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HARDNESS AND ELASTIC MODULUS PROPERTIES OF POLY ETHER ETHER KETONE AS AN ALTERNATIVE TO POLY METHYL METHA ACRYLATE (IN- VITRO STUDY)

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ABSTRACT

Objectives: To assess hardness and elastic modulus properties of Poly Ether Ether ketone (PEEK) as an analogue to Poly methyl Metha Acrylate (PMMA) denture-base material, this in-vitro experiment was carried out.

Material and methods: Overall forty sample specimens (n=40) of PEEK (n=20) Group K and PMMA(n=20) Group P were prepared; each was then split into two subgroups: subgroup K1(PEEK) (n=10) and subgroup P1(PMMA)(n=10) for hardness test using Vickers microhardness tester and group K2 (PEEK) (n=10) and group P2 (PMMA)(n=10) for elastic modulus test by three-point bend test. Obtained values were subjected to statistical analysis using student t-test in order to compare hardness and elastic modulus of PEEK and PMMA.

Results: It was discovered that PEEK groups had statistically significant greater Vickers hardness values and elastic modulus average values than PMMA group as tested by student t-test (p = <0.0001 <0.05).

Conclusions: PEEK has superior hardness and elastic modulus properties that can serve as an alternate base material for dentures to overcome some problems of Poly Methyl Metha Acrylate denture-base material.

KEYWORDS: PEEK, PMMA, hardness, Elastic modulus, denture-base

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INTRODUCTION

Poly Methyl Metha Acrylate (PMMA) is a common material used in the creation of temporary restorations. Because of advantageous qualities which include ease of use, can be repair, minimal irritation, high flexibility, and cheap PMMA is frequently utilized to create the basis for dentures and temporary restorations [(1-3)]. Conversely, PMMA's intrinsic shortcomings that limit its application, such as its brittleness, excessive polymerization shrinkage, poor mechanical qualities, and limited antimicrobial properties [(4,5)].

Inside an effort to improve the qualities of acrylic resin, resin composite-polymer restorative materials enhanced with silica particles were first developed[(6)]. Resin composites offer better mechanical qualities than acrylic resins. They also have a lower thermal expansion coefficient, which results in less dimensional change as a result of setting reactions. In addition, composite resins function better in clinical settings than PMMA because they are harder and more wear resistant [(7)].

PEEK is a higher intensity polymer that resembles bone in terms of its physical and mechanical properties. Because to its positive in vivo and in vitro results, PEEK is widely used in healthcare purposes, like as orthopedic and spinal implants,[(8-10)] whereas within the past 10 years, its viability for dentistry applications has also been studied. PEEK was already discovered to have qualities that make it biocompatible. For several different intra-oral fixed and removable prosthetic restoration types, the use of PEEK has been recommended [(11,12)]. As PEEK can employ further favorable orthodontic stresses than traditional orthodontic wires, it has also been employed to fabricate aesthetic orthodontic wires [(13)].

An innovative lightweight framework material is PEEK. Moreover, both traditional heat-pressing methods and CAD/CAM procedures can be used to create PEEK RPDs. In the case of failure, CAD/CAM procedures are simply repeatable [(14)], and for resorption, PEEK frames may be quickly relined [(15)]. Furthermore, PEEK RPDs created with quick designing and building, show promising outcomes in the area of framework correctness [(16)].

Clinical studies have demonstrated that compared to CoCr RPDs, PEEK (Bio-HPP) RPDs have a lesser specific weight, which results in more patient comfort [(17,18)]. Ten patients were instructed to use metallic and PEEK framework RPDs for three months in a randomized controlled experiment, and their satisfaction levels were compared [(19)]. The milled PEEK framework RPDs were preferred by patients over the CoCr framework RPDs. Yet, a further randomised clinical experiment looked at 26 patients' satisfaction with CoCr and PEEK frameworks at four, six, and twelve months. The results of the Oral Health Impact Profile were not significantly impacted by PEEK frameworks [(20)].

This in vitro experiment's hypothesis was that PEEK material will vary from PMMA material in terms of both hardness and elastic modulus.

MATERIAL AND METHODS

Study Design: an invitro comparative trial study

Ethical approval was obtained from Research Ethics Committee, Faculty of Dental medicine Al-Azhar University Under the No. (EC Ref No.: 956/2935_29-11-23).

Calculation of Sample Size: based on the results of Muhsin's et al [(3)] earlier research, a sample size calculation using power analysis revealed that a minimum of 7 specimens for each group were needed to identify a significant variation among groups. The necessary sample size (df=6.479) and effect size (df=6.479) were computed with a power of.95% and a 95% confidence interval (0.9774).

Samples fabrication: PMMA samples were manufactured from ready-made blocks that were laser-cut to 65x10x2.5mm dimensions for tests on elastic modulus (group P2 n=10) and hardness (group P1 n=10). In order to prepare PEEK samples for micro hardness and elastic modulus measurements, a CAD/CAM machine was used to cut ready-made blocks that have been 65 x 10 x 2.5 mm in size. After being polished using sandpaper, the specimens were cooled to room temperature.

Samples grouping: A total of 40 test specimens (n=40) were split into 2 main groups, Group P (n=20 PMMA) and Group K (n=20 PEEK), and then into two subgroups, Group P1 (n=10 PMMA) and Group K1 (n=10 PEEK), respectively, for the hardness test and Group P2 (n=10 PMMA) and Group K2 (n=10 PEEK), respectively, for the elastic modulus test.

Laboratory tests

Hardness testing:

Vickers diamond indenter (the Vickers indenter is a square, pyramid pattern diamond that indented the surface of the substance under examination in a square pattern) and digital Vickers Micro-hardness Tester (HVS-50 version, Laizhou Huayin Testing Instrument Co., Ltd. China) were utilized to measure the surface micro-hardness of the samples. The specimens' surfaces were subjected to a 200g stress for 15 seconds. Three indentations were created on each sample's surface, equally distributed across a ring and not further than 0.5 mm apart from each other. By using the integrated scaled microscope to quantify the diagonal distance of the indentations. Then Micro-hardness scores were created by transforming Vickers readings [21].

Measurement of microhardness;

The subsequent formula was used to determine the microhardness: [22]

$$HV=1.854\ P/d^2$$

wherever, Vickers hardness (**HV**) is measured in Kg/mm^2, load (**P**) is measured in Kg, and diagonal distance (**d**) is measured in mm.

Elastic modulus test: On a computerized substance measuring device with a 5 KN strain gauge, every sample was placed separately and horizontally in a custom loading rig (setup for a 3-point bend test; sample is supported by two parallel, 60 mm-long stainless steel bars, with the damage spot in the middle of the tensile axis), and a software was used to capture the information. The specimens were then statically compressed loaded at a crosshead acceleration of 5 mm/min till break. Software was utilized to record the stress-strain curves. After recording the highest load applied to the specimens, the elastic modulus was computed using the formula shown below [23]:

$$E=PL^3/4bh^3d$$

Whereas E: is the elastic modulus (MPa), P: is the breaking strain (N), L: is the span length of the sample (mm), b: is the specimen breadth (mm), h: is the heights of the sample (mm), and d: is the deviation (mm).

SPSS software was used to gather, collate, and statistically evaluate the information.

RESULTS

Vickers hardness (HV)

It was discovered that the PEEK group had statistically significantly greater Vickers hardness average scores (37.187±2.115 HV) than PMMA group (25.2131.559 HV) as tested by student t-test as demonstrated by picture (1) and table (1).

TABLE (1) Comparison of Vickers hardness test (HV) outcomes (Mean±SD) between each group:

Groups	Descriptive statistics			P value
	Mean±SD	95% confidence intervals		
		Lower	Upper	
Group K1 (PEEK)	37.187 ± 2.115	36.116	38.257	<0.0001*
Group P1 (PMMA)	25.213 ± 1.559	24.424	26.002	

; significant (p < 0.05)** ***ns; non-significant (p>0.05)

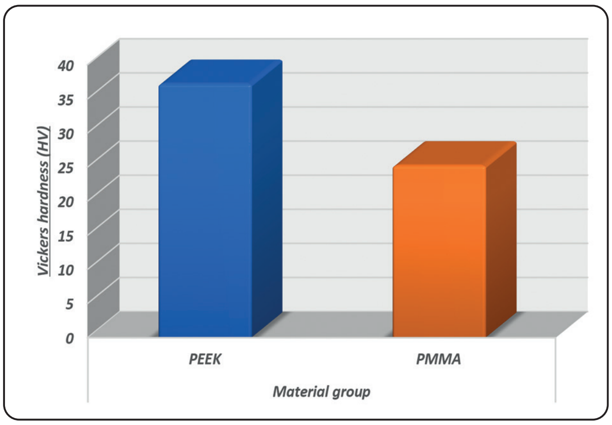

Fig (1) Column chart comparing the mean scores Vickers hardness of each group.

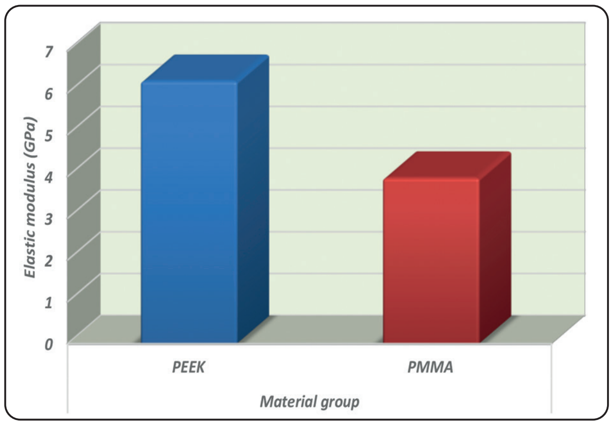

Fig. (2) Column chart comparing the mean scores Elastic Modulus of each group.

Elastic modulus (GPa)

It was discovered that the PEEK group had statistically significantly greater elastic modulus average scores (*6.281 ± 0.244* GPa) than *PMMA* group (*3.962 ±0.204* GPa) as tested by student t-test (p = <0.0001 < 0.05) as demonstrated by picture (2) and table (2).

TABLE (2) Comparison of elastic modulus test (GPa) outcomes (Mean±SD) among each group:

Groups	***Descriptive statistics***			***P value***
	Mean±SD	***95% confidence intervals***		
		Lower	***Upper***	
Group K1 (PEEK)	***6.281 ± 0.244***	6.157	6.44	<0.0001*
Group P1(PMMA)	***3.962 ± 0.204***	3.859	4.066	

; significant (p < 0.05)

ns; non-significant (p>0.05

DISCUSSION

PEEK, an engineered plastic substance with good mechanical and thermal qualities, is semi-crystalline. PEEK offers a number of benefits, including being lightweight, non-toxic, bioinert, having good corrosion resistance, and having an elasticity modulus that is comparable to bone [24-26].

At the moment, it is frequently employed as an abutment in dental implant therapy, permanent and removable dentures, and orthodontics [25, 26]. Any material that may be used as a denture base should be able to withstand such action, so it was required to examine it in the current study. Surface microhardness of denture base material is significant since cleaning methods induce scratching and scrubbing of denture base surface [27].

High elastic modulus denture base materials can tolerate mastication-induced persistent deformation. Due to flexure, fracture of the top dentures always happens through the midline of the denture. Consequently, it was beneficial to assess elastic modulus in the current study. The denture foundation should have adequate flexural strength to withstand breakage [3].

I-hardness:

The study's findings demonstrated that the PEEK group had harder data than the PMMA group, and such variation was statistically significant. Our findings agreed with study that was conducted to [28] compare mechanical characteristics of PEEK with PMMA, and resulted in PEEK's hardness ratings are higher than those of PMMA's.

Also, the acquired results are consistent with those of another investigation. PEEK material has more flexural strength than PMMA material, according to a study [20] that was carried out to assess the material's flexural strength. As well as flexural strength, hardness a further crucial mechanical feature was too evaluated with current research. Our outcome showed that PEEK and PMMA differ significantly in terms of hardness. This outcome can be explained by the peak material's resistance to dissolving in common solvents, as well as by high volume resistivity and surface resistivity. Such materials' inherent purity makes them resistant to scuffing and indentation by various things [29].

These findings conflict with those of Parinaz Ansari et al.[30] who discovered that PEEK demonstrated a lower microhardness than the other two materials, which was consistent with earlier studies.[31-33] PEEK is a semi-crystalline, thermoplastic material with no traces of monomer remaining in the matrix.[32] Because of the matrix characteristics and low filler percentage of the PEEK blocks utilised in this work, PEEK demonstrated poorer microhardness than the indirect composite. Its microhardness was nearly identical to PMMA's. PEEK's mechanical qualities would be enhanced by the addition of substances like carbon fibre or glass to its short chains, which would also reduce the substance's water sorption and solubility. [34]

II- modulus of elasticity

According to the study's findings, the elastic modulus of the PEEK group was larger than that of the PMMA group, and such variation was statistically significant. Our findings concur with those of Muhsin S et al [20], who discovered that the PEEK polymer had a higher Young's modulus than PMMA. Also, these findings were consistent with a study that examined the impact of polymeric restorative materials on the load sharing in posterior fixed partial dentures [35]. This outcome may be explained by the peak material's strong temperature resistance, rigidity, and stiffness, all of which increase elastic modulus [16].

PEEK is more lightweight than conventional materials and demonstrates good mechanical characteristics. Its elastic modulus is comparable to that of human bone tissue[36] which has the effect of dampening PEEK restorations[37] and lowering stress shielding. Less evaluations, meanwhile, have fully summarised the developments in PEEK research for a range of dental applications.

There is a greater chance of fracture and PEEK's stiffness could not be sufficient to endure load-bearing stresses.[38] PEEK can be combined with substances like fibres and ceramics to increase its mechanical strength and offer benefits in a variety of dental applications. Recently, PEEK scaffolds and prosthetics have been produced via 3D printing. This process can result in end products that are more sophisticated and precise.[39]

Evidence is required to establish the mechanical characteristics, accuracy, and precision of PEEK prosthetics, in contrast to materials like metals. [40]

CONCLUSION AND RECOMMENDATIONS

PEEK has superior hardness and elastic modulus properties that can be utilized as an alternate material for denture base to overcome some problems of PMMA denture base material, also further clinical studies are required to guarantee applicability of PEEK as base material for different prosthetic devices.

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