The Deflection Force of Polyetheretherketone as a Clasp Material for Removable Partial Denture

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Abstract

Polyetheretherketone is one of the polymers developed as a material to produce a removable partial denture clasp. Clasp characteristics that affect retention strength are the clasp's size and shape. This study was conducted to investigate the effect of the dimensions polyetheretherketone rods on the force needed to produce 0.5 mm deflection.

This is a laboratory study. A total of 32 specimens of polyetheretherketone rods were made in 2 lengths (15 mm and 9 mm), 2 thicknesses (2,5 mm and 1,5 mm), and 2 shapes (taper and rectanguler), and were divided into 8 groups. The deflection measurement with a radius of 0.5 mm was carried out using a hydraulic universal testing machine with a speed of 5 mm/min.

The most significant force was found in polyetheretherketone rods which were 9 mm long, 2.5 mm thick, both taper and rectangular, and significantly different from other rod sizes. The rod with a 2.5 mm thickness showed more force than the 1.5 mm. Furthermore, the tapered shape did not show significantly different force than the rectangular shape.

The polyetheretherketone rod's length and thickness affect the force's magnitude for a deflection of 0.5 mm.

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Introduction

A removable partial denture is one of the dental care for a case of partially missing teeth [1]. This denture type is broadly used for several benefits, such as more manageable and economical production than the fixed partial denture and dental implant [2]. One of the removable partial denture components is a clasp, which is responsible for retention. The retention enables the partial denture to stay firmly in the oral cavity [3].

The primary material of the removable partial denture clasp is cobalt-chromium (Co-Cr) alloys. The material has a high modulus of elasticity (220 GPa), making it more rigid [4]. Although such a physical character makes the Co-Cr clasp provide high retention, its usage still leaves several problems, including an allergy reaction, heavy prosthesis, and complex manufacture [5]. A metal clasp can result in tooth decay, such as caries and fractures, and increase the gingival plaque and calculus index [6–8]. During the use of the metal clasp, the retention strength will reduce due to permanent deformation and fractures on the clasp [9,10]. A decrease in retention causes a decrease in mastication ability, leading to the user's dissatisfaction [11]. A broken clasp becomes the main factor in producing the new partial denture after a 5 to 6-year usage [10]. Based on the aesthetic point of view, removable partial denture users will feel uncomfortable if a part of the clasp is visible [12,13]. This issue encourages the researchers to develop a metal-free clasp material [14].

The development of dentistry always strives for better materials that can fulfill the deficiency of the previous material. Polyetheretherketone (PEEK) is one of the materials that has been developed and been proved to demonstrate better elements than the previous one [15]. Polyetheretherketone has good

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biocompatibility and an elastic modulus of 4 GPa, which resembles the elastic modulus of bone [16]. This material does not cause an allergy reaction, is metal fragrance-free, and is more aesthetic [17]. Therefore, PEEK is a good material as a nylon and metal replacement in the removable partial denture treatment [18], although a more in-depth study is still needed.

The removable partial denture retention is obtained from the clasp arm holding the tooth at the tip of the arm in the undercut area [3]. Retention occurs when there is a shifting force in the partial denture, and the most prominent tooth contours restrain the position of the arm clasp. If the shifting force is more significant than the clasp strength, the arm will stretch and move in an occlusal direction, passing the most extensive tooth contours [1]. The clasp and the tooth factors determine the retention strength. The tooth factor covering the depth of the undercut and the tooth size is inspected and performed by a dentist [19]. The clasp factor, including its flexibility, is inspected by the dentist but carried out by technicians in the dental laboratory [20]. The flexibility of the clasp arm is influenced by the length, the diameter, taper, cross-section shape, guiding planes, and the clasp material [21].

Polyetheretherketone has a lower modulus of elasticity than the Co-Cr alloy. It is higher than nylon thermoplastic, so the PEEK flexibility is between Co-Cr alloy and nylon thermoplastic [22]. Therefore, the clasp size made from PEEK can be modified to provide adequate retention [18].

This study aims to identify the effect of the size and shape of the PEEK needed to produce deflection force with a radius of 0.5 mm.

Materials and methods

Specimen Design

Thirty-two pieces of the specimen were produced as a cantilever rod and divided into eight groups. This cantilever rod consisted of 2 parts: the base and the arm parts. The arm part represented the clasp arm and had half cross-section. Furthermore, there were two types of shapes on specimen arms: taper and rectangular. The tapered shape had a wider part of the base than the tip (base: 3,5 mm; tip: 2,5 mm) (Figure 1). The rectangular shape showed when the base and the tip had the same width (3,5 mm) (Figure 2). Specimens are also made in 2 lengths: 15 mm and 9 mm, and two thickness sizes: 3.5 mm and 2.5 mm. In rectangular specimens, the rod had the same base and tip in thickness, while in the taper specimen, the base is thicker than the tip.

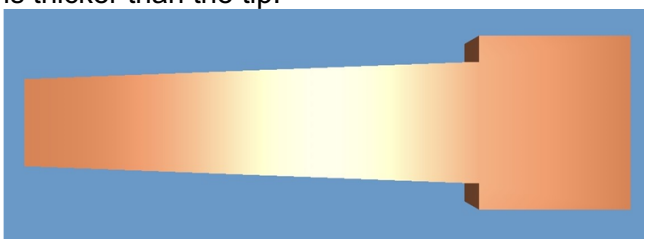

Figure 1. Taper shape.

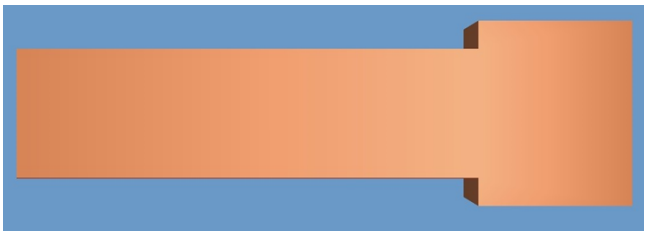

Figure 2. Rectangular shape.

Code	n	Shape	Length (mm)	Base		Tip	
				Width (mm)	Thickness (mm)	Width (mm)	Thickness (mm)
T.9.1	4	Taper	9	3.5	2.5	2.5	2.3
T.9.2	4	Taper	9	3.5	1.5	2.5	1.3
T.15.1	4	Taper	15	3.5	2.5	2.5	2.3
T.15.2	4	Taper	15	3.5	1.5	2.5	1.3
R.9.1	4	Rectangular	9	3.5	2.5	3.5	2.5
R.9.2	4	Rectangular	9	3.5	1.5	3.5	1.5
R.15.1	4	Rectangular	15	3.5	2.5	3.5	2.5
R.15.2	4	Rectangular	15	3.5	1.5	3.5	1.5

*n: number of specimens

Table 1. The size of the PEEK rod's arm.

Each group was given a code based on its size and shape. The code consisted of 3 parts, and each part was separated by a dot (.). The first part showed the shape of the rod; T for taper and R for rectangular. The second part showed the length of the rod, 15 mm or 9 mm. The third section shows the thickness of the rod base; code 1 showed a 2.5 mm thickness, and code 2 showed a 1.5 mm thickness. The arm size and code for each group are shown in Table 1.

Group	n	Force (N) ± SD
T.9.1	4	20.475 ± 0.7273
T.9.2	4	7.575 ± 0.2175
T.15.1	4	7.025 ± 0.0250
T.15.2	4	3.900 ± 0.0707
R.9.1	4	20.450 ± 1.1765
R.9.2	4	7.675 ± 0.4871
R.15.1	4	5.825 ± 0.3326
R.15.2	4	3.900 ± 0.180

*n: number of specimens ; N: newton ; SD: Standard Deviation

Table 2. The mean force for 0.5 mm deflection.

Group T.9.1 shows specimens with a tapered shape, 9 mm in length, and a type 1 thickness, i.e., a thickness at the base of 2.5 mm and a thickness at the tip of 2.3 mm. Group T.9.2 shows specimens with a tapered shape, 9 mm in length, and a type 2 thickness, i.e., a thickness at the base of 1.5 mm and a thickness at the tip of 1.3 mm. Group T.15.1 shows specimens with a tapered shape, 9 mm in length, and a type 1 thickness, i.e., a thickness at the base of 2.5 mm and a thickness at the tip of 2.3 mm. Group T.15.2 shows specimens with a tapered shape, 9 mm in length, and a type 2 thickness, i.e., a thickness at the base of 1.5 mm and a thickness at the tip of 1.3 mm.

Group R.9.1 shows specimens with a rectangular shape, 9 mm long, and type 1 thickness, which is 2.5 mm thick both at the base and the tip. Group R.9.2 shows specimens with a rectangular shape, 9 mm long, and type 2 thickness, which is 1.5 mm thick both at the base and the tip. Group R.15.1 shows specimens with a rectangular shape, 15 mm long, and type 1 thickness, which is 2.5 mm thick both at the base and the tip. Group R.15.2 shows specimens with a rectangular shape, 9 mm long, and type 2 thickness, which is 1.5 mm thick both at the base and the tip.

Producing Specimen

The production of the PEEK specimen used the injection molding method. The modeling wax and its sprue were molded using certain investment materials. The mold was put into preheating furnace and heated slowly with an average temperature increase of 8°C per minute, up to 630° C. Next, the mold was cooled to a temperature of 400° C. The BioHPP pellet (Bredent, Chesterfield, UK) was added to the mold, entered into the preheating furnace, and heated for 20 minutes at 400° C. The press plunger was put on top of the mold and quickly moved into the pressing unit. 0.45 MPa was given in the vacuum condition. After that, the mold is cooled and continued with the devesting process. The investment material was removed, then the PEEK specimen was finished and polished (Figure 3).

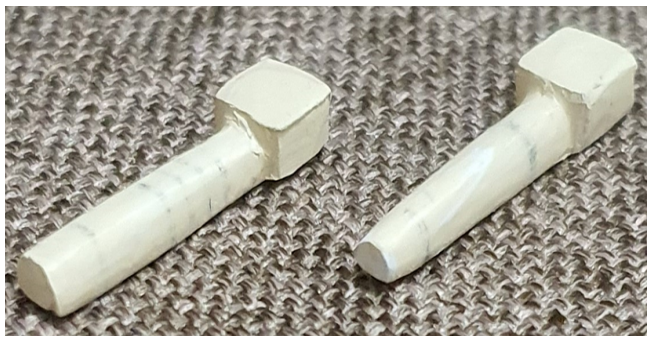

Figure 3. Polyetheretherketone specimen.

Force Measurement

This study aims to identify the force needed to move the tip by 0.5 mm. This test used a hydraulic universal testing machine (Tokyo Testing Machine, Japan). This tool is equipped with a plate on the bottom that can move vertically to the top. A fixed rod was placed facing downwards on the top of the tool. The base of the specimen was fixed on an artificial fixator and placed on the bottom plate. The fixator position was set, making the arm specimen touch the rod's tip at the top (Figure 4).

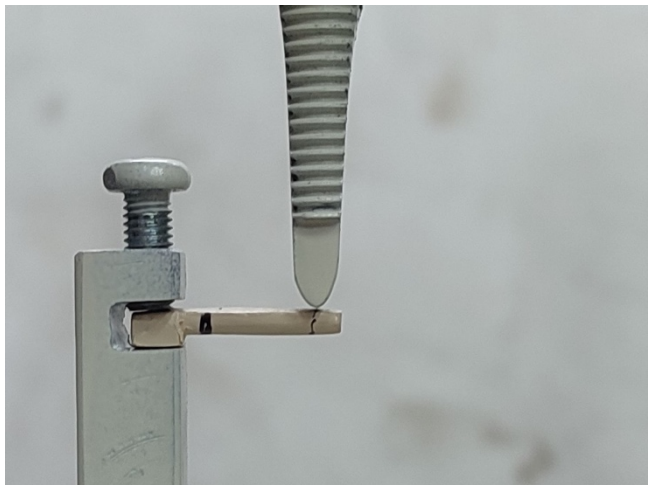

Figure 4. Position of the specimen during testing.

Furthermore, the speed of the bottom plate was set at 5 mm/min. The range of movement of the lower plate is also controlled by 0.5 mm and 0.75 mm by placing a Peacock dial gauge (Ozaki MFG, Japan) on the lower plate. When the bottom plate moved vertically, the arm tip of the specimen was pushed by the rod as far as 0.5 and 0.75 mm. The force magnitude produced from the shifting arm tip was then recorded. Each specimen was treated ten times, then the average was calculated.

The data were analyzed statistically using SPSS version 26 (IBM Corp, New York). If the data are homogeneous and normally distributed, a one-way ANOVA test will be conducted to identify the difference between the groups. A Duncan post hoc test will be conducted if there is a difference.

Results

Measurement of the Deflection Force

The mean force on all specimen groups is displayed in Table 2. In the group of taper-shaped specimens, tremendous force is obtained from the specimen with 9 mm in length and thickness type 1. On the other hand, the minor force is obtained from the specimen with 15 mm in length and thickness type 2.

In the rectangular group, the enormous force is obtained from the specimen with 9 mm in length and 3.5 mm in thickness (type 1). On the other hand, the most negligible force is obtained from the specimen with 15 mm in length and 2.5 mm in thickness (type 2).

Based on the magnitude of the force, it can be divided into four groups. It started from a group with the most significant force of 9 mm in length and thickness type 1, both taper and rectangular shape. It was followed by a group of specimens with 9 mm in length and thickness type 2, both taper and rectangular shape, and a group of taper specimens with 15 mm in length and thickness type 1. The third group was a group of rectangular specimens with 15 mm in length and thickness type 1. The lowest force was shown in a specimen group with 15 mm in length and thickness type 2, both taper and rectangular shape.

Statistical Analysis

Statistical analysis with SPSS version 26 showed homogeneous and normally distributed data. One-way ANOVA test showed p = 0.000, indicating a significant difference between the groups (Table 3). The Duncan post hoc test was performed to identify the distinguished pair of groups. The Duncan post hoc summary is shown in Table 4.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1318.622	7	188.375	161.999	.000
Within Groups	27.907	24	1.163		
Total	1346.530	31			

Table 3. One-way ANOVA

Group	Mean of Deflection Force
T.9.1	20.475 [e]
T.9.2	7.575 [cd]
T.15.1	7.025 [bc]
T.15.2	3.900 [a]
R.9.1	20.450 [e]
R.9.2	7.675 [d]
R.15.1	5.825 [b]
R.15.2	3.900 [a]

*Note: A value with the same letter is not distinguished at a significance level of 5%.

Table 4. Duncan post hoc summary.

Based on the post hoc summary, it can be seen that the mean deflection force of the T.9.1 group was not significantly different from the R.9.1 group. Similarly, group T.15.1 did not differ from group R.15.1, group T.15.2 did not differ from group R.15.2, and group T.9.2 did not differ from group R.9.2 and T.15.1, and vice versa. In contrast, the pairs of other groups have a mean value of the deflection force that differs significantly from each other.

Discussion

Retention is such an essential character in dentures. It enables the denture to remain firm during use. The removable partial denture component responsible for the retention is a direct retainer, one of which is a clasp[3]. This research specifically identified PEEK rod as a material for clasp production. Due to its sound characteristics, this material was considered a replacement for the Co-Cr alloy [17,18].

The specimens in this study were subjected to a force at the tip, resulting in a deflection of 0.5 mm. It reflected the arm clasp

movement when forces tried to release the clasp from the abutment teeth. The recorded force magnitude was the maximum limit the clasp could withstand before being released from the abutment teeth [1,18]. In other words, the force needed to move the tip of the specimen at a 0.5 mm distance was the retention strength of the PEEK specimen.

This research specimen was made in 2 variations of sizes for the length, thickness, and shape of the arm. The result showed that the most significant force was obtained from the taper-shaped specimen with 9 mm in length and thickness type 1. The force magnitude was similar to the rectangular specimen with 9 mm in length and thickness type 1. If both groups are compared to the specimen with the 9 mm in length, thickness type 2, and both taper and rectangular shape, there will be a significant difference. It indicates that thickness becomes a differentiating factor on the arm with 9 mm in length, while the shape has no significant effect on the force for 0.5 mm deflection.

If all specimen groups with 9 mm in length are compared with all the groups with 15 mm in length, generally, there will be a significant difference. It indicates a contribution factor of arm's length on the force magnitude. The arm length is measured from the base to the tip. The longer the arm, the bigger the flexibility [21].

Furthermore, in terms of the thickness, the specimen with thickness type 1 had a more considerable deflection value than the specimen with thickness type 2 between groups of the same shape and length. Statistical analysis showed a significant difference. It indicated that thickness also played a role in deflection force. The thicker the arm is, the lower the flexibility will be. The correlation between the arm size and the flexibility has been formulated mathematically through the cantilever beam deflection formula: $D=4PL^3/Ewt^3$ (D:deflection; P:power; L:length; E: modulus of elasticity; w:width; t:thickness) [23].

The value of the deflection in the formula showed flexibility. The deflection magnitude is directly proportional to the length but inversely proportional to the width and thickness. As a result, the longer the clasp, the bigger the flexibility. Furthermore, the lower the width and the thickness of the clasp, the bigger the flexibility. It resulted in a decrease in P value (power) as a retention strength [23]. Therefore, a flexible clasp will quickly produce deflection, although the force will likely be lower.

In this study, the lowest deflection force was 3.9 N, and the minimum retention strength on the removable partial denture clasp was 1.6 N [24]. It indicated that the PEEK could be considered suitable material for the removable partial denture clasp.

Conclusions

Based on the result of this study, it can be concluded that PEEK showed a more considerable deflection force than the minimum retention strength of the removable partial denture clasp. Clasp length has a significant effect on deflection force. The deflection force on PEEK can be upgraded by reducing the arm length and adding the arm thickness so that the retention strength on the PEEK clasp can be clinically applicable.

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All authors have made substantive contribution to this study and/or manuscript, and all have reviewed the final paper prior to its submission.

Declaration of Interest

The authors report no conflict of interest.

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