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Original article

Retention of CAD PEEK versus metallic partial denture frameworks in patients with mandibular Kennedy Class I

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ABSTRACT

Background: *Traditionally, removable partial denture (RPD) frameworks have been made from metal alloys, with patients expressing dissatisfaction regarding esthetics, metallic taste, and weight. Several attempts have been made to introduce new materials suitable for RPD frameworks.* ***Purpose:*** *This study aims to compare the retention of polyetheretherketone (PEEK) and metallic computer-aided designed (CAD) removable partial dentures (RPD) in patients with mandibular Kennedy Class I.* ***Methods:*** *Twenty-four patients with Kennedy Class I partially edentulous mandibles were randomly assigned to two parallel groups. Computer-aided design of the RPD's frameworks was used to produce a sacrificial resin pattern, then cast into cobalt chromium (Co-Cr) or pressed into PEEK to produce RPD frameworks. An acrylic resin denture base and teeth were attached to the framework, processed, finished, polished, and delivered to the patients. Retention in Newtons was measured for both groups by pulling the RPDs from their geographic center at the time of insertion, after one and three months.* ***Results:*** *At each time interval, a repeated measures ANOVA revealed statistically significantly higher mean retention values for the metal group compared to the PEEK group. Retention did not decrease significantly in the PEEK group, whereas a significant retention decrease was observed in the metal group. An independent student's T-test revealed a significant difference between retention loss for the metal and PEEK groups.* ***Conclusion:*** *Within the limitations of this study, although metal RPD frameworks provide higher mean retention values than PEEK RPD frameworks, both show clinically acceptable retention levels. Nevertheless, PEEK maintains retention more than metal in the short term.*

Keywords: *CAD/CAM; mandibular Kennedy Class I; PEEK; Retention; RPD*
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INTRODUCTION

Tooth loss substantially impacts various aspects of a patient's life, including overall health, psychological well-being, aesthetics, and function, ultimately leading to a diminished quality of life.[1,2] Aiming to avoid this, patients seek to restore lost teeth either by tooth or implant, supported or retained, fixed or removable partial dentures (RPDs).[3] Although, in many clinical scenarios (such as the absence of distal abutment or long edentulous span), RPDs could be considered the optimum solution, particularly when there are anatomical, psychological, or financial limitations for using dental implants.[4,5] Removable partial dentures offer benefits such as being noninvasive and more cost-effective. Consequently, there is a growing demand for RPDs, with ongoing efforts to enhance materials and techniques for their construction.[6]

In the current era of digital dentistry, important advancements in computer-aided design (CAD) have led to the availability of software packages tailored for designing removable partial dentures, addressing numerous challenges associated with traditional techniques.[7] The computer-aided designed RPD has several advantages, including instant surveying, automatic determination of the best path of insertion, easy blockage of undesirable undercuts, accurate measurement of desirable undercuts, controlling the thickness of the RPD framework with high precision and reliability, all while reducing time and effort. These advancements contribute to improved quality standards in dental laboratories.[8,9]

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Traditionally, metal alloys have been the material of choice for RPD frameworks owing to their excellent rigidity, thermal conductivity, and affordability with low cost.[10,11] However, patients often express dissatisfaction with metal frameworks due to issues such as metallic taste, allergic reactions, increased weight, and poor aesthetics.[9,10] Accordingly, with the growing interest in metal-free prosthetics, thermoplastic polymers have emerged as potential substitutes for metal in RPD frameworks as thermoplastic polyamide (nylon), thermoplastic polyester (polycarbonate), thermoplastic acetal and polyetheretherketone (PEEK)[12,13] Nylons and polycarbonates, however, lack the necessary rigidity and occlusal rests, leading to sinking and occlusal instability, which renders nylons and polycarbonates unsuitable for definitive partial denture frameworks.[13,14] Conversely, acetal provides sufficient rigidity in thick sections but may be less comfortable for the tongue and covers more of the teeth.[7,12]

Polyetheretherketone is a partially crystalline high-performance polymer that has been used in dentistry due to its optimal stiffness, tensile strength and toughness, low moisture absorption, excellent chemical stability to organic and inorganic compounds, high melting point (around 343°C), high chemical resistance, excellent biocompatibility and low modulus of elasticity simulating that of enamel, dentin and bone.[15] Owing to this property, the use of PEEK as an RPD framework in Kennedy Class I instances reduces the distal torque and strains on the abutments.[11,16,17]

Retention is a critical aspect of mandibular RPDs, with a lack of retention being a commonly reported complication. Yamamoto et al.[18] found that a retention force of 4–5 N was sufficient to meet patient satisfaction. Peng et al.[19] highlighted that PEEK clasps exhibit superior flexibility, enabling them to engage deeper undercuts with reduced force transmitted to the abutment. However, this flexibility could adversely impact retention.[20] Accordingly, this clinical study aims to compare the retention of RPD frameworks manufactured from PEEK and metal (Co-Cr) using CAD. The hypothesis was that both would yield similar retention values.

MATERIALS AND METHODS

This research was a randomized clinical trial with a parallel design and allocation ratio of 1:1. In this study, the statistician was blinded; however, neither the operator nor the patient could be blinded due to the difference in color between the two RPDs.

Ethical approval for this research was granted by the Research Ethics Committee, Faculty of Dentistry, Cairo University, with number (9-11-22). The protocol registration number is NCT05670899 on clinicaltrials.gov.

Sample size calculation was done using the R statistical package, version 3.5.2 (23-04-2018) Copyright © 2018, the R Foundation for Statistical Computing. As reported in Maryod and Taha,[21] the difference between study groups regarding retention was 18.55 (SD=2.97). To calculate Cohen's d Effect size, we used the equation (d=Mean Difference / SD); therefore, d=4. T-test power calculation was used to detect the proper sample size at a 0.05 significance level and 80% power. We added 15% compensation for the non-response rate.

The results showed that a total sample size of 24 patients, including the 15% compensation stated above (equally allocated to two groups; 12 patients per group), is adequate to detect a mean difference in retention between study groups of 18.55 mm (SD=2.97) with a power of 80% and a two-sided significance level of 5%.

Participants included in this trial were patients presenting with a Kennedy Class I partially edentulous mandible with the last remaining abutment a premolar, all abutments sound or restored and exhibiting vital pulp, a well-developed ridge, opposing dentition fully intact or restored, Angle's Class I maxilla-mandibular relationship, good oral hygiene, and willingness to cooperate and commit to follow up. Patients with uncontrolled diabetes, HbA1c exceeding 7.5, osteoporosis, neural disorders, inter-arch space less than 7 mm, or who refused to participate in the trial were excluded from the study.

From the out-patient clinic of the Prosthodontics Department, Faculty of Dentistry, Cairo University, a total of twenty-seven patients were assessed for eligibility, and twenty-four patients (twenty-two females and two males) who met the eligibility criteria were enrolled in this study (Figure 1).

Every patient underwent a comprehensive preoperative evaluation through the collection of medical and dental history, thorough clinical examination, and a periapical digital radiograph for principal abutments. Primary impressions using irreversible hydrocolloid impression material (Trapicalgin, Zhermack SpA, Italy) were made to obtain study casts. The study casts were used to confirm diagnosis and determine a possible treatment plan, then casts were digitized using a bench scanner (DOF – Freedom HD Dental Scanner) to allow digital primary surveying to determine the mouth preparations needed and confirm the proposed design. A facebow (Bio-Art Equipamentos Odontológicos Ltda) record was done to help mould the maxillary cast, and then the lower cast was mounted using a jaw relation record.

At this stage, computer-generated simple randomization (www.Random.org) was used to randomly assign participants into two parallel groups. The intervention group received a PEEK RPD, and the control group received a metallic RPD. This ensured equal allocation of interventions and controls. From a box, each person picked up an opaque sealed envelope, which included a number that matched the treatment group; this ensured allocation concealment.

Mouth preparations were then done according to the proposed design, including a meshwork saddle, lingual

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plate major connector, RPA (rest, proximal plate, Akers) retainer, and an indirect retainer in the form of a rest on the distal side of the abutment adjacent to the principal abutments.

A diamond fissure stone size 14 was used to prepare the guiding planes on the distal surface of the abutment. On the mesial side of the principal abutments, a round carbide bur size 4 was used to prepare the occlusal rest seats, rounded triangular with the base at the marginal ridge and apex toward the central fossa. The floor was spoon-shaped, deeper toward the central fossa, and deeper for the PEEK group (0.5 mm). If no undercut was present on the buccal surface, it was created using a round stone size 25. Secondary impressions were made using addition silicone impression material (Ghenesyl addition silicone, Lascod, Italy) and poured using extra-hard dental stone type IV (SHERA Werkstoff-Technologie GmbH & Co. KG) to obtain the master cast.

A bench scanner (DOF – Freedom HD Dental Scanner) was used to scan the master casts. RPD frameworks were then digitally designed in compliance with RPD principles and manufacturer instructions for the two materials, then 3D printed into a castable resin pattern. The finished resin pattern was then cast into metal (Co-Cr) by conventional

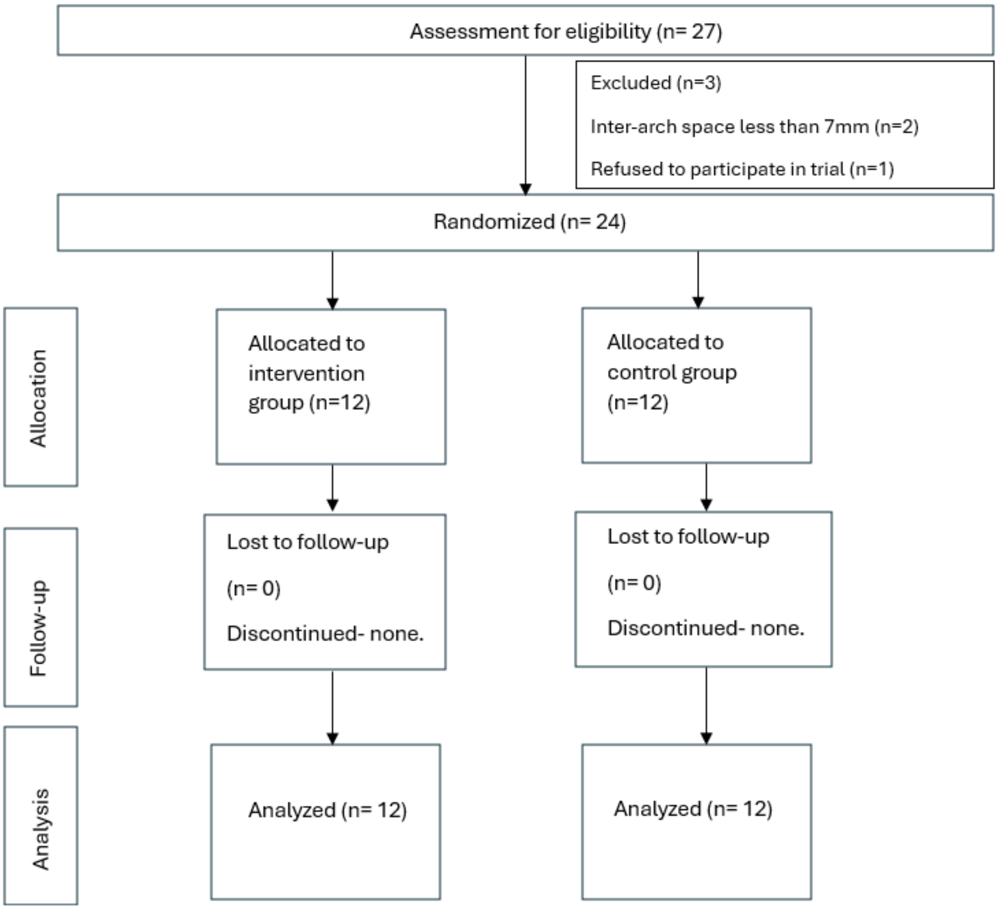

Figure 1. Study flowchart.

Figure 2. Intra-oral try-in of the metal and PEEK frameworks.

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casting for the control group or vacuum pressed into PEEK using a For2Press machine for the intervention group. The frameworks were then finished, followed by intra-oral try-in of the metal and PEEK to check framework seating, stability, retention, and occlusal interferences using pressure-indicating paste and articulating paper (Figure 2). Necessary adjustments were made, and the frameworks were polished.

A jaw relation record was made with the aid of the frameworks to mount the master casts on a semi-adjustable articulator (Bio-Art Equipamentos Odontológicos Ltda). This was followed by setting up artificial teeth, and a try-in was performed intra-orally. The denture base was waxed, followed by wax elimination, flasking, and acrylic resin processing done conventionally. The produced denture was finished and checked clinically for seating and painful areas using pressure-indicating paste.

On the duplicate of the master cast, the geographic center was determined by drawing four lines on the cast (Figure 3).[23] The first line connected the apices of the retromolar pad, and the second line passed through the incisal edge of the central incisors and parallel to the first line. The third line passed through the midline, intersecting with the other lines. A point was determined midway between the two lines along the third line; this point is the geographic center where the hook should be placed. The fourth line was drawn parallel to the first two lines at the point of the geographic center. Three 18-gauge orthodontic wire loops were attached: two on the lingual flanges posteriorly and one anteriorly, ensuring the hook was placed in the geographic center.

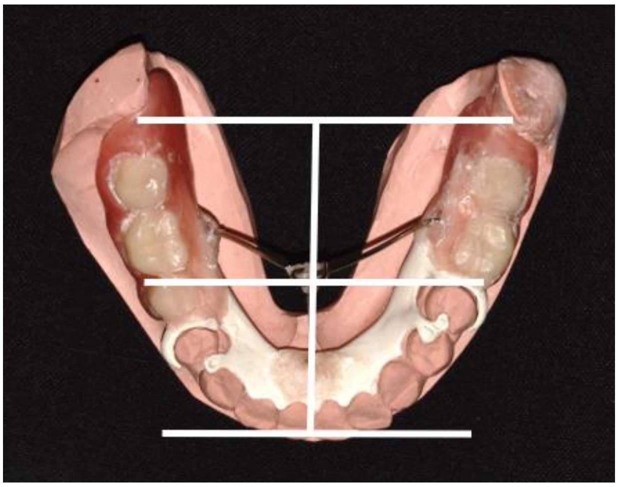

Figure 3. Determining the geographic center.

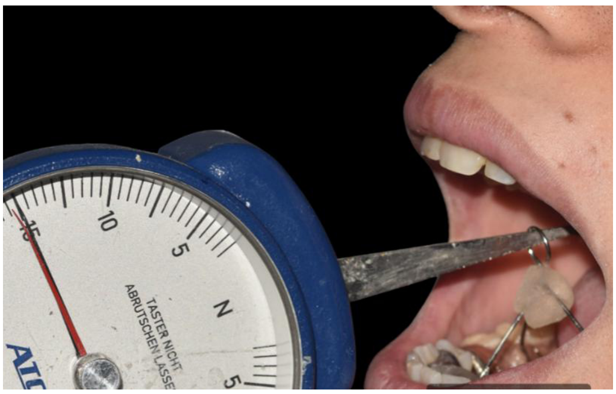

Figure 4. Measuring retention.

In terms of Newton (N), a spring balance (Atorn, Hommel Hercules, Germany) was used to measure RPD retention at the time of denture insertion, after one month, and three months later. The measurements were performed while the patients were sitting in an upright position with the head on the headrest and the occlusal plane parallel to the floor (Figure 4). The process was repeated until three readings were obtained, and the average was recorded.

After the measurements were taken, the orthodontic wires were removed, and the point of attachment of the wires was marked using a large round bur for attaching the same wires during the remaining time intervals. The RPDs were polished and delivered to the patient. The collected data were tabulated and statistically analyzed.

Data were analyzed using the statistical package SPSS version 22 and examined for normality using the Shapiro-Wilk test. Data were normally distributed and therefore were expressed as mean and standard deviation (SD). A repeated measures ANOVA was used to compare different timelines: at insertion, after one month, and after three months for both PEEK and metal frameworks. When a repeated measures ANOVA yielded significant results, it was followed by Tukey's post hoc pairwise comparison between groups. An independent student's T-test was used to compare PEEK and metal frameworks at each timeline, at insertion, after one month, and after three months. An independent student's T-test was also used to compare between retention loss for both PEEK and metal frameworks. Retention loss percentage was calculated as the percentage of difference between retention values at insertion and retention values at three months for both PEEK and metal frameworks, as follows:

$$\frac{At\ insertion - three\ months \times 100}{At\ insertion}$$

RESULTS

Intra-group comparison for the effect of time on retention: PEEK retention showed no significant difference over time, with the highest mean value at insertion (13.50±0.213 N) and the lowest at three months (13.04±0.144 N; Table 1). Metal frameworks recorded the highest mean retention value at insertion (21.37±0.644 N), and the lowest mean value was recorded after three months (18.50±0.640 N). A repeated measures ANOVA revealed a statistically significant decrease in retention with time ($p<0.05$). (Table 1). Tukey's post hoc pairwise comparison revealed a significantly higher retention at insertion when compared with one month and three months. A significantly higher

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retention was also observed at one month when compared with three months (Table 2).

Inter-group comparison of retention mean value: At insertion, a significantly higher mean value was recorded in metal frameworks (21.37±0.64 N) when compared with PEEK frameworks (13.5±0.21 N; P<0.05). At one month, a significantly higher mean value was also recorded in metal frameworks (19.67±0.577 N) when compared with PEEK frameworks (13.25±0.26 N; P<0.05). Similarly, at three months, a significantly higher mean value was also recorded in metal frameworks (18.5±0.640 N) when compared with PEEK frameworks (13.04±0.144 N; P<0.05; Table 3).

Inter-group comparison for the decrease in retention by time: A statistically significantly higher mean decrease in retention was observed in metal frameworks with time (21.29±3.86 %) when compared with PEEK frameworks (3.37±1.86 %; P<0.05; Table 4).

DISCUSSION

This study aims to compare the retention provided by CAD PEEK and CAD Co-Cr RPD frameworks. As the mean retentive values were significantly higher for Co-Cr than PEEK RPD frameworks, the hypothesis of this study was rejected.

Assessing retention is of paramount importance due to its association with the main complaint often reported regarding mandibular dentures: decreased retention, which typically correlates with diminished patient satisfaction.[18,21,22] A systematic review in 2023 by Dawid et al.[23] found retention to be one of the most commonly reported technical complications for RPDs.

Although retention is identified as a primary reason for discontinuing denture wear, there is no consensus in the literature regarding the technique or instrument to be

Table 1. Descriptive statistics and comparison of retention for PEEK frameworks and metal frameworks at insertion, after one month, and after three months (repeated measures ANOVA)

Material	Time	Mean ± SD	Std. Error	Min	Max	F-Value	Adjusted P-Value
PEEK frameworks	At insertion	13.50±0.213	0.0615	13.000	14.000	1.28	0.300
	One month	13.25±0.261	0.0754	13.000	13.500		
	Three months	13.04±0.144	0.0417	13.000	13.500		
Metal frameworks	At insertion	21.37±0.644 [A]	0.186	20.500	22.500	9.83	0.000*
	One month	19.67±0.58 [B]	0.167	18.500	20.500		
	Three months	18.50±0.640 [C]	0.185	17.500	19.500		

Significance level P<0.05, *significant. Means with different superscript letters are significantly different.

Table 2. Tukey's post hoc pairwise comparison between groups for both materials

Material	Difference of Levels (time *material)		95% Confidence Interval	T-Value	Adjusted P-Value
Metal frameworks	At insertion	Three months	(2.554, 3.196)	22.51	0.000*
	One month	Three months	(0.846, 1.487)	9.14	0.000*
	One month	At insertion	(−2.029, −1.388)	−13.38	0.000*

Significance level P<0.05, *significant.

Table 3. Independent Student's T-test for comparison between PEEK frameworks and metal frameworks at insertion, after one month, and after three months

Time	Group	Mean ± SD	Mean difference	95% CI for Difference	P value
At insertion	Metal frameworks	21.37±0.64	7.875	(−8.298, −7.452)	0.000*
	PEEK frameworks	13.5±0.21			
One month	Metal frameworks	19.67±0.577	6.417	(−6.807, −6.027)	0.000*
	PEEK frameworks	13.25±0.261			
Three months	Metal frameworks	18.5±0.640	5.458	(−5.871, −5.046)	0.000*
	PEEK frameworks	13.04±0.144			

Significance level P<0.05, *significant.

Table 4. Independent Student's T-test for comparison of decrease in retention between PEEK frameworks and Metal frameworks

	Group	Mean ± SD	Mean difference	95% CI for Difference	P value
Decrease in retention (%)	Metal frameworks	21.29±3.86	17.92	(−20.55, −15.28)	0.000*
	PEEK frameworks	3.37±1.86			

Significance level P<0.05, *significant.

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used as a gold standard for measuring retention clinically.[7] Additionally, there is a debate regarding the acceptable retention value. Yamamoto et al.[18] reported that four to five N would provide clinically acceptable retention, whereas Lyu et al.[24] found that acceptable retention could be two to 10 N. However, Alageel et al.[25] highlighted a deficiency in the guidelines to determine suitable retention and tried to find a way to determine it clinically. They measured the forces exerted by sticky food on each tooth and found that caramel candy produced forces ranging between 4.7 to 12.2 N on mandibular premolars and molars. Consequently, they concluded that the retentive forces of the clasps needed to be higher to ensure sufficient retention.[25] Accordingly, given the results of the current clinical study, both metal and PEEK could provide clinically acceptable mean retention values.

In the current study, Co-Cr RPD frameworks showed significantly higher mean retention values than PEEK at all time intervals; however, the retention values of both groups were within the clinically acceptable retention level. This was in agreement with several authors who reported higher retention values of Co-Cr than PEEK, regardless of the clasp design and method of retention measurement.[26–30] The difference in mean retention values was attributed to the rigidity of the metal clasps with corresponding increased flexibility of the PEEK clasps. Tribst et al.[20] observed that PEEK clasps offer inadequate retention, possibly due to the use of smaller cross-sectional areas and increased lengths of the retentive arm, practices that diverge from recommendations provided by other studies. In contrast, Muhsin et al.[31] found that PEEK clasps provide higher retention values than CO-Cr, which was attributed to engaging a deeper undercut of 0.75 mm.

In this study, within the PEEK group, there was no significant change in retention over time; on the other hand, there was a significant decrease in retention for the metal group over time. Between the PEEK and metal groups, there was a significant difference, with metal showing significantly higher retention loss over time. The lower modulus of elasticity (4 GPa) of PEEK is thought to contribute to a reduced amount of retention loss over time, whereas the higher modulus (240 GPa) of Co-Cr leads to significant retention loss due to the permanent deformation of the metal.[31,32] Conversely, Gentz et al. found that both PEEK and Co-Cr clasps show an initial increase in retentive forces followed by a continued decrease after simulated use.[30]

The short follow-up period could be considered a limitation of this study, and further studies with a longer follow-up period are recommended. PEEK is a promising material with many advantages and continuous improvement; however, studies conducted to test this material as an RPD framework under clinical conditions are lacking. The presence of milled PEEK with a higher modulus of elasticity might provide better retention properties than pressed PEEK, and milled Acetal may combine the advantages of both PEEK and Co-Cr. Therefore, future studies could test the retentive properties of milled PEEK and milled Acetal clasps, as different types of clasps may provide different results due to engaging different depths of undercut and different modes of action as RPI clasps (rest, proximal plate, I-bar clasps). Although of great importance, retention is not the only factor affecting patient satisfaction results,[33] where low retention values do not necessarily indicate unsatisfied patients. Therefore, further research into the correlation between patient satisfaction and retention would be valuable.

Clinical implications: Due to their high cost and complicated production process, PEEK RPDs are only suggested for patients who specifically desire an RPD with reduced weight and improved aesthetics.

In conclusion, within the limitations of our study, although metal RPD frameworks provided higher mean retention values than PEEK RPD frameworks, both showed clinically acceptable retention levels. Nevertheless, PEEK maintained retention more than metal in the short term.

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