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Original Article

EFFECT OF THERMOCYCLING ON FLEXURAL AND IMPACT STRENGTH OF POLYMETHYL METHACRYLATE AND POLYETHERETHERKETONE DENTURE BASE MATERIAL

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ABSTRACT

Objective: The most widely used resin as denture base is Polymethyl Methacrylate (PMMA). But due to its low impact and flexural strength, it increases the risk of failure during clinical use. To lower the risk of denture base fracture in PMMA full denture, reinforcement material is used. Nowadays, Polyetheretherketone (PEEK) has been introduced in dentistry with better mechanical and physical properties than PMMA. However, there has been no study looking at the effect of aging on the flexural strength and impact of PEEK as a denture base material.

Methods: A total of 42 samples consisting of 21 PMMA samples and 21 PEEK samples were made for each Flexural and impact test. The samples were divided into three groups: control, 2000 and 5000 *thermocycling* cycles, with each group have 7 samples. Flexural strength testing was carried out using the three-point bending method with a universal testing machine while the impact strength test was carried out by the charpy method using a charpy impact testing machine.

Results: There was a significant difference in flexural strength between PMMA and PEEK based on the duration of use with a value of $p<0.05$. There was also a significant difference in he impact strength between PMMA and PEEK based on the length of use with a value of $p<0.05$. In PMMA group testing on the flexural strength and Impact of PMMA, there was a significant effect with $p<0.05$. In PEEK group testing on the flexural strength and impact strength, there was no significant effect on the duration of use with $p>0.05$.

Conclusion: PEEK can be used as a base material for dentures that aim to increase flexural and impact strength in the required clinical conditions. There was no significant effect on PEEK mechanical properties in 5 y of use.

Keywords: Flexural strength, Impact strength, *Thermocycling*, Polymethyl methacrylate, Polyetheretherketone

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INTRODUCTION

The number of patients using complete dentures is increasing along with the increase in the elderly population [1]. Because the best full denture must fulfill the functional requirements of the oral cavity in order to improve the quality of life of edentulous patients, it is challenging for dentists to provide them with the best full denture treatments [1]. A complete denture consists of a base and a denture attachment. Denture base is the part where denture artificial teeth is attached and part of the denture seat on oral cavity soft tissue [2].

Biocompatibility of denture bases with oral tissues, odorless, aesthetics, capable of being easily repaired and manipulated, high elastic modulus, impact strength, flexural strength, hardness was the ideal requirements for denture bases [2, 3]. Based on the ADA (American Dental Association Specification) No. 12 (ISO (International Organization for Standardization) 1567), the substance of denture base polymer was classified into five different types, with type 1 being the most often used, namely heat polymerizable acrylic resins or also known as Polymethyl Methacrylate (PMMA) which is processed by the compression molding method [2]. Walter Wright in 1937 introduced the first acrylic resin material [3]. Due to its many benefits, such as its low weight, biocompatibility, aesthetic appeal, affordability, low water absorption, ease of polishing, manipulation, and repair, this material is widely used [1, 2]. However, because of its comparatively low elastic modulus, impact strength, and flexural strength, this material's mechanical requirements make it unsuitable for a denture foundation and increases the possibility of failure due to clinical use [1, 3-5].

Based on observations made by Martu *et al.* in 2017, 49% of complete PMMA dentures experienced fractures in 0-4 y of use, the cause of fractures in the upper jaw as much as 43% was caused by unstable dentures followed by accidents as much as 25%, while the most vulnerable area to fracture was in the midline section of 60-62% of the samples examined experienced fractures in the midline section [6]. One way to reduce the risk of maxillary denture base fractures in cases that require base strength such as flat margins, geriatric patients, Parkinson's can be a combination of PMMA with cobalt chromium (Co-Cr) metal base [7]. Framework metal has advantages over PMMA such as being able to be used in thin areas, having high strength and stiffness, good thermal conduction, as a stable denture base, and being resistant to corrosion [8]. However Co-Cr has disadvantages such as potentially causing hypersensitivity, aesthetic problems, oral galvanism, heavy denture and biofilm attachment [8-10]. To solve the disadvantages of metal framework bases, high-performance polymers have been researched in order [8].

Polymer framework base recently introduced consisting of a polymer modification of Polyetheretherketone (PEEK) is used in conjunction with an acrylic denture base and a conventional PMMA denture base [11]. British scientists created PEEK, a semi-crystalline linear polycyclic aromatic polymer, in 1978, nowadays, PEEK is being introduced for widespread use [12]. PEEK is still being researched and improved for usage in dentistry. PEEK has been used as an implant, a fixed prosthesis, a removable prosthesis, a surgical guide, an occlusal splint, and others [9-11]. In prosthodontics, the PEEK framework has been introduced to the market to replace the traditional cobalt-chromium (Co-Cr) framework, thanks to the emerging materials available and the present state of technology [11].

Although there have been many studies that state the superiority of peek material in terms of mechanical properties, biological properties and chemical properties, and exclusively focus on PEEK's ability to prevent hypersensitivity reactions, despite widespread use, no case of hypersensitivity or allergy related to PEEK has been reported [9-11]. But nowadays some Studies reports note a "minimal" inflammatory response. A case reports the first case of confirmed delayed-type hypersensitivity reaction to PEEK material, although this reports of sensitivity to PEEK material are not related to its use as a denture framework [13].

Many studies report that the durability of dental materials used in oral cavity decreases after used for a period of time. This condition is taken into consideration in *in vitro* studies to simulate clinical conditions with artificial aging. The most effective protocol in artificial aging to use is thermocycling [14]. Takahasi *et al.* reported significant changes in impact strength of injection-molded thermoplastic denture base resin after thermal shock [15]. According to Turgut, his investigation revealed a noteworthy distinction in flexural strength between PMMA bases that were thermocycling-treated and those that were not [16]. The majority of studies reported that the thermocycling temperatures used for dental material tests were 5 °C and 55 °C [14-18, 22].

To study the thermocycling effect on flexural strength and impact strength on PMMA and PEEK, a thermocycling machine (SD mechatronic GMBH, Germany) was used to subject the specimen to 2000 cycle to simulate 2 y of denture use in mouth and 5000 cycle to simulate 5 y of use. In previous studies [17-19], thermocycling (5 °C and 55 °C) for 2000 cycles in distilled water simulated clinical use of denture base for 2 y. However, Barjini *et al.* thermocycled (5 °C and 55 °C) 5000 cycles of distilled water to observe changes in flexural strength of PEEK [20]. Li *et al.* also applied thermocycling (5 °C and 55 °C) 5000 cycles of distilled water to 3D printed denture base materials to illustrate temperature changes in the oral cavity over 5 y [21].

There has been no research that has tested the effect of thermocycling on the mechanical strength of PEEK as a denture base. Therefore, this study's objective was to compare the mechanical characteristics of PEEK and PMMA both before and after thermocycling.

MATERIALS AND METHODS

Fabrication of specimen

The flexural strength sample in this study is Compression Molding PMMA and vacuum injection molding PEEK shaped rod with a size (65 mm length, 10 mm width, 2.5 mm thick)±0.1 in accordance with ADA specification no. 12 [22]. The impact strength sample in this study is Compression Molding PMMA and vacuum injection molding PEEK shaped rod with size (50 mm length, 6 mm width, 4 mm thick)±0.1 with V-notch in the center of the sample with a depth of 1.2 mm based on previous Studies [23, 24].

Three groups of samples were created for this study using thermocycling simulation:

-The first group with the number of samples (n=7) in each sample group → control group consisting of PMMA produced by compression molding technique and PEEK produced by vacuum injection molding.

-Second group with number of samples (n=7) in each sample group → 2000 cycle thermocycling group consisting of PMMA produced by compression molding technique and PEEK produced by vacuum injection molding.

-Third group with number of samples (n=7) in each sample group → group thermocycling 5000 cycles, consisting of PMMA produced by compression molding technique and PEEK produced by vacuum injection molding.

Bar-shaped metal with size (65 mm length, 10 mm width, 2.5 mm thick)±0.1 mm for flexural strength test and size (50 mm length, 6 mm width, 4 mm thick)±0.1 mm for impact strength test were used for making stone mold in dental flask. PMMA samples were prepared by heat curing PMMA (meliodent, Heraeus Kulzer) denture base resin with 3 g polymer: 1.5 ml monomer according to the manufacturer's instructions, then stirred slowly. After the mixture reached the dough phase, the mixture was put into the mold, then pressed slowly on the mold with a hydraulic press reaching 1000 psi, Afterwards, the mold was opened and the excess PMMA was removed with a lecron. It was then pressed again with a pressure of 2200 psi.

The curing process was carried out using a water bath. Time and temperature control was carried out during curing. In stage 1, the cuvette was inserted at 70 °C and left for 90 min. In stage II, the temperature was raised to 100 degrees Celsius and allowed to remain for half an hour. For the cooling procedure, the cuvette was submerged in the water bath for half an hour. The cuvette was then left to cool to room temperature for fifteen minutes while running water. The sample was removed from the cuvette, then the excess was removed and smoothed with a fraser bur to remove sharp parts and then smoothed with silicone carbide sandpaper until a size (65 mm length, 10 mm width, 2.5 mm thick) was obtained for the flexural strength sample and (50 mm length, 6 mm width, 4 mm thick) for the impact strength sample. In the impact strength samples, a V-notch was also made in the center of the sample with a depth of 1.2 mm.

For the manufacture of PEEK samples, rod-shaped wax with a size requied for flexural strength test and a size requied for impact strength test were used for the manufacture of stone molds using investment material in the crucible. The melting of BioHPP PEEK granule (Bredent Gmbh, Germany) was carried out in a preheated oven. The melting temperature is 400 °C (for 20 min no more) should be precisely controlled and checked. Vacuum injection molding of PEEK was carried out using a for 2 press (Bredent Gmbh, Germany) for 35 min, this process took place automatically. The PEEK specimens were then removed from the cuvette, then the PEEK specimens were smoothed with a bur fraser to remove sharp edges and smoothed with silicon carbide sandpaper until a size of 65 mm x 10 mm x 2.5 mm was obtained for the flexural strength samples and 50 mm x 6 mm x 4 mm for the impact strength samples. In the impact strength samples, a V-notch was also made in the center of the sample with a depth of 1.2 mm.

Thermocycling

Thermocycling was performed using a Thermocycler machine (fig. 1. SD mechatronic GMBH, Germany) on distilled water with temperatures of 5 °C and 55 °C with a 30s dwell time and 20s of transfer time. Thermocycling was divided into 2 groups where the first group with 2000 cycles representing 2 y of use and the second group with 5000 cycles representing 5 y of use.

Thermocycling was performed in distilled water rather than artificial saliva due to equipment constraints.

Fig. 1: Thermocycling machine (SD mechatronic GMBH, Germany)

Fig. 2: Universal testing machine, shimadzu EZ-S 500N

Fig. 3: Charpy impact testing machine (HT-8041B Charpy impact testing machines hung Ta taiwan)

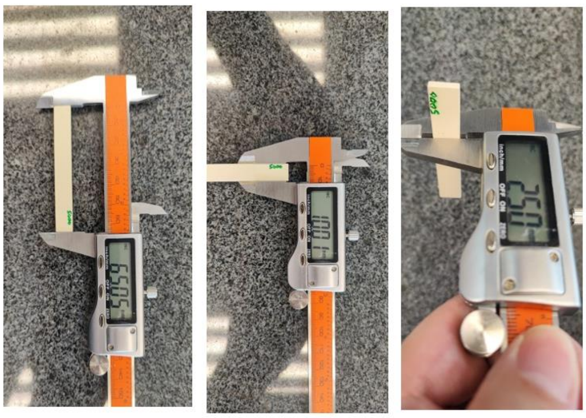

Fig. 4: PEEK sample size for flexural strength test

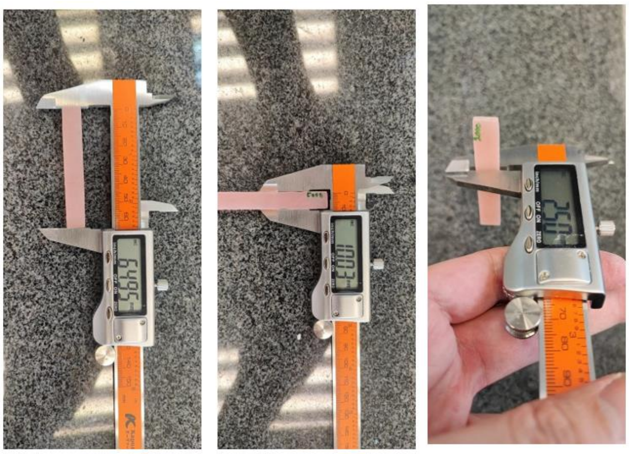

Fig. 5: PMMA sample size for flexural strength test

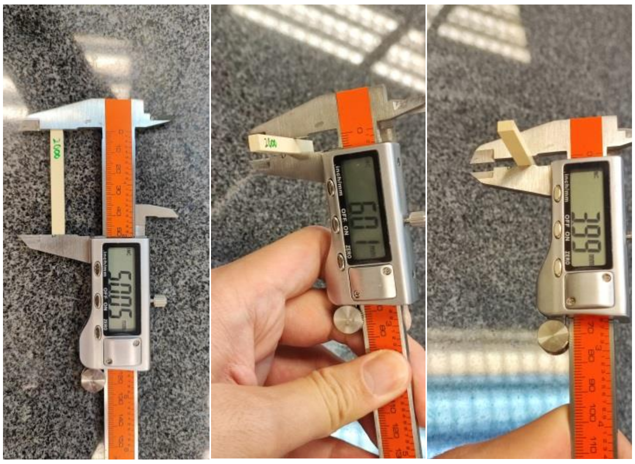

Fig. 6: PEEK sample size for Impact strength test

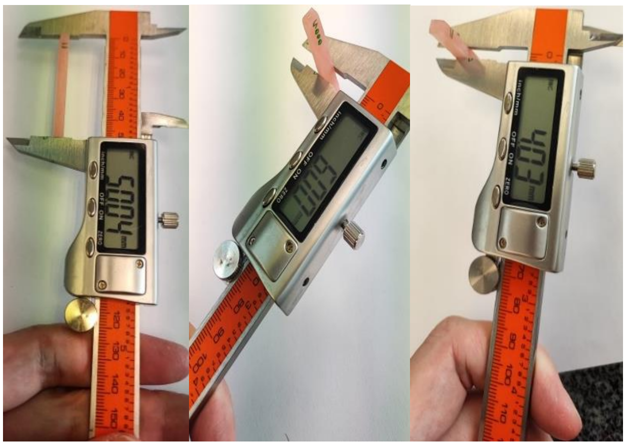

Fig. 7: PMMA sample size for impact strength test

Testing of specimen

Universal Testing Machine was used to assess each specimen's flexural strength using the three-point bending method. (fig. 2. Universal Testing Machine, Shimadzu EZ-S 500N), with a maximum load cell of 500 N, a crosshead speed of 5 mm/min and a support arm distance of 50 mm according to ISO 1567 standards. With a mono beveled chisel blade placed flat on the center of the sample with 5 mm/min of crosshead speed until failure occured, each measurement result was then recorded.

A Charpy Impact Testing Machine was used to measure the samples' impact strength. (HT-8041B Charpy Impact Testing Machines Hung Ta Taiwan) with a pendulum arm of 0.2238 m and a pendulum weight of 0.71 Kg with an initial pendulum angle of 150°, The sample was positioned horizontally on the holding arm, after which, the lock of the striking arm was released and the striking arm hit the sample until it broke then each measurement result was recorded.

d. The data analysis used for this research is:

1. Unpaired t-test to see the difference in flexural strength and impact strength of RAPP and PEEK materials based on the duration of use.

2. One way Analysis of Variance (ANOVA) with post-hoc LSD to see the effect of duration of use on the flexural strength and impact strength of RAPP and PEEK materials using the thermocycling method.

RESULTS

The PMMA and PEEK materials' flexural strength mean and standard deviation in the control group, thermocycling 2000 cycles and 5000 cycles can be seen in table 1. According to this study, the PEEK denture base's mean flexural strength in the control group was higher at 156.01 Megapascal (MPa) than the PMMA denture base's mean flexural strength in the same group, which was 93.43 MPa, whereas in the PEEK denture base group with 2000 cycles of thermocycling and 5000 cycles of thermocycling, The average flexural strength values for each group were 159.22 MPa and 156.01 MPa, respectively. Moreover, this result exceeded the average flexural strength values in the PMMA denture base group after 2000 thermocycling cycles and 5000 cycles of thermocycling, which were 83.70 MPa and 79.17 MPa, respectively.

The impact strength mean and standard deviation of PMMA and PEEK materials in the control group, thermocycling 2000 cycles, and thermocycling 5000 cycles are displayed in table 2. In testing the impact strength between PMMA and PEEK denture bases when compared to the mean impact strength of the PMMA denture base in the control group, which was 4.02 kilojoules per square meter (KJ/m^2), it was discovered that the PEEK denture base's impact strength in the control group was higher, at 6.94 KJ/m^2, whereas in the PEEK denture base group with thermocycling 2000 cycles and thermocycling 5000 cycles, the mean value of the impact strength of each group was at a value of 6.68 KJ/m^2 and 6.15 KJ/m^2. This value was also greater than the average impact strength in the PMMA denture base group after 2000 and 5000 cycles of thermocycling, which came out to 2.89 KJ/m^2 and 1.99 KJ/m^2, respectively.

According to table 3. T-test results, which show a significant difference in flexural strength between PMMA and PEEK based on the length of use in the 2000 cycle and 5000 cycle thermocycling groups with p value = 0.0001* (p<0,05), there was a difference between the two materials based on the length of use for 2 and 5 y.

Table 4 displays a significant difference in flexural strength between PMMA and PEEK based on the length of use in the 2000 cycles and 5000 cycles thermocycling groups, as indicated by the T-test results on the difference in impact strength of PMMA and PEEK based on the length of use for 2 and 5 y with p value = 0.0001* (p<0,05).

Based on the results of testing using the one-way Anova test on the effect of length of use for 2 and 5 y on the flexural strength of PMMA denture bases with the thermocycling method, it can be seen that there was an effect of length of use with the thermocycling method on the flexural strength of PMMA in the control and thermocycling groups as shown in table 5 with a p value = 0.001* (p<0,05). With a significant difference in one way anova testing, post hoc analysis was continued to determine differences in the effect of length of use with the thermocycling method between groups of sample. A significant difference in flexural strength was found in post hoc analysis in comparison to the control group and the 2000 cycle thermocycling group with p value = 0.003* (p<0,5) and between the control group and the 5000 cycle thermocycling group with p value = 0.0001* (p<0,5). Conversely, the thermocycling groups that underwent 2000 and 5000 cycles did not differ significantly with p value = 0.120 (p>0,5).

Table 1: Mean values of flexural strength based on PMMA and PEEK base materials without thermocycling, with 2000 cycles of thermocycling and with 5000 cycles of thermocycling

Sample	Flexural strength (MPa)					
	Control group		*Thermocycling* 2000 cycle		*Thermocycling* 5000 cycle	
	PMMA	PEEK	PMMA	PEEK	PMMA	PEEK
1	89.77	156.01	82.81	154.02	79.77	151,76*
2	93.57	158,71**	89.38	158.02	84,12**	155.56
3	96.57	153,81*	72,44*	153,28*	78.39	163.9
4	100,69**	155.29	91,29**	159,14**	82.81	165,80**
5	92.12	157.96	75.8	157.01	77.1	158.71
6	87,45*	156.15	88.4	157.15	77.19	157.43
7	93.89	154.13	85.82	154.22	74,81*	161.39
x̄	93.43	156.01	83.7	156.12	79.17	159.22
SD	4.35	1.83	7.15	2.26	3.32	4.87
Description: *smallest value **largest value						

Mpa = Megapascal, PMMA = Polymethyl Methacrylate, PEEK = Polyetheretherketone, SD = Standard Deviation

Table 2: Mean values of impact strength based on PMMA and PEEK base materials without thermocycling, with thermocycling 2000 cycles and with thermocycling 5000 cycles

Sample	Impact strength (KJ/m^2)					
	Control group		*Thermocycling* 2000 cycle		*Thermocycling* 5000 cycle	
	PMMA	PEEK	PMMA	PEEK	PMMA	PEEK
1	3.75	6,26*	2,22*	6.32	1.5	6.31
2	4.57	7.23	2.99	5,71*	2,99**	6.26
3	4,72**	7.17	3,70**	7,17**	2.19	5,29*
4	3.75	7.15	3.99	6.27	1.46	6.3
5	3.77	8,04**	2.99	7.07	2.18	7,07**
6	4.51	6.37	2.24	7.11	1,46*	6.33
7	3,03*	6.37	3.06	7.12	2.19	5.5
x̄	4.02	6,94**	2.89	6.68	1,99*	6.15
SD	0.61	0.64	0.52	0.58	0.57	0.59
Description: *smallest value **largest value						

KJ/m^2= kilojoules per square meter, PMMA = Polymethyl Methacrylate, PEEK = Polyetheretherketone, SD = Standard Deviation

Table 6 shows a p value of 0.0001* (p<0,5) for the control and thermocycling groups PMMA denture base's impact strength, which is based on the results of a one-way ANOVA test that examined the impact of the length of use for two and five years on the impact strength of the PMMA denture base using the thermocycling method. To determine the impact of the duration of usage of the thermocycling methode among sample groups, one-way anova testing revealed a significant difference, it was continued with post hoc analysis. In the post hoc analysis, there was a significant difference between the control group and the 2000 cycle thermocycling group p = 0.001* (p<0,05) and between the control group and the 5000 cycle thermocycling group p = 0.0001* (p<0,05), and significant difference in impact strength between the 2000 cycle and 5000 cycle thermocycling groups with p value = 0.009* (p<0,05).

Based on the results of one-way Anova testing on testing the effect of length of use for 2 and 5 y on the flexural strength of the PEEK denture base with the thermocycling method, Table.7 shows that the flexural strength of the PEEK denture base in both the control and thermocycling groups was unaffected by the duration of use of the thermocycling method, with a p value of 0.143** (p>0,05).

Regarding the outcomes of one-way ANOVA testing on the impact of usage duration for 2 and 5 y on the impact strength of PEEK denture bases with the thermocycling method, there was no visible effect of length of use with the thermocycling method on the impact strength of PEEK in the control group and the thermocycling group as it be seen in table 8 with a p value = 0.070** (p>0,05).

Table 3: T-test results of differences in flexural strength of PMMA and PEEK based on duration of use (thermocycling 2000 cycles and 5000 cycles)

Group	Base material	Samples N	Flexural strength x̄±SD (Mpa)	p
Thermocycling	PMMA	7	83,71±7,15	0,0001*
2000 cycle	PEEK	7	156,12±2,26	
Thermocycling	PMMA	7	79,17±3,32	
5000 cycle	PEEK	7	159,22±4,87	
Description: *significant (p<0,05)				

Mpa = Megapascal, PMMA = Polymethyl Methacrylate, PEEK = Polyetheretherketone, SD = Standard Deviation

Table 4: T-test results of differences in impact strength of PMMA and PEEK based on duration of use (thermocycling 2000 cycles)

Group	Base material	Samples N	Impact strength x̄±SD (KJ/m²)	p
Thermocycling	PMMA	7	2,89±0,52	0,0001*
2000 Cycle	PEEK	7	6,68±0,58	
Thermocycling	PMMA	7	1,99±0,57	
5000 Cycle	PEEK	7	6,15±0,59	
Description: * significant (p<0,05)				

KJ/m^2= kilojoules per square meter, PMMA = Polymethyl Methacrylate, PEEK = Polyetheretherketone, SD = Standard Deviation

Table 5: ANOVA test results of the effect of 2 and 5 y of use on the flexural strength of PMMA using the thermocycling method

Group	Samples N	Flexural strength x̄±SD (Mpa)	p
Control PMMA	7	93,43±4,35	0,0001*
PMMA *Thermocycling* 2000 cycle	7	83,71±7,15	
PMMA *Thermocycling* 5000 Cycle	7	79,17±3,32	
Post Hoc Test			
Control-2000 Cycle			0,003*
Control-5000 s Cycle			0,0001*
2000 Cycle – 5000 Cycle			0.12
Description: * significant (p<0,05)			

Mpa = Megapascal, PMMA = Polymethyl Methacrylate, PEEK = Polyetheretherketone, SD = Standard Deviation

Table 6: ANOVA test results of the effect of 2 and 5 y of use on the impact strength of PMMA using the thermocycling method

Group	Samples N	Impact Strength x̄±SD (KJ/m²)	p
Control PMMA	7	4,02±0,61	0,0001*
PMMA *Thermocycling* 2000 cycle	7	2,89±0,52	
PMMA *Thermocycling* 5000 Cycle	7	1,99±0,57	
Post Hoc Test			
Control-2000 Cycle			0,001*
Control-5000 s Cycle			0,0001*
2000 Cycle – 5000 Cycle			0.009
Description: * significant (p<0,05)			

KJ/m^2= kilojoules per square meter, PMMA = Polymethyl Methacrylate, PEEK = Polyetheretherketone, SD = Standard Deviation

Table 7: ANOVA test results of the effect of 2 and 5 y of use on the flexural strength of PEEK by thermocycling method

Group	Samples N	Flexural strength x̄±SD (Mpa)	p
Control PMMA	7	156,01±1,83	0,143 **
PMMA *Thermocycling* 2000 cycle	7	156,12±2,26	
PMMA *Thermocycling* 5000 Cycle	7	159,22±4,87	
Description: * significant (p<0,05), ** Not Significant (P>0,05)			

Mpa = Megapascal, PMMA = Polymethyl Methacrylate, PEEK = Polyetheretherketone, SD = Standard Deviation

Table 8: ANOVA test results of the effect of 2 and 5 y of use on the impact strength of PEEK by thermocycling method

Group	Samples N	Impact strength x̄±SD (KJ/m²)	p
Control PMMA	7	6,94±0,64	0,07 **
PMMA *Thermocycling* 2000 cycle	7	6,68±0,58	
PMMA *Thermocycling* 5000 Cycle	7	6,15±0,59	
Description: * significant (p<0,05), ** Not Significant (P>0,05)			

KJ/m²= kilojoules per square meter, PMMA = Polymethyl Methacrylate, PEEK = Polyetheretherketone, SD = Standard Deviation

DISCUSSION

Flexural strength describes the durability of the denture base in accepting repeated masticatory loads. Meanwhile, impact strength describes the resistance of the denture base to sudden impact. A denture base's resistance to fracture can be determined by its flexural and impact strength. ISO 1567 states that a denture base's minimum flexural strength is 65 MPa.

According to this study, the PEEK denture base's mean flexural strength in the control group was higher at 156.01 MPa than the PMMA denture base's mean flexural strength in the same group, which was 93.43 MPa. In the PEEK denture base group with thermocycling 2000 cycles and thermocycling 5000 cycles, The average flexural strength for each group was between 156.01 MPa and 159.22 MPa. This number was also greater than the mean flexural strength values of 83.70 MPa and 79.17 MPa in the PMMA denture base group after 2000 and 5000 cycles of thermocycling. When the PMMA and PEEK denture bases were tested for impact strength, it was discovered that the PEEK base's mean value of 6.94 KJ/m² was higher in the control group than the PMMA base's mean value of 4.02 KJ/m². In a similar way the PEEK denture base group's mean value of impact strength was 6.68 KJ/m2 after 2000 cycles of thermocycling, and 6.15 KJ/m² after 5000 cycles of thermocycling. This value was also greater than the average impact strength in the PMMA denture base group after 2000 and 5000 cycles of thermocycling, which came out to 2.89 KJ/m² and 1.99 KJ/m², respectively. From these results, it can be concluded that PEEK denture bases had higher flexural and impact strength values than PMMA denture bases in all tested groups.

The results showed a decrease in flexural strength along with the length of use of PMMA caused by the thermocycling process. Research conducted by Raszewski *et al.* stated that the cause of the decrease in flexural strength is the effect of absorption in water which allows water molecules to penetrate into the region between polymer chains and act like wedges between the links. Water enters the polymer during immersion primarily through diffusion, and some unsaturated molecules and unbalanced intermolecular forces cause the polymer chains to become polar. The penetration of water molecules softens the denture base, which lowers the material's mechanical qualities [1].

Sasaki *et al.* in their research stated that the thermocycling process caused a hydration process similar to clinical conditions, therefore acrylic resins absorbed water and broke bonds due to the voids between layers. The primary mechanism by which water enters the polymer material during immersion is diffusion, and unsaturated molecules and imbalanced intermolecular forces contribute to the polymer chain's polarity. The absorbed water softens the denture base because it can penetrate the polymer of the heat polymerization acrylic resin denture base by acting as a plasticizer [25]. As a result, the chains of polymers separate because the water may now occupy the space between them. Additionally, according to Raszewski, modifications to the polymer chains made them unstable under stress, which reduced the impact strength [1].

Takahashi *et al.* attributed the decrease in flexural strength of polyamide thermoplastic base to ongoing thermal changes that caused continuous expansion and contraction which lead to static fatigue of the material, the decrease in flexural strength of polyamide thermoplastic base is caused due to temperature changes [15]. Mc. Keen stated that PEEK was a thermoplastic material with superior mechanical properties where PEEK was also resistant to thermal degradation with a melting point of about 350 °C, High-aromatic polymers exhibited minimal or no branching and were linear. PAEK polymers' linear, aromatic, and structured structure enhances both the material's physical and thermal resistance [26].

With PEEK semi-crystalline structure, it allows to maintain its properties, including dimensional stability, over a wide temperature range. The crystallinity of PEEK also contributes to its strength and impact resistance. PEEK also has a very high melting point around 334 °C and does not exhibit a glass transition, which is a phase change that can weaken polymers. This high melting point and lack of glass transition contribute to PEEK's thermal stability and ability to withstand repeated heating and cooling cycles. These properties contribute to PEEK's exceptional dimensional stability and strength retention, even at elevated temperatures. In terms of water absorption, PEEK shows relatively low water absorption compared to other polymer materials. This makes it difficult for water molecules to enter the polymer chain, which can cause cause a decrease in the mechanical properties of the polymer material [26].

There was a significant effect between PMMA and PEEK mechanical properties after thermocycling. The mechanical characteristics of PEEK were not significantly altered either before or after the thermocycling process, whereas the mechanical properties of PMMA were significantly altered both before and after the thermocycling process. It can be concluded that PEEK exhibits greater longevity and clinical success than PMMA.

One of the study's limitations is that thermocycling was done using destilled water rather than artificial saliva, which may not fully replicate the ionic composition and enzymatic activity of the oral environment. Future studies should validate these findings under simulated saliva conditions."

CONCLUSION

Based on the results of this study it was found that PEEK has better flexural and impact strength compared to PMMA both before and after thermocycling. this shows that PEEK has better strength than PMMA so that by using PEEK as a denture base it is expected to increase the resistance of the denture base in long-term use against fracture. However, further research is still needed on long-term clinical use to support the results of this study.

This study already have ethical approval from Komite Etik Pelaksanaan Penelitian Kesehatan No. 182/KEPK/USU/2023. Author declare no conflict of interest.

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AUTHORS CONTRIBUTIONS

Kriswandy Putra: Data Collection, Analysis, Interpretation, Literature Review, Writing the article, Materials, Fundings, Ismet Danial Nasution: Research concept, Supervision, Design, Critical Review, Muhammad Indra Nasution: Research concept, Supervision, Design, Critical Review, Ariyani: Data Collection, Design, Analysis, Literature review, Critical Review, Anucharte Srijunbarl: Data Collcection and processing

CONFLICT OF INTERESTS

Declared none

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