

The Impact of Adding Different Proportions of Recycled Polyetherether Ketone (PEEK) Particles Fibers as a Denture Repairing Material on Mechanical Properties of Polymethyl Methacrylate

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Abstract Aim: This laboratory research aimed to assess the impact of addition of various proportions of recycled Polyetherether Ketone (PEEK) particles fibers as a reinforcing filler material on Surface hardness, Surface roughness and Flexural strength of heat cured Polymethyl methacrylate. **Materials and methods:** A total of 90 ; specimens of heat polymerized PMMA stored at 37°C water bath prior to breaking were divided into 3 main groups; 30 to test surface hardness, 30 for surface roughness, and 30 to test Flexural strength with different specifications rather than those which test the surface hardness and surface roughness. For each test, the specimens were subdivided into 3 subgroups; Group I (control group n=10): specimens repaired with auto polymerizing PMMA without any additives. For Group II(n=10), and III(n=10), the discarded PEEK particles remained After CAD/CAM milling process, gathered from the device, and recycled to produce particle size of 150 µm using standard sieves of ISO standardization, no 40, 60 and 100. Group II and III specimens repaired with auto polymerizing PMMA strengthened with 1%wt. and 2%wt PEEK particles respectively. Hardness Testing Instrument FH-5 and Laser Abrasion Measurement System LAS-20 devices used to measure surface hardness and surface roughness, respectively. Hardness Testing Instrument Fh-5 was used to measure the Flexural strength. Statistical analyses were done using the One-way ANOVA test. **Results:** regarding surface hardness, there were significant improvements in Groups II&III. than group I. Insignificant differences in surface roughness between group I&II, and between Group II&III were documented. Conversely, a marked improvement in the surface roughness was recorded between group I&III. Regarding flexural strength, a significant improvement in Group III in comparison with group I or II **Conclusion:** Addition of PEEK particles fibers as filler material can be used to repair heat polymerized PMMA with improvement of the surface hardness, flexural strength, and decreased surface roughness.

Keywords: Denture Repair, PMMA, recycled PEEK particles, mechanical properties

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1. Introduction

Polymethyl methacrylate (PMMA) is still one of the best widespread dentures base materials regarding esthetics and stability in the oral environment, its relatively be easy fabrication and modification processes and its low cost but its poor mechanical properties are a major problem that limits its use. Medline fractures are the most frequent fracture unfortunately may occur because of errors in denture construction, ill-fitting, inability to achieve balanced articulation, and poor fracture resistance [1,2] It is essential to select proper, efficient repair

material and methods. Auto-polymerized PMMA, even with its low mechanical properties, is still considered the most used material for the dentures repair. Several studies suggested various procedures to improve the PMMA mechanical properties such as addition of various fibers, modification in the inorganic fillers. [3-5] Recently, PEEK has been commonly used in fixed and removable prosthodontics [6,7]. It is biocompatible, light in weight, has high corrosion resistance, high hardness and has a modulus of elasticity near that of natural bone [8,9]. The high-cost CAD-CAM PEEK blocks-even with the improved cutting accuracy of advanced milling machines-has been denoted as the main limitation of its use. After milling, the unused PEEK particles represent a big prob-

lems in dental labs, and no definite rules in several countries on recycling these particles. In the past treatment with non-degradable dental waste materials did not take the concern until the term green environment has become of major importance. Recycling of these materials became one of the most essential factors in accreditation of dental clinics and labs. [10]. The aim of the current research was to estimate impact of addition of dissimilar proportions of recycled Poly ether her Ketone (PEEK) particles fibers as a reinforcing filler material on Surface Hardness, surface Roughness and flexural strength, of Polymethyl methacrylate.

2. Materials and Methods

After finishing CAD-CAM milling technique, the remaining PEEK* particles were scrubbed from the CAM machine.** After drying and during vibrating sieving process, a horseshoe magnet was used to separate any metal traces that may be cut from the machine bur. To attain reasonable small fibers, the standard stainless-steel sieves of ISO standardization of 3310-1. [11] no. 40,60, and 100 to produce fine fibers of 420 μm , 250 μm , and 150 μm respectively was used. [12]



Figure 1. The analytic balance device

3. Surface Hardness and Surface Roughness

Sixty-round samples were prepared; 30 to measure surface hardness and 30 to investigate the surface roughness, then each main group was subdivided into 3 subgroups I, II and III, 10 specimens each. The auto polymerized PMMA repairing material* was prepared by adding the PEEK fibers at 0%wt, 1%wt. and 2%wt in

Group I, (Control), II, and III respectively to PMMA powder after being pre weighed on the analytic balance device** (Figure 1).

To obtain homogenous, and smooth spreading of PEEK fibers in PMMA powder, a magnetic stirrer machine*** was switched at 450 rpm for 30 minutes. 2mm thick round wax disc specimens with a diameter of 12 mm were prepared and duplicated to produce silicone mold. Heat polymerization of PMMA was done according to the conventional technique. Figure 2 Hardness Testing Instrument FH-5**** The FH- 5 sequence of micro-macro-Vickers Knoop& Brinell hardness tester has an effective proposal with worldwide provisions provide accurate results in short time. It directs load, computes, sorts, and directs arithmetical information in built in computer. its 4-situation steeple make it able to be modified through different purposes, or phases and thus suits all technical requirements.



Figure 2. Hardness Testing Instrument Fh-5

laser profilometer (Laser Abrasion Measurement System LAS-20)*****. was used to measure surface roughness and indicate the spread of crystals and fibers within the PMMA. Its advantages are highly accurate, and its high resolution enables discovering any tiny and small cracks or roughness and detecting its depth in short time, also no need to apply any surface treatment material. To get results: Mount the specimens inside the Laser scanner, Define the measurement scales, set perception limits, and start scanning .and result analysis. The process takes about fifteen minutes. It has an internal camera and adaptable LED illumination that enable high precise scanning and allow saving of pictures on the computer in several formats (Figure 3)

* Peek-Juvora™, Uk
** Roland- Dwx-50, Usa
* Province, Shofu In., Japan

** Kern, Merck KGaA, Darmstadt, Germany
*** IKA® RW20 digital, Stauffen, Germany
**** Tinius Olsen India Pvt Ltd, India
***** SD Mechatronics, Westerham, Germany



Figure 3. Laser Abrasion Measurement System LAS-20

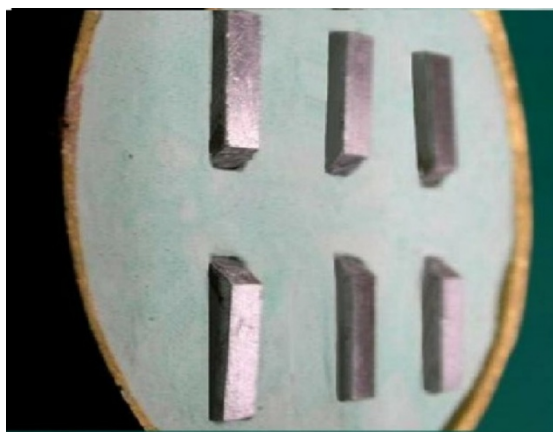


Figure 4. Metal bars

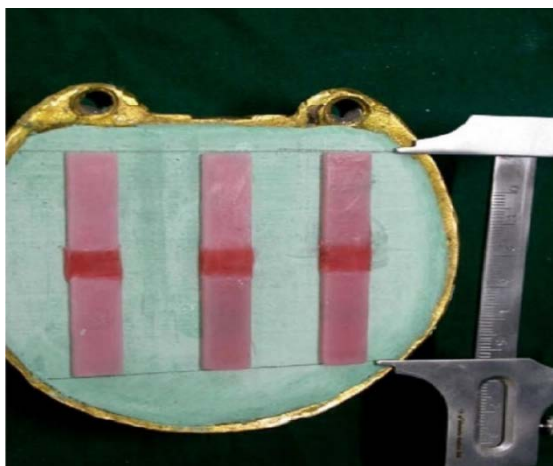


Figure 5. smooth box in the middle of the specimens

4. Flexural Strength

Metal bars [Figure 4](#) with dimensions of 64 mm length, 10 mm width and 3.3 mm depth were prepared according to the international standards organization ISO 20795-1 (2013) [\[13\]](#). and duplicated to produce silicon mold. The study samples were produced by pouring Melted base plate wax into the mold in increments, the study specimens were distributed into three groups 10 specimens each. Group I: PolyMethyle Methacrylate specimens alone without any additives (mentor), Group II&III: adding 1%wt. 2%wt peek to PMMA respectively.

Ultrasonic waves with distilled water were used to clean the samples and then left 10 seconds to dry in the air. [\[14\]](#) $5 \times 5 \times 2$ mm. smooth box was sliced in the middle of the thirty samples to incorporate different reinforcement materials [\[15\]](#) ([Figure 5](#)). Indices were created to confirm accurate repositioning, then paint separating material on all walls. Group I box was filled with PMMA without addition of PEEK fiber (control group) while Group II and III filled with a mix of PMMA and 1&2%wt. PEEK respectively, prior to application of PMMA liquid. To compensate polymerization shrinkage, the mix overfilled the box. The sample was left to polymerize under pressure and then finished and polished, and stocked in a rubber Powel filled with distilled water at 37°C 16. A digitalized ruler was utilized to determine and identify the midpoint of each specimen. A universal testing machine *****([Figure 6](#)) was manipulated to evaluate flexural strength.

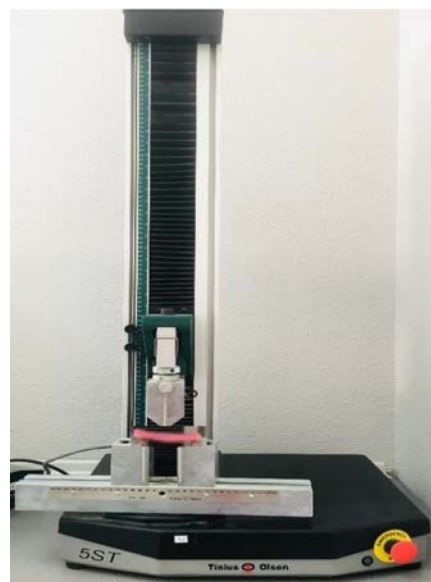


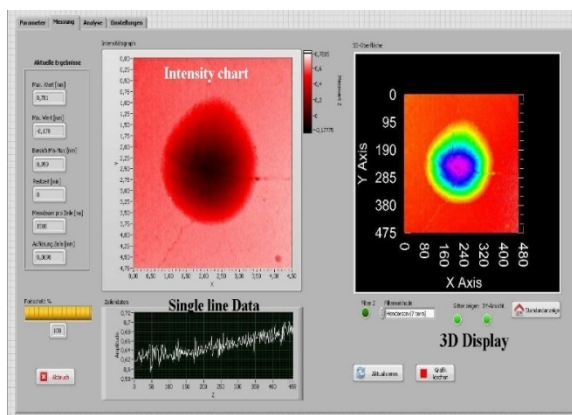
Figure 6. 5 ST Testing Machine

load pieces were applied to adjust the equipment, and a couple of adaptable maintaining pieces were separated by 50 mm. A force of 500 N. with a crossheading velocity of 5 mm/min was applied in the center of the specimen. The evenly added load was applied until rupture of the samples. According to 2013-ISO 20795-1 [\[13\]](#) the formulation

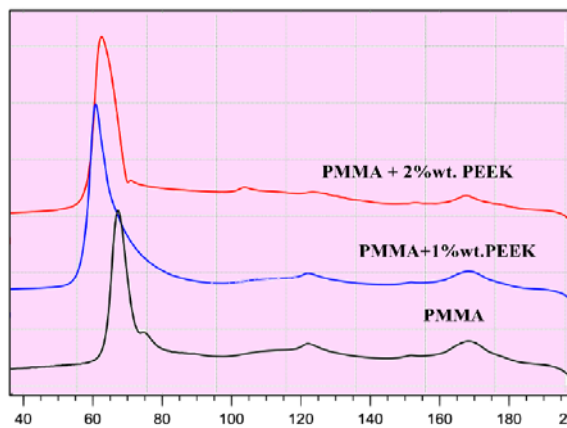
($S = 3PL/2bd^2$ (N/mm²)) used to determine the flexural strength. (where: S = flexural strength, P = greatest load in Newton, L= distance, b = width in mm, and d = depth of sample in mm.).

5. Results

During scanning in Laser profilometer, the images can be seen growing in strokes. The time remaining, maximum, and minimum estimated data are shown on the monitor. Three graphic shapes namely 3D Display, the Intensity chart, and Single line data. are shown in (Figure 7a.). A detailed image of the surface is expressed in the intensity chart. The measurement dimensions are represented by X & Y axes, while the assessed variable (Z axis) is denoted via colour.s.



(a)



(b)

Figure 7. (a): 3 graphical displays on the screen. (b):Single line data of different study groups.

In 3D Display figure, a colour spectrograph. Usually illustrate the surface. The single line data of all the specimens are shown in Figure 7b.

6. Surface Hardness and Surface Roughness

Regarding surface hardness findings, there were statistically significant differences between the monitor

control group and that of study groups ($p=0.0003, 0.0009$, and 0.0002). For surface roughness, there were insignificant variations concerning group I & II, also between Group II & III ($P=0.098, 0.072$ respectively). Conversely, variations were statistically significant concerning group I and III ($p=0.003$) (Figure 8, Figure 9) and Table 1.

Table 1. Mean differences in surface hardness and surface roughness between different study groups

		Surface hardness		Surface Roughness	
		Mean Difference	p-value	Mean Difference	p-value
PMMA	PMMA + 1% wt. PEEK	-4.9000	0.0003*	0.3969	0.098
	PMMA + 2%wt. PEEK	-11.2000	0.0009*	0.7946	0.003*
PMMA + 1% wt. PEEK	PMMA + 2%wt. PEEK	-6.3000	0.0002*	0.5867	0.072

*Sign. $P < 0.05$

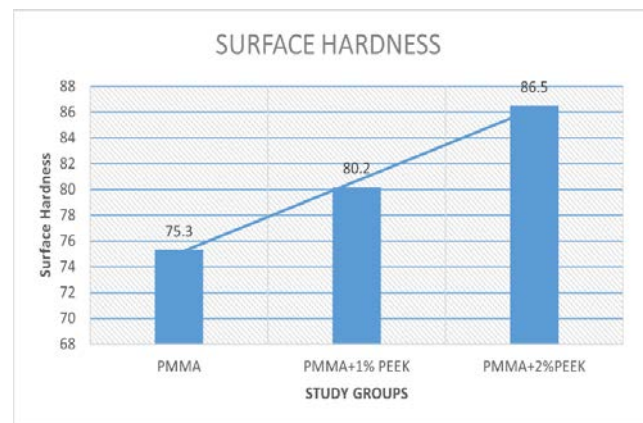


Figure 8. Surface Hardness of different study groups

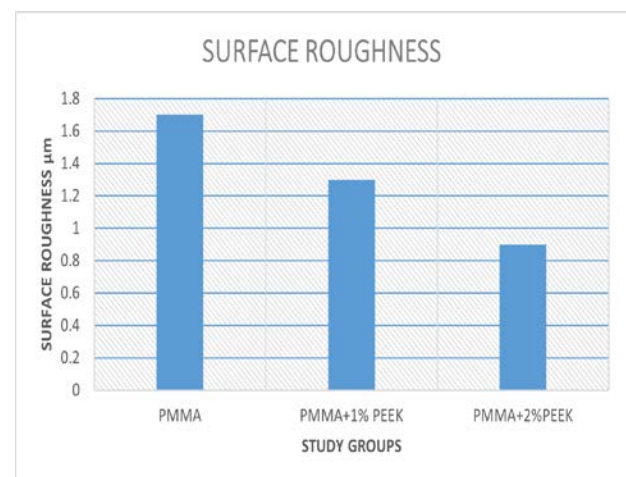


Figure 9. Surface Roughness of different study groups

7. Flexural Strength

Adding 2%wt PEEK fibers developed a marked improvement in Flexural strength in comparison with other groups. The mean differences between different study groups were explained in Table 2.

Table 2. Mean differences in Flexural Strength of different study groups

Group	FLEXURAL STRENGTH		
		Mean Difference	p-value
I	II	3.5538	0.3219
	III	6.03175	0.034*
II	I	1.55318	0.3219
	III	8.79603	0.007*
III	I	5.90644	0.034*
	II	8.79603	0.007*

*Sign. P < 0.05

8. Discussion

The inferior mechanical properties of PMMA was the main disadvantage that limit its application as of denture bases material. Different studies have been conducted to improve its mechanical properties. PEEK has appropriate biocompatibility, exceptional superior mechanical properties; mainly excellent edge and fatigue strength and advanced wear resistance so it can be utilized as a denture base and in clasp construction. [16]

The surface hardness might be improved by increasing PEEK filler percentage. [17] this was in agreement with conclusion of another study that found that the presence of high crystalline polymeric substance may improve the surface hardness [9]. Conversely, the reinforcing PMMA with 1%wt. and 2% wt. PEEK as a filler was statistically insignificant surface roughness findings with the lowest findings in group III; these results suggest its use as a novel material with smooth surface that will prevent accumulation of microorganisms this was in accordance with another studies [18-20].

Flexural strength is an indicator of the rigidity and thus the fracture resistance of any material. Complete or partial dentures are exposed to flexural bending stresses during mastication so they should be constructed from a material of high flexural strength. The present study assisted the influence of reinforcement of repaired PMMA with PEEK fibers in different percentage weight. It is important to determine the type, length, form, and distribution of fiber. [15] Adding E-glass fibers to heat cured PMMA improves the Flexural strength. SiO₂ is a hard substance which distributes the forces between PMMA to the glass fibers and thus enhances the denture base strength and stability of. [21,22]

9. Conclusions

Reinforcing PMMA with 1%wt. and 2% wt. recycled PEEK fiber as filler material can be judged as an successful methodology to enhance surface hardness, flexural strength and decrease surface roughness of a repaired PMMA.

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