Selcuk Dental Journal 12/1 (Nisan 2025): 14-19

Research / Araştırma Makalesi

Evaluation of the Effects of Hemp Fiber Addition on Fracture Strength, Acrylic Tooth Bonding, and Water Absorption of Polymethyl Methacrylate

Kenevir Lifi İlavesinin Polimetil Metakrilatın Kırılma Dayanımı, Akrilik Dişe Bağlantısı ve Su Emilimi Üzerindeki Etkilerinin Değerlendirilmesi

Fatma Dilara BAYSAN[α], **Süha KUŞÇU**[β], **Nesrin KORKMAZ**[ε], **Nilüfer ÇELEBİ**[β]

[α]Department of Pediatric Dentistry, Faculty of Dentistry, Yozgat Bozok University, Yozgat, Türkiye
[α]Yozgat Bozok Üniversitesi, Diş Hekimliği Fakültesi, Çocuk Diş Hekimliği AD, Yozgat, Türkiye
[β]Department of Prosthetic Dentistry, Faculty of Dentistry, Yozgat Bozok University, Yozgat, Türkiye
[β]Yozgat Bozok Üniversitesi, Diş Hekimliği Fakültesi, Protetik Diş Hekimliği AD, Yozgat, Türkiye
[ε]Department of Basic Sciences and Health, Hemp Research Institute, Yozgat Bozok University, Yozgat, Türkiye
[ε]Yozgat Bozok Üniversitesi, Kenevir Araştırma Enstitüsü, Temel Bilimler ve Sağlık Bölümü, Yozgat, Türkiye

ABSTRACT

Background: In this study, it was aimed to evaluate the effect of adding hemp fiber to polymethyl methacrylate (PMMA), the most commonly used heat-polymerized base material for dental prosthesis, on the fracture strength of the denture, its connection to the acrylic tooth and water absorption.

Methods: Three main working groups were formed in this study: PMMA (group-A) with the addition of raw hemp fiber, PMMA (group-B) with the addition of lignin and pectin removed hemp fiber, and PMMA without added fiber (group-C). Shear bond strength test was performed to evaluate how the addition of hemp fiber to PMMA affects the connection to the acrylic tooth. Three-point bending test was applied to measure the breaking strength of the base material. The effect of adding hemp fiber to PMMA on water absorption was evaluated.

Results: There was no statistically significant difference between the study groups in terms of shear bond strength test mean values (p=0.122). There was no statistically significant difference between the study groups in terms of three-point bending test mean values (p=0.140). In this study, it was determined that the addition of raw and chemically treated hemp fiber significantly reduced the water absorption of the acrylic base material (p<0.001).

Conclusions: It has been observed that the addition of hemp fiber in two different forms (raw and processed) to the PMMA reduces the water absorption of this material. It was determined that the addition of hemp fiber did not have a significant effect on the connection of the base to the acrylic tooth and its fracture strength.

Keywords: Denture prosthesis, Hemp, PMMA

ÖZ

Amaç: Bu çalışmada kenevir lifinin diş hekimliğinde protez yapımında en sık kullanılan ısıyla polimerize olan kaide materyali polimetil metakrilata (PMMA) ilave edilmesinin protezin kırılma dayanımı, akrilik dişe bağlantısı ve su emilimi üzerine etkisinin değerlendirilmesi amaçlanmıştır.

Gereç ve yöntem: Bu çalışmada; işlem görmemiş ham kenevir lif ilave edilen PMMA (grup-A), lignin ve pektin uzaklaştırılmış (kimyasal ön işlem görmüş) kenevir lifi ilave edilen PMMA (grup-B) ve lif ilave edilmeyen PMMA (grup-C) olmak üzere üç ana çalışma grubu oluşturulmuştur. PMMA'ya kenevir lif ilavesinin akrilik diş materyaline bağlantıyı nasıl etkilediğini değerlendirmek için makaslama testi yapılmıştır. Kaide materyalinin kırılma dayanımını ölçmek için 3 nokta bükme testi uygulanmıştır. PMMA'ya kenevir lif ilavesinin su emilimi üzerindeki etkisi değerlendirilmiştir.

Bulgular: Çalışma grupları arasında makaslama testi ortalama değerleri açısından istatistiksel olarak anlamlı bir fark bulunmamıştır (p=0,122). Çalışma grupları arasında 3 nokta bükme testi ortalama değerleri açısından istatistiksel olarak anlamlı bir fark bulunmamıştır (p=0,140). Bu çalışmada ham ve kimyasal işlem görmüş kenevir lifi ilavesinin akrilik kaide materyalinin su emilimini istatistiksel olarak anlamlı derecede azalttığı tespit edilmiştir (p<0,001).

Sonuçlar: Dental protez yapımında kaide materyali olarak kullanılan PMMA'ya kenevir lifinin iki farklı formda (saf ve işlem görmüş) ilavesinin kaide materyalinin su emilimini azalttığı görülmüştür. Kenevir lif ilavesinin kaidenin akrilik dişe bağlantısı ve kırılma dayanımı üzerine anlamlı etkisi bulunmadığı tespit edilmiştir.

Anahtar Kelimeler: Dental protez, Kenevir, PMMA

Introduction

Polymethyl methacrylate (PMMA) has been the most preferred prosthetic base material in dentistry. PMMA is a low-cost, biocompatible, and easy-to-use material. Additionally, PMMA exhibits acceptable stability and aesthetic properties in the oral environment.[1] However, the major disadvantage of the material is its susceptibility to fracture or deformation due to its low mechanical and physical properties.[2] The weakness in the flexural strength of acrylic denture base can lead to fractures in prostheses under occlusal loads. Similarly, the weakness in compressive strength of acrylic denture base can result in the fracture of acrylic upon impact or sudden forces.[3] Therefore, high flexural strength, compressive strength, hardness, and resilience are desired properties of acrylic denture base material. Changes in the mechanical properties have been investigated for years by incorporating reinforcing materials such as various nanoparticles and fibers into acrylic denture base.[4,5] The addition of carbon fibers,[6] polyamide fibers,[7] glass fibers,[8] stainless steel mesh[9] or ultra-high modulus polyethylene fibers[10] to PMMA has been attempted in these studies. The addition of these materials to PMMA has been reported to improve the strength and fatigue resistance of the denture base material, but there is limited evidence on the use of natural fibers.[11] Recently, there has been a growing trend towards the use of plant fibers due to their low cost, easy accessibility, and eco-friendliness.[12] Natural fibers are materials that have become viable alternatives to traditional synthetic or artificial fibers. Natural fibers attract attention with their attractive properties such as being lightweight, having high specific modulus, renewability, and biodegradability.

Hemp, one of the oldest plants in history, is a valuable plant that has economic value in many different fields and has advantages in almost all areas of use.[13] Hemp is becoming increasingly important in scientific, industrial, and economic aspects due to its renewable and sustainable nature and its multifunctional characteristics.[14] Hemp is utilized in many fields, including cosmetics and medicine, especially its fibers and seeds. Hemp fibers are natural fibers that provide excellent strength and durability.[15] Hemp fibers contain hemicellulose, lignin, and pectin in addition to cellulose. The chemical composition consists of approximately 74 % cellulose, 14 % hemicellulose, 5 % lignin, 1 % pectin, and 6 % wax.[16] Pectin is present in the primary wall and middle lamella as an insoluble form. Pectin is found as calcium, magnesium, and iron salts of pectic acid. Another component found in hemp fibers is "lignin."

Gönderilme Tarihi/Received: 14 Mayıs, 2024
Kabul Tarihi/Accepted: 8 Temmuz, 2024
Yayınlanma Tarihi/Published: 21 Nisan, 2025
Atıf Bilgisi/Cite this article as: Baysan FD, Kuşçu S, Korkmaz N, Çelebi N. Evaluation of the Effects of Hemp Fiber Addition on Fracture Strength, Acrylic Tooth Bonding, and Water Absorption of Polymethyl Methacrylate. Selcuk Dent J 2025;12(1): 14-19 Doi: 10.15311/ selcukdentj.1483484

Sorumlu yazar/Corresponding Author: Fatma Dilara BAYSAN
E-mail: fatma.dilara1993@hotmail.com
Doi: 10.15311/ selcukdentj.1483484

It is the second most abundant biopolymer after cellulose. Lignin, which contains aromatic and aliphatic groups, is a difficult molecule to break down. It is highly resistant to enzymes and chemicals. It is known that when hemp fibers are used in high proportions, they provide high strength and stiffness performance and possess antimicrobial properties. Additionally, due to its flexibility, it is resistant to breakage during processing.[16] Based on this information, it is considered to reinforce the heat-polymerized denture base material used in dentistry with hemp fibers. The aim of our study is to evaluate the effects of adding hemp fibers to the heat-polymerized denture base material on its mechanical properties, water absorption, and acrylic tooth bond.

Materials and Methods

Obtaining Hemp Fiber Material

In this study, the hemp fiber material required for the project was obtained from the specialized hemp cultivation fields of our university, which is a specialized university in the field of "Industrial Hemp." Field trials of Narlı Saray population were established under Yozgat conditions in May 2020. The physiological maturation of the plants was completed in August-September. The harvested plants were equalized in terms of moisture levels and the fibers were obtained from the dried stems in a suitable environment. The separation of fibers from the stems was carried out by mechanical separation method within the Faculty of Agriculture of Yozgat Bozok University. Through this process, the woody (core) parts in the stems were removed, and the fibers were extracted.

Preparation of Hemp Fibers

Two different experiments were planned to be conducted using the fibers to be used in the study. Firstly, the fibers obtained from harvested hemp were air-dried without any treatment, cleaned from the impurities, and ground into fine powder using a ball mill available at the Science and Technology Application and Research Center of Yozgat Bozok University. The powdered samples were characterized by SEM (Scanning Electron Microscopy) and EDX (Energy Dispersive X-ray) (**Figure 1,2**).

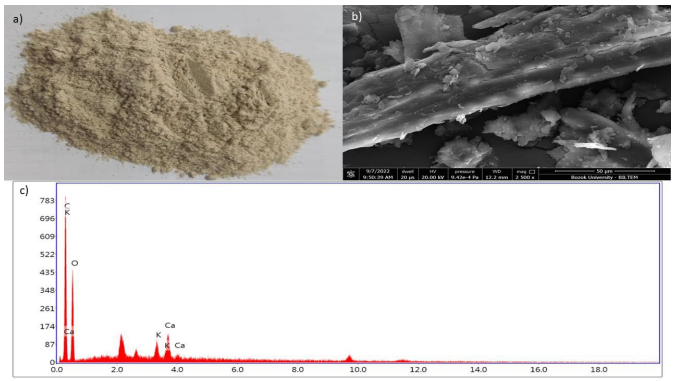

Figure 1. a) Image of Ground Raw Fiber, **b)** SEM Image of Unprocessed Raw Fiber, **c)** EDX Analysis of Unprocessed Raw Fiber

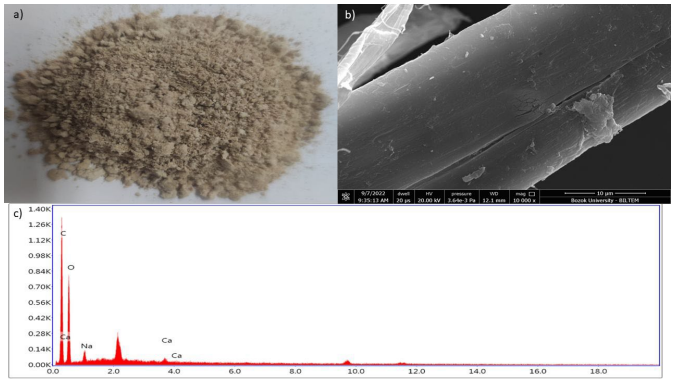

Figure 2. a) Image of Processed Fiber, **b)** SEM Image of Processed Fiber, **c)** EDX Analysis of Processed Fiber

Secondly, thinning of hemp fibers was performed through a chemical treatment to remove lignin and pectin content in the fibers, and a second experiment was conducted to compare the results of two samples (1. raw fiber, 2. chemically treated fiber). In the literature, various chemicals such as ethylene, oxalic acid, sulfuric acid, sodium hydroxide, acid and sodium carbonate, hydrogen peroxide, soda, sodium sulfite, etc. have been used for delignification and thinning processes in fiber plants.[17,18] Based on the information in the literature, the best thinning process was achieved with NaOH treatment.[17] Following the method used by Gunnarsson et al. in 2015, a 2 % NaOH solution was prepared, and then the fiber-solution mixture was autoclaved at 121°C for 4 hours.[19] At the end of the period, the mixture was left to cool to room temperature. The upper part of the mixture was decanted, and the settled fibers were dried and characterized by SEM and EDX.

Comparison of Two Samples

As seen in **Figure 3**, the physically visible difference between the processed and unprocessed fiber samples is the difference in color, with the processed sample having a darker color compared to the lighter color of the ground raw fiber. While this is the only physically visible data, microscope images and elemental analysis provide more detailed information.

The SEM images of unprocessed hemp biomass revealed the presence of a sedimentary layer on the surface area of the biomass (**Figure 3-d**). After the pre-treatment, the SEM images of the hemp biomass indicated that the surface area of the biomass was partially purified and became cleaner and smoother (**Figure 3-c**). Morphological changes indicating damage were observed in the structure of the biomass. It can be said that 2 % NaOH increased the surface area by breaking the connection between lignin and hemicellulose.

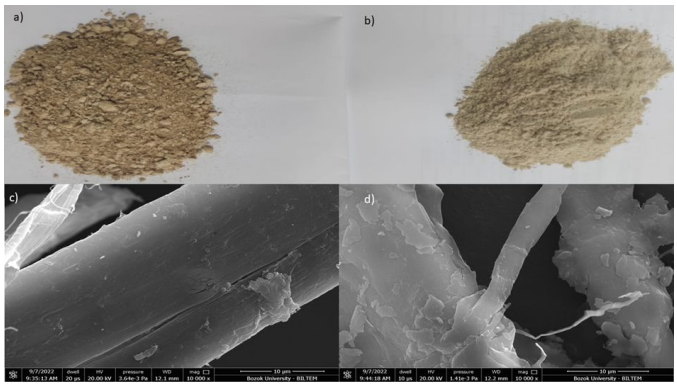

Figure 3. a-c) Images of Pre-processed Fiber, **b-d)** Images of Raw Fiber

To observe the effect on the oxygen and carbon content in the fibers, an EDX analysis was performed (**Table 1**). The oxygen-to-carbon ratio (O:C) explains the amount of lignin and hemicellulose in natural fibers. When the O:C ratio of any natural fiber is higher, the amount of lignin and hemicellulose in that fiber is lower. For alkaline-treated fibers, the O:C ratio increases.[20] When the elemental analysis of the unprocessed raw fiber and the processed fiber is examined (**Figure 1 and 2**), the O:C ratio of the unprocessed raw fiber is found to be 0.75, while the O:C ratio of the processed fiber is 0.84. This indicates that the O:C ratio of the alkaline-treated fibers increased.

Table 1. Elemental Trace Data in Raw Fiber and Chemically Processed Fiber Content

Raw fiber			Chemically Processed Fiber		
Element	**Weight %**	**Atomic%**	**Element**	**Weight %**	**Atomic%**
C	55.95	63.44	C	52.76	60.31
O	42.19	35.92	O	44.26	37.98
K	0.67	0.23	K	2.70	1.16
Ca	1.19	0.41	Ca	0.28	0.10

Preparation of Heat-Polymerizing Acrylic Resin Incorporating Hemp Fiber Powder

The following steps were carried out to prepare the heat-polymerizing acrylic resin samples for evaluating the effects of adding hemp fiber powder on the mechanical properties, adhesion to teeth, and water absorption of the acrylic resin:

Three main groups were formed in our study: heat-polymerizing acrylic resin incorporating untreated raw hemp fiber (Group A experimental group), heat-polymerizing acrylic resin incorporating lignin and pectin removed (chemically pre-treated) hemp fiber (Group B experimental group), and heat-polymerizing acrylic resin alone (Group C control group). After preparing these three main groups, a total of nine subgroups were created, with three subgroups for each group (**Table 2**).

Table 2. Study Groups

	Group A (experimental group)	Group B (experimental group)	Group C (control group)
Main groups	PMMA with raw hemp fiber additive (n=30)	PMMA with chemically treated hemp fiber additive (n=30)	PMMA (n=30)
Subgroups	Shear Bond Strength Test (n=10)	Shear Bond Strength Test (n=10)	Shear Bond Strength Test (n=10)
	Bending Test (n=10)	Bending Test (n=10)	Bending Test (n=10)
	Water Absorption Test (n=10)	Water Absorption Test (n=10)	Water Absorption Test (n=10)

To standardize the acrylic molds for measuring the mechanical strength difference and water absorption differences of the heat-polymerizing acrylic resin, a power analysis was performed, and the sample size required in each subgroup was determined to be 10 samples, with dimensions of 65 × 10 × 3.3 mm (ISO 20795-1:2013). A total of 60 resin samples were prepared using standardized metal molds. To measure the difference in adhesion strength between the heat-polymerizing acrylic resin materials in the study groups, 30 upper 1st molar acrylic artificial teeth (Vita, Vita Zahnfabrik, Bad Säckingen, Germany) were embedded with self-curing acrylic resin (Paladent, Heraeus Kulzer, Germany) so that the bonding surfaces of the artificial teeth were exposed. The bonding surfaces of the artificial teeth were smoothed with 1200 grit silicon carbide abrasive paper under water to obtain a flat surface and eliminate surface residues. The prepared samples were soaked in distilled water before polymerization. Cylindrical wax molds with a diameter of 4 mm and a height of 5 mm were prepared to be centered on the samples.

The prepared samples were embedded in hard plaster to facilitate wax elimination and placed inside a flask. The flask was closed with a flask cover and compressed under pressure using a press. The flask, along with the samples inside, was placed in a wax elimination device at a temperature of 100°C and left for 8 minutes. After removing the flask from the hot water, wax elimination was performed by immersing it in hot water. The isolation of the plaster edges of the flask was ensured, excluding the wax cavities.

The heat-polymerizing acrylic resin was prepared by mixing 25 g of acrylic powder with 10 ml of liquid, according to a powder-to-liquid ratio. The liquid was mixed with acrylic powder to obtain an acrylic dough following the recommended time by the manufacturer. The polymerization of the conventional acrylic resin was carried out according to ADA Standard No. 12. After placing the wax samples in the flask, they were immersed in boiling water. After 5 minutes, the flask was opened and washed with detergent water and clean boiling water. When the flasks became touchable with bare hands, the sample cavities were coated with varnish (Aislar, Heraeus Kulzer, Germany). The flasks were left at a temperature of 23±2°C for 1 hour.

Once the acrylic dough reached a non-sticky consistency on the sides of the mixing bowl, it was placed in the sample cavities, and the flasks were closed. After 10 minutes of pressing, the flasks to be polished were kept in a water bath at 73±1°C for 90 minutes. Then, they were boiled at 100°C for 30 minutes. After completion of the heating process, the flasks in the polishing device were left to cool for 30 minutes at room temperature (23±10°C). They were then immersed in 23±10°C water for 15 minutes. All acrylic test samples were removed from the flask and polished with a steel bur (15000 rpm), lightly sanding any surface irregularities.

The addition of hemp powder to the acrylic powder was achieved by using a homogeneous mixing device. The weight ratio of acrylic powder to hemp fiber was measured using a precision balance. The hemp fiber powder was added to the acrylic powder at a ratio of 1% of the weight of the acrylic powder.

Bending Test

A three-point bending test was conducted to determine the flexural strength. The transverse strength test was performed using a universal testing machine (Shimadzu AGS-X, Shimadzu Scientific Instruments, Columbia, North Carolina, USA). The distance between the metal supports, where the sample was placed, was set at 50 mm, and the crosshead speed was set to 1 mm/min. A perpendicular force was applied to the exact center of the sample. The fracture values were automatically recorded in Newton units by the computer system of the machine. The flexural strength values were calculated using the following formula:

S = (3FL) / (2bd^2)
S: Transverse strength (N/mm^2)
F: Load at fracture (N)
L: Distance between supports (mm)
b: Width of the sample (mm)
d: Thickness of the sample (mm)

Water Absorption Test

Acrylic samples were stored in distilled water at a temperature of 37±2°C for 1 day. After 1 day, the samples were completely dried with a clean towel, and their weights were recorded using a precise scale. The recorded acrylic samples were then stored in distilled water at a temperature of 37±2°C for 6 days. Afterward, they were dried with a clean towel, and their weights were recorded to determine water absorption over 1 week. To determine water absorption over 1 month, the samples were stored in distilled water at a temperature of 37±2°C for 23 days. At the end of the period, the samples were dried with a clean towel, and their final weights were recorded. The following formulas were used to calculate water absorption:

Water Absorption (1 day) = (M2 - M1) / S
Water Absorption (1 week) = (M3 - M1) / S
Water Absorption (1 month) = (M4 - M1) / S
M1: Initial weight of the samples kept in a desiccator (mg)
M2: Weight of the samples after 1 day in distilled water (mg)
M3: Weight of the samples after 1 week in distilled water (mg)
M4: Weight of the samples after 1 month in distilled water (mg)
S: Surface area of the samples (cm^2)

Shear Bond Strength Test

The difference in bond strength between the heat-polymerizing acrylic resin and the acrylic denture material was determined using a shear bond strength test. The obtained samples were subjected to shear strength testing using a universal testing machine (Shimadzu AGS-X, Shimadzu Scientific Instruments, Columbia, North Carolina, USA) at a crosshead speed of 1 mm/min. The obtained data were converted to MPa using the formula F/N (N: Newton, A: Surface Area).

Statistical Method

The data were analyzed using IBM SPSS V23. Normality of the data was assessed using the Shapiro-Wilk test. One-way analysis of variance (ANOVA) was used for comparing normally distributed data among groups. The Kruskal-Wallis test was used for comparing non-normally distributed data among groups, and multiple comparisons were performed using the Dunn test. The analysis results were presented as mean ± standard deviation or median (minimum-maximum). The significance level was set at $p < 0.05$.

Results

The difference in bond strengths between PMMA with the addition of chemically treated hemp fiber, PMMA without the addition of hemp fiber, and PMMA with the addition of untreated raw hemp fiber was measured using a shear bond strength test. The mean shear bond strength value for the study group of PMMA with chemically treated hemp fiber was 411.327, for the study group of PMMA without the

addition of hemp fiber was 347.035, and for the study group of PMMA with the addition of untreated raw hemp fiber was 266.787. **Table 3** shows that comparison of shear bond strength test values among the study groups. There was no statistically significant difference in shear bond strength values among the study groups (p = 0.122).

Table 3. Comparison of shear bond strength test values among study groups

	Study Groups			Test Statistics	p
	Group A PMMA with raw hemp fiber additive	Group B PMMA with chemically treated hemp fiber additive	Group C PMMA		
Shear bond strength test values	266.787 ± 182,227	411.327 ± 162,383	347.035 ± 117.199	2.266	0.122
	265.239	439.615	348.856		
	(15.52 – 542.31)	(122.57 – 656.34)	(190.88 – 529.25)		

One-way analysis of variance (ANOVA); Mean ± standard deviation; Median (minimum- maximum)

The flexural strength of heat-polymerized acrylic denture base material was measured using a three-point bending test. In the study group where chemically treated hemp fiber was added to PMMA, the mean value of the three-point bending test was 185.618. In the working group of PMMA without the addition of hemp fiber, the mean value of the three-point bending test was 238.058. And in the working group where untreated raw hemp fiber was added to PMMA, the mean value of the three-point bending test was 214.496. **Table 4** shows that comparison of three-point bending test values among study groups. There was no statistically significant difference in the mean values of the three-point bending test among the study groups (p=0.140)

The water absorption levels of PMMA with chemically treated hemp fiber added were found to have a median value of 0.017. In the study group of PMMA without the addition of hemp fiber, the median value of water absorption was 0.021. And in the study group where untreated raw hemp fiber was added to PMMA the median value of water absorption was 0.004. **Table 5** shows that comparison of water absorption levels among study groups. There was a statistically significant difference in the median values of water absorption among the study groups (p<0.001). The median value of water absorption in the group where untreated raw hemp fiber was added to PMMA differed from the values obtained in the other groups.

Table 4. Comparison of three-point bending test values among study groups

	Study Groups			Test Statistics	p
	Group A PMMA with raw hemp fiber additive	Group B PMMA with chemically treated hemp fiber additive	Group C PMMA		
Three-point bending test values	214,496 ± 44,101	185,618 ± 17,63	238,058 ± 68,011	2,165	0,14
	208,463	179,1	225,587		
	(158,93 - 270,82)	(155,94 - 205,13)	(178,32 - 383,83)		

One-Way Analysis of Variance; Mean ± standard deviation; Median (minimum - maximum)

Table 5. Comparison of water absorption test values among study groups

	Study Groups			Test Statistics	p
	Group A PMMA with raw hemp fiber additive	Group B PMMA with chemically treated hemp fiber additive	Group C PMMA		
Water Absorption Amount	0,004 ± 0,004	0,017 ± 0,003	0,022 ± 0,004	22,816	**<0,001**
	0,004	0,017	0,021		
	(0,001 -0,012)a	(0,013 -0,022)b	(0,017 - 0,03)b		

Kruskal-Wallis Test; Mean ± standard deviation; Median (minimum- maximum); a-b: There is no significant difference between groups with the same letter.

Discussion

PMMA (polymethyl methacrylate) is commonly used in dentistry for the fabrication of denture bases due to its low cost, biocompatibility, ease of application, stability in the oral environment, and acceptable aesthetic properties. However, its main drawback is its low mechanical and physical properties, which can lead to fractures or deformations in the prosthesis.[3] Although PMMA has superior features such as aesthetics, easy manipulation, biocompatibility, suitable working characteristics, and low cost, its weak fatigue resistance and tendency to fracture under excessive occlusal forces require the addition of various reinforcing materials to improve the mechanical properties of acrylic resin.[21] These materials include nanoparticles or fibers.[8,22] The most commonly added reinforcing fiber in the strengthening of acrylic resins is glass fiber. There are numerous studies in the literature investigating the effect of adding glass fiber to PMMA on its mechanical properties. These studies have reported that the addition of glass fiber to PMMA enhances its flexural and impact resistance as well as hardness.[5,8]

The literature suggests that natural fibers can also be used to reinforce PMMA, but further research is needed in this area. There are limited studies on the addition of natural fibers to PMMA.[23,24] One study reported that the addition of oil palm empty fruit bunch (OPEFB) fiber increased the flexural strength and elastic modulus of acrylic resin.[23] Another study compared traditional PMMA with a base material containing ramie fiber and found that the addition of ramie fiber increased the elastic modulus but reduced the strength due to weak interfacial bonding.[24] In another study, the addition of 7.5% weight of Hibiscus sabdariffa fibers to PMMA was found to improve its strength properties.[11]

Hemp fiber is known to provide high strength and stiffness performance when used in high proportions. It also has antimicrobial properties and is resistant to breakage during processing due to its flexibility. In a study where hemp fiber and walnut shell nanoparticles were added to PMMA, the effect of hemp fiber and walnut shell nanoparticles on the mechanical and physical properties of PMMA was investigated.[12] According to the results of this study, the composite material consisting of 0.9% hemp fiber and 0.3% walnut shell nanoparticles increased the elastic modulus and tensile strength. However, water absorption also increased in this composite material.[12] Based on this information, in our study, chemically treated hemp fiber (with separated lignin and pectin) and raw hemp fiber in powder form were added as reinforcing materials to the heat-polymerized denture base material commonly used in prosthodontics. A shear bond strength test was performed to evaluate the effect of hemp fiber addition on the bond between the denture base material and acrylic teeth. The results showed that in the group where chemically treated hemp fiber was added to the heat-polymerized acrylic (group B), the bond between the acrylic and the teeth was better compared to the other study groups, but there was no statistically significant difference among groups A, B, and C (p=0.122).

In the three-point bending test, which measured the fracture strength of the acrylic, it was observed that the addition of raw and chemically treated hemp fiber reduced the fracture strength of the acrylic. However, this difference among study groups was not statistically significant (p=0.140).

In our study, it was found that the addition of raw and chemically treated hemp fiber reduced the water absorption of the acrylic. The acrylic denture base material with the addition of raw hemp fiber showed less water absorption compared to the acrylic denture base material with the addition of chemically treated hemp fiber. The difference in water absorption rates among study groups was found to be statistically significant (p<0.001).

Within the limitations of our study, it was determined that the addition of raw and chemically treated hemp fiber significantly reduced the water absorption of the acrylic. In our study, raw and chemically treated hemp fibers were added to the acrylic at a rate of 1 % by weight of the acrylic. Further studies are needed to evaluate the effects of adding hemp fiber at different proportions on the fracture strength, bond strength to acrylic teeth, and water absorption of the acrylic.

Conclusion

In line with the limitations of this study;

- It was determined that the addition of raw and chemically treated hemp fiber significantly reduced the water absorption of PMMA.
- There was no significant effect of the addition of hemp fiber to PMMA on its connection with acrylic teeth.
- There was no significant effect of the addition of hemp fiber to PMMA on the fracture strength of acrylic.

Acknowledgements / Teşekkürler

I would like to thank Yozgat Bozok University Scientific Research Projects Coordination Unit for supporting funding for this project.

Bu projeye fon sağladığı için Yozgat Bozok Üniversitesi Bilimsel Araştırma Projeleri Koordinasyon Birimi'ne teşekkür etmek istiyorum.

Değerlendirme / Peer-Review

İki Dış Hakem / Çift Taraflı Körleme

Etik Beyan / Ethical statement

Bu çalışmanın hazırlanma sürecinde bilimsel ve etik ilkelere uyulduğu ve yararlanılan tüm çalışmaların kaynakçada belirtildiği beyan olunur.

It is declared that during the preparation process of this study, scientific and ethical principles were followed and all the studies benefited are stated in the bibliography.

Benzerlik Taraması / Similarity scan

Yapıldı – ithenticate

Etik Bildirim / Ethical statement

dishekimligidergisi@selcuk.edu.tr

Finansman / Grant Support

Bu çalışma Yozgat Bozok Üniversitesi Bilimsel Araştırma Projesi Koordinasyon Birimi tarafından (Proje kodu: THD-2022-983) desteklenmiştir.'

This work was supported by Yozgat Bozok University Scientific Research Project Coordination Unit (Project code: THD-2022-983).'

Çıkar Çatışması / Conflict of Interest

Yazarlar çıkar çatışması bildirmemiştir. | The authors have no conflict of interest to declare.

Yazar Katkıları / Author Contributions

Çalışmanın Tasarlanması | Design of Study: FDB (%30) SK (%30) NÇ (%20) NK (%20)
Veri Toplanması | Data Acquisition: FDB (%35) SK (%35) NK (%30)
Veri Analizi | Data Analysis: FDB (%50) SK (%50)
Makalenin Yazımı | Writing up: FDB (%40) SK (%30) NÇ (%15) NK (%15)
Makale Gönderimi ve Revizyonu | Submission and Revision: FDB (%60) SK (%20) NÇ (%20)

REFERENCES

1. Thomas TC, K AK, Mohamed S, Krishnan V, Mathew A, V M. The effect on the flexural strength, flexural modulus and compressive strength of fibre reinforced acrylic with that of plain unfilled acrylic resin - an in vitro study. Journal of clinical and diagnostic research : JCDR. 2015;9(3):Zc12-14.
2. Frazer RQ, Byron RT, Osborne PB, West KP. PMMA: an essential material in medicine and dentistry. Journal of long-term effects of medical implants. 2005;15(6).
3. Faot F, Costa MA, Cury AADB, Garcia RCR. Impact strength and fracture morphology of denture acrylic resins. The Journal of prosthetic dentistry. 2006;96(5):367-373.
4. Sukumaran K, Ravindran S. Comparative Evaluation of the Flexural Strength of Heat-Activated Polymethyl Methacrylate Denture Base Resin With and Without 0.2% by the Weight of Silver Nanoparticles Cured by Conventional and Autoclave Methods: An In Vitro Study. Cureus. 2024 Jun 19;16(6):e62675.
5. Tomar P, Chandra Gope P. Effect of glass fiber and nylon fiber reinforcement on the mechanical and thermal properties of styrene butadiene rubber mixed PMMA denture base material. Journal of the Mechanical Behavior of Biomedical Materials. 2024 Feb;150:106308.
6. Yerliyurt K, Taşdelen TB, Eğri Ö, Eğri S. Flexural Properties of Heat-Polymerized PMMA Denture Base Resins Reinforced with Fibers with Different Characteristics. Polymers (Basel). 2023 Jul 28;15(15):3211.
7. Soygun K, Bolayir G, Boztug A. Mechanical and thermal properties of polyamide versus reinforced PMMA denture base materials. The journal of advanced prosthodontics. 2013;5(2):153.
8. Farina AP, Cecchin D, Soares RG, et al. Evaluation of Vickers hardness of different types of acrylic denture base resins with and without glass fiber reinforcement. Gerodontology. 2012;29(2):e155-e160.
9. Vallittu PK. Comparison of the in vitro fatigue resistance of an acrylic resin removable partial denture reinforced with continuous glass fibers or metal wires. Journal of Prosthodontics. 1996;5(2):115-121.
10. Vijaysinh Mori H, Jadhav R, Sabane A, Patil A, Gachake A, Gurunath Kalsekar B. An In Vitro Study Comparing the Impact and Flexural Strength of Leucitone 199 Denture Base Resin and Conventional Denture Base Resin Enhanced With Glass Fibre Mesh and Polyethylene Fibre Mesh. Cureus. 2023 Sep 25;15(9):e45935.
11. Okeke KN, Vahed A, Singh S. Improving the strength properties of denture base acrylic resins using hibiscus sabdariffa natural fiber. Journal of International Dental and Medical Research. 2018;11(1):248-254.
12. Ahmed S, Salih W. Mechanical properties of acrylic laminations resin (PMMA) reinforced by natural nanoparticles and hemp fibers. Paper presented at: IOP Conference Series: Materials Science and Engineering2021.
13. Andre CM, Hausman J-F, Guerriero G. Cannabis sativa: the plant of the thousand and one molecules. Frontiers in plant science. 2016;7:19.
14. Lacasse H, Kolodinsky J. Consumer trends and the consumption of industrial hemp-based products. In: Industrial Hemp. Elsevier; 2022:367-381.
15. Faruk O, Bledzki AK, Fink H-P, Sain M. Biocomposites reinforced with natural fibers: 2000–2010. Progress in polymer science. 2012;37(11):1552-1596.
16. Shahzad A. Hemp fiber and its composites–a review. Journal of composite materials. 2012;46(8):973-986.
17. Zhao J, Xu Y, Wang W, Griffin J, Roozeboom K, Wang D. Bioconversion of industrial hemp biomass for bioethanol production: A review. Fuel. 2020;281:118725.
18. Ji A, Jia L, Kumar D, Yoo CG. Recent advancements in biological conversion of industrial hemp for biofuel and value-added products. Fermentation. 2021;7(1):6.
19. Gunnarsson IB, Kuglarz M, Karakashev D, Angelidaki I. Thermochemical pretreatments for enhancing succinic acid production from industrial hemp (Cannabis sativa L.). Bioresource Technology. 2015;182:58-66.
20. Rajkumar S, Tjong J, Nayak S, Sain M. Wetting behavior of soy-based resin and unsaturated polyester on surface-modified sisal fiber mat. Journal of Reinforced Plastics and Composites. 2015;34(10):807-818.
21. Chen SY, Liang WM, Yen PS. Reinforcement of acrylic denture base resin by incorporation of various fibers. Journal of Biomedical Materials Research: An Official Journal of The Society for Biomaterials, The Japanese Society for Biomaterials, and The Australian Society for Biomaterials and the Korean Society for Biomaterials. 2001;58(2):203-208.
22. Monteiro DR, Gorup LF, Takamiya AS, de Camargo ER, Filho ACR, Barbosa DB. Silver distribution and release from an antimicrobial denture base resin containing silver colloidal nanoparticles. Journal of Prosthodontics: Implant, Esthetic and Reconstructive Dentistry. 2012;21(1):7-15.
23. John J, Ann Mani S, Palaniswamy K, Ramanathan A, Razak AAA. Flexural properties of poly (Methyl Methacrylate) resin reinforced with oil palm empty fruit bunch fibers: a preliminary finding. Journal of Prosthodontics. 2015;24(3):233-238.
24. Xu J, Li Y, Yu T, Cong L. Reinforcement of denture base resin with short vegetable fiber. Dental materials. 2013;29(12):1273-1279.