital Queensland Health, Queensland, Australia

Article information

Received: 25 January 2023
Accepted: 7 March 2023
Available online:10September 2024

Keywords
Treated fiber reinforcement
Flexural strength
Heat-cured PMMA denture base resin.

***Correspondence:**
E-mail: reem40344@gmail.com

Abstract

Aims: This study was carried out to evaluate the flexural strength of heat-polymerized acrylic denture base material that is readily accessible commercially after strengthening with two kinds of saline treatment fibers. **Material and Methods**: Samples were created using traditional acrylic resin, the same resin that was reinforced with glass and polypropylene fibers, and conventional acrylic resin alone . A 3-point bending test was used to gauge the flexibility of the material, and the findings were then examined using a one-way analysis of variance **Results**: The flexural strength of all strengthened samples was greater compared to that of standard acrylic resin; those reinforced with polypropylene fibers had the highest flexural strength, followed by those reinforced with glass fibers. **Conclusion:** Heat-polymerized PMMA denture resin's flexural strength was increased following reinforcing with treated glass or polypropylene fibers, within the confines of the fibers used in this study. These findings might be used as the bases of distal extension partial dentures and temporary fixed partial dentures.

تأثير تقوية الألياف المعالجة على الانحناء لمادة الراتنج الأســـاســـية لأطقم الأسنان المعالجة بالحرارة

الملخص

الأهداف: تم إجراء هذه الدراسة لتقييم مقاومة الانحناء لمادة قاعدة الاسنان الأكريليك المبلمر بالحرارة والتي يمكن الوصول إليها بسهولة تجاريًا بعد تقويتها بنوعين من ألياف معالجة بمادة السيلان. **المواد وطرائق العمل**: العينات التي تم إنشاؤها باستخدام راتينج الأكريليك التقليدي ، والراتنج نفسه الذي تم تقويته بالالياف الزجاجية وألياف البولي بروبلين ، وراتنج الأكريليك التقليدي وحده. تم استخدام اختبار الانحناء من 3 نقاط لقياس مرونة المادة ، ثم تم فحص النتائج باستخدام واحدة طريقة تحليل التباين. **النتائج**: كانت قوة الانحناء لجميع العينات المقواة أكبر مقارنةً براتنج الأكريليك القياسي؛ كانت تلك المقواة بألياف البولي بروبلين تتمتع بأعلى مقاومة للثني، تليها تلك المقواة بألياف زجاجية.**الاستنتاجات:** تمت زيادة قوة الانحناء لراتنج PMMA المبلمر بالحرارة بعد التعزيز بالالياف الزجاجية أو ألياف البولي بروبيلين المعالجة ، ضمن حدود الألياف المستخدمة في هذه الدراسة. يمكن استخدام هذه النتائج في قواعد التمديد الجزئي لأطقم الأسنان الجزئية البعيدة وأطقم الأسنان الجزئية الثابتة المؤقتة.

DOI: 10.33899/rdenj.2023.137992.1193,

INTRODUCTION

Polymethyl methacrylate (PMMA), another name for acrylic resin, is one of the most often used polymeric materials for denture bases because it has superior mechanical and physical characteristics to others polymers [(1)]. There is a need to strengthen the denture base material to improve its mechanical properties even though its properties are not perfect in every manner. This is because they can be easily damaged if dropped or if the patient uses a lot of mastication force on the denture base [(2)]. One of these reinforcement methods the reinforcement of PMMA denture base resin with various types of fibers which include glass fiber, aramid fiber, carbon fibers, nylon fibers and polyethylene fiber.

The glass fiber is an inorganic substance, considered the predominant reinforcement for polymer matrix due to their high mechanical properties, low susceptibility to moisture absorption, thermal stability and high melting point [(3)]. Polypropylene which are the most common members of olefin family, these fibers are very light weight, have high strength and modulus, resistant to deterioration by chemicals, abrasion resistant, resistant to moisture absorption, resilient, and not brittle [(4)]. However, these fibers break-up the homogeneous matrix of acrylic resin due to poor interface between fiber and resin affecting the mechanical properties. In order to avoid this problem, silane surface treatment of fibers have been used [(5)], which is chemical substance enhance the bonding among polymer matrix and fiber surface, the silane coupling agent serves as a molecular link (interfacial connection), because the passage of applied load from the matrix to the fibers requires this interfacial connection since improper bonding could materially alter the mechanical parameters [(6)].

MATERIALS AND METHODS

Using stain-free steel dies with appropriate dimensions, thirty dental stone molds were created. The three various test groups contained traditional acrylic resin and the same resin reinforced with glass and polypropylene fibers that had been treated with saline. For each of the experimental groups, ten specimens were created in a consistent manner. Flexural strength was tested with a 3-point universal testing machine. With premade stainless steel metal dies, 30 dental stone molds were created in dental flasks (each 65 × 10 × 3 min) [(7)]. Before each die was used to make dental stone, A thin coating of petroleum jelly was put on it. The flask was opened and the die was carefully taken out of the investing material once the dental stone had finished setting [(8)]. For simple removal from the stone mold, the master die had a threaded hole in the center. The constructed molds were then submerged in hot water to eliminate any remaining contaminants and make applying the separating medium easier. The prepared acrylic resin test specimens were made in the mold cavities that were obtained.

Conventional heat-polymerized acrylic resin was used to create the test specimens for the control group (SR Triplex® Hot, Ivoclar Vivadent). And allowed to reach the dough stage before being kneaded and placed in the mold. A hydropress set at 40,000 N was used to close the trial (KaVo EWL, Leutkirch, Germany). In order to ensure proper polymerization of the monomer, even material flow, and the outflow of excess material, Low pressure was maintained in the flask for 30 minutes with the clamp in place.

The flask was kept at room temperature and submerged with water in a dental acrylizer/polymerzition (controlled temperature of polymerzition) The temperature was raised 100°C for 90 minutes and maintained for 45 minutes of boiling. The flask was allowed to reach room temperature while cooling in the water bath. the polymerization cycle was finished before being deflasked. The specimens made of acrylic were then retrieved, finished, and polished [9].

The other 2 experimental groups used PMMA specimens of the same size reinforced with salinated glass (chopped, France) and polypropylene fibers (multifilament fibers, USA) (2.5% by weight) with mixing ratio showed in Table (1) these fibers had a thickness of 10 to 15 m and were cut to 5 mm length. The cut fibers were immersed for 60 minutes in a solution of 0.3 g of silane coupling agent and 100 ml of a water and alcohol solution (50 ml from each). Then these fibers were then dried at 110–120 °C for 10 minutes [10]. The fibers were evenly distributed and mixed thoroughly for combining the resin and fibers. When the mixture had reached dough stage, it was rolled out and placed inside the ready mold. The samples were polymerized and recovered in the same way as the control group. Prior to testing, all samples were kept in water at room temperature for a week for residual monomer elimination [11]. Before testing, specimens were labeled on both ends so that broken parts could be put back together and studied; With a universal testing device (GESTER Total Test Solution Machine, China) and a crosshead speed of 2 mm/min, all samples were examined for flexural strength using a 3-point bending test. A rod in the middle of the structure applied a load until a fracture developed. The formula used to determine the flexural strength (MPa) is as follows.

Where FS (MPa) stands for flexural strength, $S = 3PI/ 2bd2$

p for peak load,

l for span length,

b for sample width, and d for sample's thickness. In order to examine the results, a one-way analysis of variance was used (ANOVA).

Table (1) Ratio for mixing fibers with PMMA powder.

Groups	Percentage of IF	Amount of IF (gm)	Amount of MMA Acrylic liquid (ml)	Amount of PMMA Acrylic powder (gm)
Fibers Free	**0**	**0**	**10ml**	**23.4g**
Fibers Containing	**2.5%**	**0.6**	**10ml**	**22.8g**

IF: Incorporated Fibers.

RESULTS

The descriptive statistical results (means and standard deviation) of the transverse strength of the test groups are shown in Table (2). These results indicated an increase in the transverse strength in all experimental groups, with the silane-treated polypropylene fibers group showing the highest transverse strength and the control group showing the lowest transverse strength.

Using one-way analysis of variance (ANOVA) for comparing the transverse strength of reinforced (glass and polypropylene) fibers in the control and saline-treated groups. The results are shown in Table (3), where the difference between the saline-treated glass and polypropylene groups and the control untreated group is highly significant at the level of significance ($P < 0.01$).

The silane-treated polypropylene fibers group had the highest significant difference from the control group at level of significance P 0.01 in accordance with Duncan's multiple range test in (Figure 1) which demonstrated that silane-treated reinforced fibers significantly increased the transverse strength of the resin from the control group.

Table (2): Descriptive Data of Transverse Strength for Saline Treated Reinforced Resin Groups.

Groups	N.	Mean	SD.
Control	10	74.6100	2.74892
Treated Glass fibers	10	96.0500	3.70982
Treated Polypropylene fibers	10	102.2900	4.14902

Table (3): ANOVA for Transverse Strength of Saline Treated Fibers Reinforced Resin Groups.

Saline Treated Groups	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	4215.979	2	2107.989	164.115	0.000*
Within Groups	346.803	27	12.845		
Total	4562.782	29			

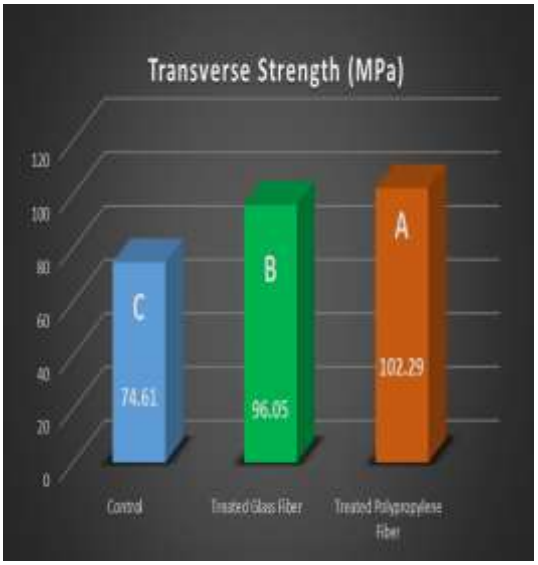

Figure (1): Transverse Strength Duncan's Multiple Range Test of Silane Treated Fibers Reinforced Resin Groups.

DISCUSSION

Transverse (Flexural) Strength of Saline Treated Glass and Poly-propylene Fibers:

Incorporating a foreign material into the prosthesis as part of the denture base material reinforcement has been found to increase the risk of prosthesis crack development rather than reduce it. This is because the foreign material may interfere with the polymer matrix's integrity, creating stress concentration points from insufficient concentration

and/or incompatibility with or weak interfacial adhesion between the reinforcing component and the prosthesis [12 & 13]; because of this, attention should be given while choosing the right type and concentration of reinforcement elements that have been employed to enhance the mechanical properties of PMMA denture base resin without adversely affecting its other attributes [14].

A: Transverse (Flexural) Strength of Saline Treated Glass Fibers:

The current study's findings demonstrated a significantly higher mean value for (transverse) flexural strength after adding silanated glass fibers to PMMA with respect to the control group (PMMA). The reason for the increase in transverse strength mean value might be related to a strong bond between glass fiber (GF) and resin matrix as a result of silanization [12]. Also, this improvement in adhesive qualities of the fiber surface with powder and matrix that caused by the saline coupling agent treatment may be the cause of this increase in the flexural properties. This outcome was in line with the findings of Hamouda and Beyari [10], who discovered that adding silanized glass fibers to acrylic resin enhanced its flexural strength.

Another factor that may have contributed to the significantly considerable rise in the mean values of the transverse strength of the glass fibers treated with saline relative to the PMMA-based control group is the appropriate impregnation of the fibers with resin polymer [15]. This finding concurred with that of Kannaiyan et al. [16], They found that glass fibers generated with a silane coupling agent and monomer liquid and reinforced with conventional heat cure denture base resin improved flexural strength compared to unreinforced high-impact denture base resin (control group). This result was consistent with earlier studies by Jaikumar *et al.* [17], Gad *et al.* [18], and Abushowmi *et al.* [19], which showed that silanized (E)-glass fibers could significantly improve the flexural strength of dental polymers. This could be because the fibers were properly impregnated with resin polymer.

Our findings conflicted with those of John and Naidu [20], who investigated the impact of fiber treatment on the flexural characteristics of hybrid composites made of sisal and glass fiber. He noted that the silane coupling agent had no appreciable impact on flexural characteristics, in fact, silane-treated sisal and glass fibers had lower flexural characteristics than untreated sisal and glass fibers.

The current investigation also refuted the findings of Ünver and Yildirim [21], who demonstrated that polyamide specimens and silane-treated glass fiber reinforced polyamide specimens (Flexural strength was

unaffected by the addition of glass fiber to the polyamide resin reinforcement). This could be attributable to the material's nonhomogeneous distribution of glass fibers.

B: Transverse (Flexural) Strength of Saline Treated Polypropylene Fibers:

The results of this study showed that adding salinated polypropylene fibers to PMMA significantly increased the transverse (flexural) strength. This improvement in the transverse strength may be due to the rough-surfaced reinforced fibers produced by the silanization process, which improves the bond between the acrylic resin matrix and the fibers Moreno-Maldonado *et al.* [22]. This was in line with Khalaf's [23] (2016) study that heat-cured PMMA strengthened transversely when silanized fibers made of siwak and polypropylene were added.

Another explanation of the increase in flexural strength after the addition of salinated polypropylene fibers to PMMA could be relevant to the increased surface energy of polypropylene fibers by chemical treatment (salinization) so, increasing the adhesion between fibers and acrylic resin matrix Mahmood *et al.* [24].

Results from the present study concurred with those from Abdul-Hadi [25], who discovered that adding plasma-treated polypropylene fibers and modified nano-Zro2 fillers increased transverse strength mean values when compared to the PMMA control group. The results of Mohammed [26]: also showed an increase in transverse strength after adding plasma-treated pp fiber, though it was not statistically significant.

Additionally, our findings were consistent with Mathew *et al.* [27] work, which discovered a notable improvement in the flexural strength of polypropylene treated with hydrogen plasma. However, the findings of Ismaeel and Alalwan [28], who found that the addition of silanated polypropylene fibers resulted in a significant decline in transverse strength mean value when compared to the control group, were not agreed upon.

The findings of Ahmed and Ismail [29] and Vallittu *et al.* [30], who observed statistically significant reductions in the transversal strength of PMMA reinforced with Nano SiO2 and polypropylene fibers, were also in conflict. This might be because of internal voids that were created in the fiber-resin composite, these voids served as oxygen reservoirs that allowed oxygen to prevent the radical polymerization of the acrylic resin inside the composite

CONCLUSION

Denture bases can be made more fracture-resistant by using fiber reinforcement, which is a practical and affordable technique. The results of the current investigation demonstrated that

the flexural strength of PMMA resin could be dramatically increased by surface-treating the fibers and reinforcing it with fibers made of glass and polypropylene that were 2.5% by weight. The denture bases can be strengthened clinically to reduce denture fracture by using saline-treated polypropylene fiber reinforcement, which demonstrates the maximum impact strength.

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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