Evaluation of Conventionally Constructed Co-Cr versus Milled PEEK Frameworks for Kennedy Class I Partial Dentures

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Evaluation of Conventionally Constructed Co–Cr versus Milled Polyetheretherketone Frameworks for Kennedy Class I Partial Dentures

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Abstract

Purpose: The study intended to evaluate the retention forces of conventional cobalt chrome (Co–Cr) framework and computer-aided design/computer-aided manufacturing (CAD/CAM) milled Polyetheretherketone (PEEK) framework for removable partial dentures (RPD). **Patients and methods:** Ten mandibular Kennedy class I patients were chosen. All the patients had bilateral lower first premolars as anterior abutments. The patients were supplied with the conventional Co–Cr framework and CAD/CAM milled PEEK framework for RPD. The retention for both types of dentures was evaluated by the universal testing machine at the time of insertion, 6 months after insertion, and 12 months after insertion. **Results:** The forces of retention for the conventional (Co–Cr group) were significantly greater than that of the CAD/CAM milled (PEEK group) catching the same undercuts. **Conclusions:** A statistical significance was recorded in the force of retention between the CAD/CAM milled PEEK framework and the Co–Cr framework in favor of Co–Cr. However, the force of retention for CAD/CAM milled PEEK framework for RPDs was within the adequate limits needed for retaining the RPD.

Keywords: Computer-aided design/computer-aided manufacturing, Co–Cr, Polyetheretherketone, Removable partial denture

1. Introduction

The goal of replacing lost teeth is to meet the patients' aesthetics and function. Removable partial dentures (RPD) are still the preferred treatment choice for patients with chronic diseases who have long saddles with significant resorption of bone regardless of developments in dental implants [1].

RPD have been made conventionally from metal alloy and were found to be an economical and reliable choice. However, the drawbacks of metal clasps include their unattractive appearance, great weight, taste of metal, and metal allergies [2].

Several examples of incorrect adaptation of metal alloy framework parts were documented. This could be solved by modest modification on the dental chair or substantial demand creation of another cobalt chrome (Co–Cr) removable partial denture framework [3].

Material industry and new technologies provide recent materials with better characteristics for RPD. Biocompatible thermoplastic materials with better aesthetics, lower plaque affinity, and characteristics comparable to dental structure are available now [4].

A quite new class of thermoplastic materials called Polyetheretherketone (PEEK), which is a linear polymer semi-crystalline in nature composed of a molecule of aromatic chains formed by ether and ketone groups [5].

PEEK has many benefits, such as being a stiff, non-allergic material with low plaque affinity and heat stability up to 335.8 °C, as well as being white in color and radiolucent. PEEK has a modulus of

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flexibility up to 140−170 MPa, mass is 1300 kg/m^3, elastic modulus (Young's) is 3−4 GPa, and conductive thermally up to 0.29 W/mK [6].

PEEK shows a relatively low elastic modulus that is comparable with bone elasticity. They offer cushion impact, and they simplify the forces that are transmitted to the abutment teeth [7].

Studies showed that PEEK has good biocompatibility, with no toxic properties or mutagenic effects. PEEK has stable mechanical qualities that do not alter through steam sterilizing, ethylene oxide, or radiation with gamma. It also does not cause clinically significant inflammation [8].

The CAD/CAM technology has many benefits over the conventional techniques including the virtual manufacturing of the frameworks and digital surveying of casts which precisely determines the desired undercuts. In addition, with the CAD/CAM technology, smaller gap distances in all the clasp regions were achieved as compared with the conventional technique [9].

The partial denture frameworks constructed by CAD-CAM technology significantly showed higher fit, fewer abutment teeth mobility, and less bone resorption recorded compared with the conventionally fabricated removable partial denture frameworks [10].

Recent studies showed that the milled PEEK frameworks showed acceptable retention forces and greater adaption to the underlining tissues with satisfying esthetics so that the PEEK frameworks can be used as a substitute for conventional Co−Cr frameworks with poor esthetics [11].

So, the study aimed to answer the following question: would the use of CAD/CAM milled PEEK framework for RPDs enhance the retention force compared with conventional Co−Cr framework for RPDs?

2. Patient and methods

The study aimed to evaluate the retention of CAD/CAM milled PEEK framework compared with the Co−Cr framework for RPDs as a control group.

2.1. Study design

Ten patients were selected to have mandibular Kennedy class I from the Outpatient Clinic of the Removable Prosthodontic Department. Faculty of Dental Medicine for Girls. Al-Azhar University.

All the patients had bilateral lower first premolar as abutments and the opposing was edentulous maxillary arch. Abutment teeth were free from any caries, restorations, mobility, or any periodontal disease. All patients had reasonable inter-arch distance. The distance between the floor of the mouth and the gingival margin in all patients was greater than 8 mm. The patients were supplied with a conventional Co−Cr framework and CAD/CAM milled PEEK framework for RPD. The study was approved by the Research Ethics Committee of the Faculty of Dental Medicine for Girls, Al-Azhar University, and had an approval code (REC-PR-23-01).

2.2. Study grouping

Twenty dentures were fabricated for ten patients, two sets for each patient, and were divided into two groups:

2.2.1. Co−Cr group

Ten RPDs had frameworks constructed by conventional Co−Cr technique (the control group).

2.2.2. PEEK group

Ten RPDs had frameworks constructed by milled PEEK using CAD/CAM technology.

2.3. Clinical steps

The design for the two types of frameworks was as follows: combined denture base (meshwork), rest, proximal plate, I bar (RPI) clasp as a direct retainer (mesial rests on the first premolars, I bar catching the mesiobuccally undercut and proximal plate at the distal surface of the abutment teeth), lingual bar as a major connector and cingulum rests on the canines as an indirect retainer.

2.4. Construction of Co−Cr frameworks

For the construction of the Co−Cr removable partial denture, upper and lower primary impressions were made using alginate impression material (Cavex Impression, Netherlands). The impressions were poured using dental stone (Zeta Dental Stone, Zeus, Egypt) to obtain the study casts.

The special tray was constructed using self-cure acrylic resin (Acrostone Manufacturing and Import Co, Egypt). Surveying for the study cast was made to determine the number of available undercuts, and the path of insertion and removal using the dental surveyor (Ney Dental Surveyor, USA).

Mounting for the upper and lower study casts was made using a semi-adjustable articulator (Hanau96H2 Articulator, Whip Mix, USA), and the upper cast was mounted using the maxillary face bow record (Hanau Face Bow, Whip Mix, USA) and centric occlusion record was used to mount the lower cast. The areas of teeth modifications and mouth preparations were marked on the cast using an indelible pencil.

The teeth preparation was made intraorally starting with the guiding planes on the distal surface of the abutment teeth; the preparation was 1.5–2 mm at occlusogingival height using tapered stone. A round bur was used for the preparation of mesial occlusal rest seats on the first premolars bilaterally with a depth of 1.5 mm and was prepared to be deeper towards the center; all the preparation was made at the enamel surface. The floor of the seat was prepared to be saucer-shaped.

The cingulum rests were prepared at the canines bilaterally using an inverted bur. The cingulum rest depth was 2 mm and the floor of the seat was prepared to be V shape.

The finishing stone was used to remove the sharp edges or line angles, and then polishing of the preparation was done using rubber cups. Fluoride paste (Colgate Duraphat, Flouride Varnish, USA) was applied to the prepared teeth surfaces.

The secondary impression was recorded using medium rubber base impression material (Zeta Plus Impression Material, Italy) after the border tracing for the special trays was made using green stick compound (HIFLEX Tracing Sticks, India), the impression was poured to get the master casts.

Surveying and modification of master cast were made; block out and relief were made for the following areas: a gingival third of the distal surface of the abutment, free end saddle areas, the minor connector as it crosses the gingival margin, and major connector areas by using modeling wax (Cavex Wax Set Up, Netherlands).

Duplication of the modified master cast was made using reversible hydrocolloid agar–agar duplicating material (STARGEL Duplicating Dental Material, Italy) in the duplicating machine (ANJAMIE Machine, China) to get the refractory cast.

The planned design of the partial denture was waxed up using a wax pattern (SCHULER Dental Wax, Southern Germany) on the refractory cast, the waxed cast was sprued and invested using investment material (Wirovest Special Investment, Germany).

Invested wax pattern was burned out in a furnace (Ney Furnace, USA), and cast into a metal framework using Co–Cr alloy (Wironit, Bego, Germany). The framework was tried at the patient's mouth to check its fitness and the clasps' retention.

The functional impression was carried out; an acrylic resin tray was added to the framework to form a base covering the distal extension area which was 2 mm shorter than the depth of the sulcus. Border tracing was made using a green stick compound and the functional impression was made under finger pressure using zinc oxide eugenol impression material (Cavex Outline, Netherlands).

The distal extension part at the master cast was removed with a saw to accept the new functional impression. The altered cast was obtained from the functional impression, and it was duplicated to be used in the construction of CAD/CAM milled PEEK framework using silicon duplicating material (Zhermack Duplicating Material, Italy) [12].

The jaw relation was recorded on the wax rim (Cavex Wax, Netherlands) using a face bow record to mount the upper cast and centric occlusion to mount the lower cast on the articulator.

Artificial acrylic teeth were selected and set up (New Acryl, Cross Linked Acrylic Teeth, Egypt). An esthetic try-in of the waxed denture was carried out. The waxed denture was processed from polymethyl methacrylate heat-cured acrylic resin (Heat-cured acrylic resin, Acrostone, Egypt), finished, and polished, inserted in the patient's mouth, and checked for retention, stability, and extension.

2.5. Construction of PEEK frameworks

For the construction of CAD/CAM milled PEEK removable partial denture, the lower duplicated altered cast was fixed on the scanner table and scanned using an extra-oral three-dimensional scanner (Ceramill map 400 Scanner, Austria) to obtain the virtual model. Digital surveying of the virtual model was made to obtain the vertical path of insertion and removal and areas of undercut in a different color for blocking out all undesirable undercuts.

The survey line was drawn following the height of the contour on the abutment teeth. The following areas were virtually relived; the lingual bar area, the crest of the saddles bilaterally, and the area gingival to the guiding planes at the distal surface of the abutment teeth, and the relief was provided by choosing the standard triangulation language (STL) file format from the software (3 Shape Dental System; 3Shape A/S, Copenhagen, Denmark).

The previous design of the Co–Cr framework was used for the construction of the PEEK framework. Digitally standardized the design of the framework on the virtual cast, including the guiding planes and the preparation of the rest seats.

All the components of the framework were chosen and placed digitally on the modified virtual cast in

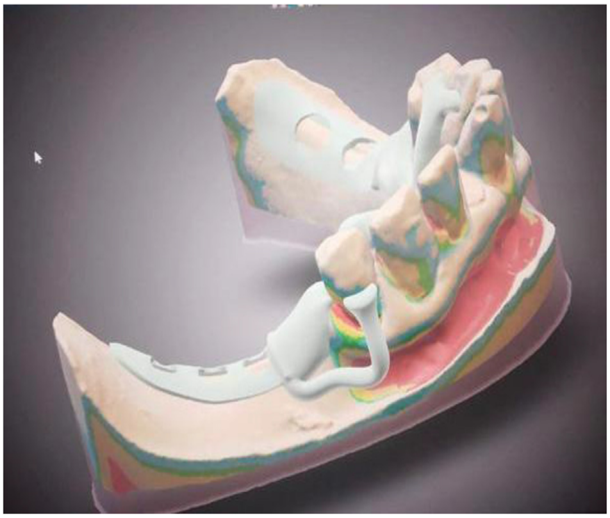

Fig. 1. Design of Polyetheretherketone and Co–Cr frameworks.

the correct position from the STL file format from the software as shown in (Fig. 1).

The virtual three-dimensional framework STL file was sent to the milling machine (Ceramill Motion Machine, Amann, Girrbach) for the milling process of the PEEK discs (Bredent, Senden, Germany). The PEEK framework was then finished and polished. The PEEK framework was tried in the patient's mouth to check its fitting and the clasps retention.

After that, the recording of jaw relationship and setting of the artificial teeth were carried out the same as the Co–Cr RPDs using the same size, shape, and type of artificial teeth, the denture was processed from heat-cure acrylic resin, finished, polished, inserted in the patient's mouth, and checked for the retention of the clasps and if the denture was fully seated as shown in (Fig. 2).

Co–Cr denture was first delivered to all patients and instructions were given to them. Retention of RPD was measured at the time of insertion, 6 months, and 12 months after insertion.

Fig. 2. Polyetheretherketone framework tried intraorally.

The washout period for 2 weeks was performed after that, the PEEK dentures were delivered to all patients and the retention was evaluated at the time of insertion, 6 and 12 months after insertion.

2.6. Evaluation of the retention

Evaluation of the retention for the two types of dentures was made using a universal testing machine (INSTRON, USA) as represented in (Fig. 3). The measuring was made in Newton's unit. Readings were recorded and the mean was calculated at the time of insertion, 6 months after insertion, and 12 months after insertion. Data were collected and statistically analyzed to compare the two dentures.

2.7. Statistical analysis

A commercially available software program (SPSS Chicago, IL, USA) was applied for statistical analysis to be carried out.

3. Results

The standard deviation and the mean were used to represent the data. After confirming variance homogeneity and error distribution normality, analysis of variations was made by one-way ANOVA, and if significant test with post-hoc Tukey's test. At each assessment time, a paired *t*-test was performed between both groups.

The influence of each part (material group and evaluation time) was compared using ANOVA two-way. The sample sizes ($n = 10$/group) have been adequately big for recognizing substantial impact sizing to obtain essential impacts, also assessments pair-wise about 80 % power and a 95 % confidence level. Windows software Graph Pad Instat (Graph Pad, Inc.) was used to analyze the data. The P less than 0.05 value has been assessed as significant statistically.

3.1. Retention

Table 1 and graph drawn in (Fig. 4) display descriptive statistics of retention outcomes assessed by Newton's force (N) for both groups as a function of assessment time.

3.1.1. PEEK group

It was revealed that the greatest retention mean value was identified at baseline (43.67N) followed by a 6-month mean value (40.92N) meanwhile the least retention mean values were identified after 12 months (39.24N) and this has been significant

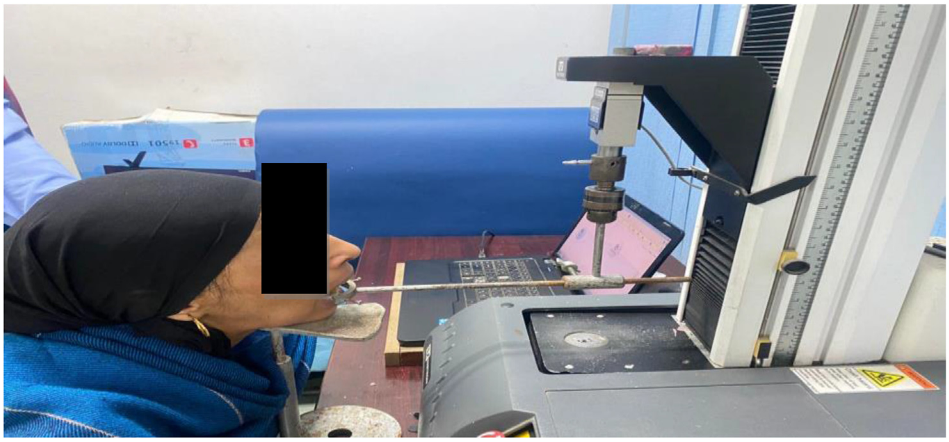

Fig. 3. Evaluation of the retention mean value by a universal testing machine.

Table 1. Comparison between the retention values of computer-aided design/computer-aided manufacturing milled Polyetheretherketone and conventionally constructed Co−Cr at the assessment times.

Material group							
	Polyetheretherketone			Co−Cr			Statistics
	95 % CI[b]			95 % CI			*t*-test
Variable	Mean ± SD	Low	High	Mean ± SD	Low	High	*P* value
Assessment time							
Baseline	43.67[A] ± 0.91	43.1	44.24	47.69[A] ± 0.95	47.1	48.28	<0.0001[a]
6 months	40.92[B] ± 0.61	40.54	41.29	43.96[B] ± 1.48	43.04	44.88	<0.0001[a]
12 months	39.24[C] ± 0.60	38.86	39.61	40.54[C] ± 0.79	40.05	41.03	0.0002[a]
Statistics							
P value	<0.0001[a]			<0.0001[a]			

[a] significant ($P < 0.05$).
[b] confidence level.

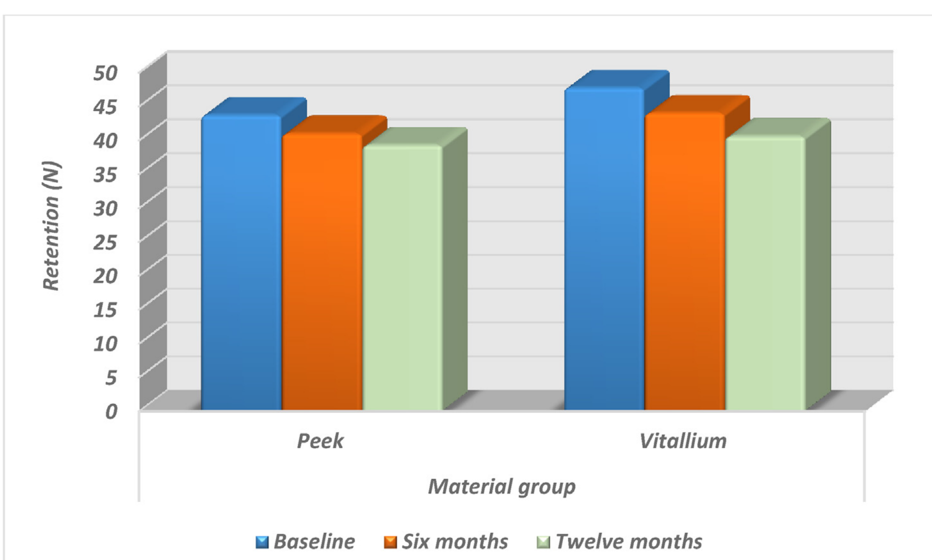

Fig. 4. Retention mean values for Polyetheretherketone and Co−Cr group displayed as function at assessment time in a column chart.

statistically by ANOVA one-way test demonstration subsequent with Tukey's pair-wise tests (P=<0.0001 < 0.05). As shown in (Table 1 and Fig. 4).

3.1.2. Co−Cr group

It was revealed that the greatest retention mean value was identified at baseline (47.69N) followed by a 6-month mean value (43.96N) meanwhile the least retention mean values identified after 12 months (40.54N) and this has been significant statistically by ANOVA one-way test demonstration subsequent with Tukey's pair-wise tests (P=<0.0001 < 0.05). As shown in (Table 1 and Fig. 4).

3.2. Comparing PEEK and Co−Cr group at each assessment time

3.2.1. At baseline

(1) For PEEK: SD ± mean values have been (43.67 ± 0.91N) while for Co−Cr: SD ± mean values have been (47.69 ± 0.95N).
(2) The Co−Cr group showed a greater retention means value (47.69 ± 0.95N) than the PEEK group (43.67 ± 0.91N).
(3) Analysis by paired t-test displayed statistically significant of both PEEK and Co−Cr at (t = 22.76; P=<0.0001). As shown in (Table 2 and Fig. 5).

3.2.2. After six months

(1) For PEEK: SD ± mean values have been (40.92 ± 0.61N) while for Co−Cr: SD ± mean values have been (43.96 ± 1.48N).
(2) Co−Cr group showed greater retention means value (43.96 ± 1.48N) than PEEK group (40.92 ± 0.61N).
(3) Analysis by paired t-test displayed statistically significant of both PEEK and Co−Cr at (t = 7.57; P=<0.0001). As shown in (Table 3 and Fig. 6).

Table 2. Comparison between the retention values of computer-aided design/computer-aided manufacturing milled Polyetheretherketone and conventionally constructed Co−Cr at the baseline.

Variable	Assessment time			Statistics
	Baseline			t-test
	95 % CI[b]			
	Mean ± SD	Low	High	P value
Material group				
PEEK	43.67 ± 0.91	43.1	44.24	<0.0001[a]
Co−Cr	47.69 ± 0.95	47.1	48.28	

[a] significant (P < 0.05).
[b] confidence level.

3.2.3. After twelve months

(1) For PEEK: SD ± mean values have been (39.24 ± 0.60N) while for Co−Cr: SD ± mean values have been (40.54 ± 0.79N).
(2) Co−Cr group showed greater retention means value (40.54 ± 0.79N) than PEEK group (39.24 ± 0.60N).
(3) Analysis by paired t-test displayed statistically significant of both PEEK and Co−Cr at (t = 5.95; P = 0.0002). As shown in (Table 4 and Fig. 7).

3.3. The overall impact of the material group on retention means value

Despite the assessment time, it was discovered that the variance between both groups of Co−Cr and PEEK has been significant statistically by ANOVA two-way test demonstration (P=<0.0001 < 0.05) where (Co−Cr > PEEK).

3.4. Impact of assessment time on retention mean value

Whatever of material groups, overall, it was discovered that the group of PEEK and a group of Co−Cr had identified a significant statistical decrease in retention mean value by assessment time with ANOVA two-way test demonstration (P=<0.0001 < 0.05) where (baseline>6 months > 12 months).

4. Discussion

RPD have been widely used to replace missing teeth aiming to restore function and esthetics for patients. Co−Cr RPD are inexpensive and have good retentive properties, but the metallic framework and direct retainers do not supply desirable good esthetics [2].

Metallic taste, allergic reactions, and weight of the prosthesis have always been problems encountered with CO−Cr RPD. Thermoplastic materials have been used in manufacturing RPDs due to their favorable mechanical properties, easy manufacturing, and better esthetics [13].

PEEK RPD are metal-free so they have good aesthetics and they provide stability for the occlusion. They absorb shock during mastication and have great decay and abrasion endurance in contrast to metal RPD [14].

In the current study, the manufacturing of frameworks by CAD/CAM milling technology provides superior fitting accuracy, fewer laboratory

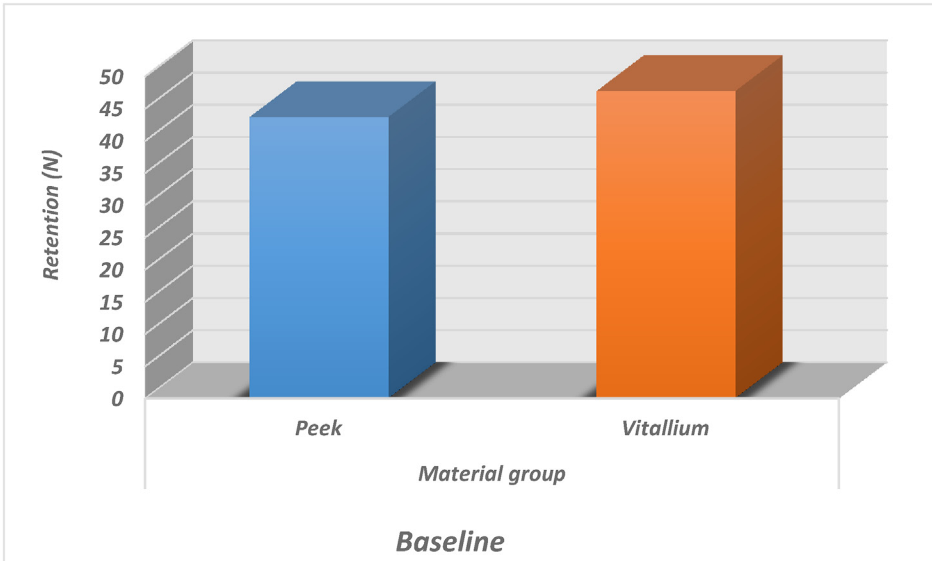

Fig. 5. Retention mean values for Polyetheretherketone and Co−Cr group displayed as function at assessment time in a column chart at baseline.

Table 3. Comparison between the retention values of computer-aided design/computer-aided manufacturing milled Polyetheretherketone and conventionally constructed Co−Cr after six months.

	Assessment time			
	6 months			Statistics
		95 % CI[b]		t-test
Variable	Mean ± SD	Low	High	P value
Material group				
PEEK	40.92[b] ± 0.61	40.54	41.29	<0.0001[a]
Co−Cr	43.96[b] ± 1.48	43.04	44.88	

[a] significant ($P < 0.05$).
[b] confidence level.

Table 4. Comparison between the retention values of computer aided-design/computer aided manufacturing milled Polyetheretherketone and conventionally constructed Co−Cr after twelve months.

	Assessment time			
	12 months			Statistics
		95 % CI[b]		t-test
Variable	Mean ± SD	Low	High	P value
Material group				
PEEK	39.24[C] ± 0.60	38.86	39.61	0.0002[a]
Co−Cr	40.54[C] ± 0.79	40.05	41.03	

[a] significant ($P < 0.05$).
[b] confidence level.

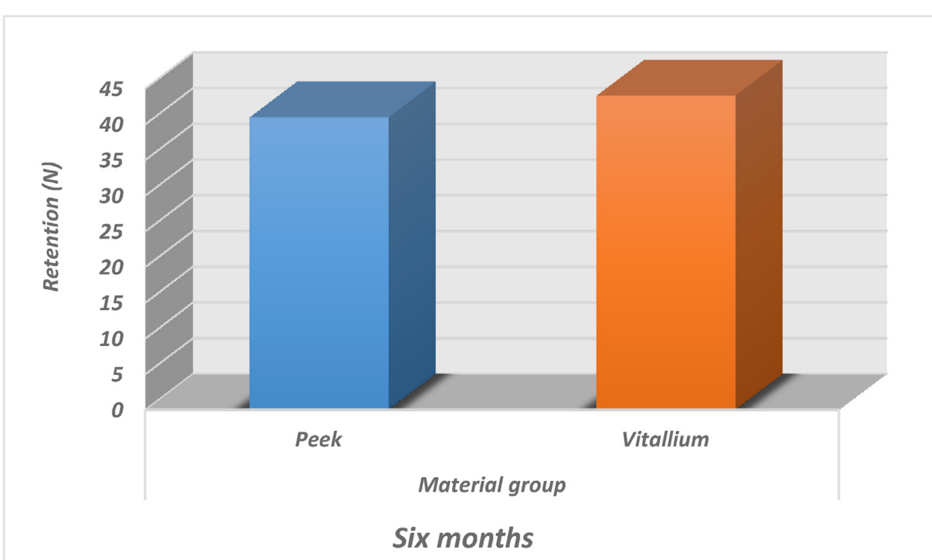

Fig. 6. Retention mean values for Polyetheretherketone and Co−Cr group displayed as function at assessment time in a column chart after 6 months.

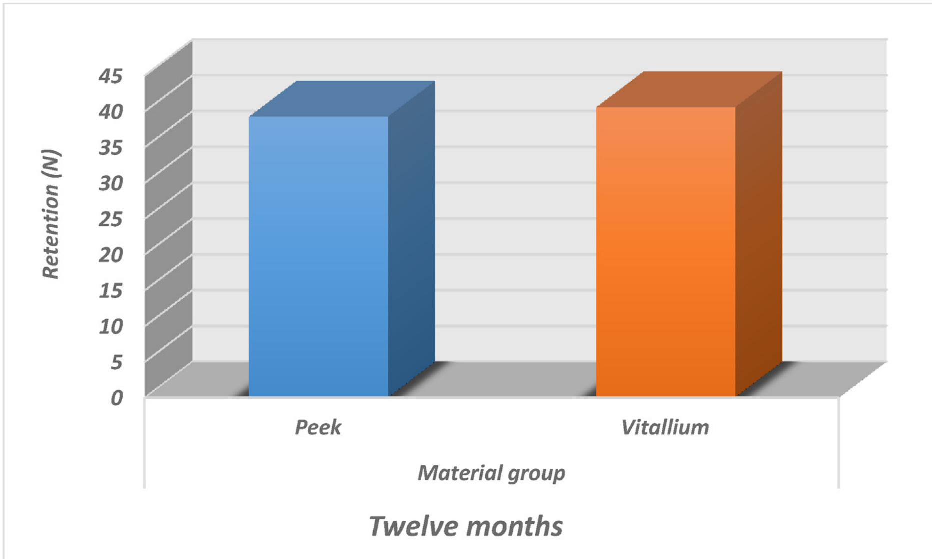

Fig. 7. Retention mean values for Polyetheretherketone and Co–Cr group displayed as function at assessment time in a column chart after 12 months.

steps, and quicker fabrication with fewer sources of errors which improves patient satisfaction [14].

In this crossover study, we could neglect factors that would not change over time in the statistical analyses. Thus, each patient received two dentures in sequence and the designs for clinical trials produced results that were statistically and clinically acceptable with fewer patients participating in the trial [15].

In the present study, the retention of CAD/CAM milled PEEK frameworks was compared with that of conventional Co–Cr frameworks using a universal testing machine, and the retention forces were measured in Newton [16].

Comparing the force of retention for the Co–Cr and PEEK groups in the current study, both groups had a gradual decrease in retention mean value by assessment time. That may be due to the amount of occlusal loading and the repetitive insertion/removal cycles of the clasps, which may cause fatigue and deformation of the clasps of both groups.

The results of the current study are in harmony with Kato et al. [17]. Who concluded that the gradual decrease in retention mean value of the clasps by the assessment time was caused by the repetitive insertion/removal cycles of the denture. In addition, the more occlusal loading on the clasps, the more gradual decrease in retention means values of the clasps by the assessment time.

Comparing the results for the Co–Cr and PEEK groups in the current study, the Co–Cr group showed a higher force of retention than that of the PEEK group, catching the same undercuts. These results may be due to the greater flexibility and lesser elastic modulus of PEEK when compared with that of Co– Cr alloy.

These outcomes in the present study are agreed with Muhammad et al. [11]. Who believed the dissimilar elastic modulus of Co–Cr and PEEK and the clasps of PEEK had inferior force of retention than clasps of metal.

The outcomes of the current study also are in agreement with Gentz et al. [18] Who concluded that PEEK removable partial denture frameworks exhibit lower retention force when compared with Co–Cr removable partial denture frameworks, which is a matter of concern. They explained that the PEEK flexibility is greater than that of Co–Cr, as the Co–Cr clasps are stiffer.

These results of the present study are also in agreement with Seif Eldien et al. [14]. They believed that the retention mean value of Co–Cr claps can be considered better than PEEK clasps engaging the same undercuts.

The results of the current study disagreed with Nagy et al. [19]. Their study found that the retention means values reduced significantly from the time of delivery until 12 months of assessment time at both groups with loss of retentive forces in Co–Cr metal groups more than in PEEK groups that may be because their study was in vitro conditions and used Aker's clasp while the current study used RPI clasp.

5. Conclusion

Within the limitation of the current study, a later conclusion could be derived, and a statistical significance was recorded in the force of retention between the CAD/CAM milled PEEK framework and the Co–Cr framework in favor of Co–Cr. However, the force of retention for CAD/CAM milled PEEK framework for RPDs was shown to be within the adequate limits needed for keeping the RPD.

5.1. Recommendations

More studies are recommended for evaluating the retention loss of different types of metal and PEEK clasps with longer time.

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Conflicts of interest

There is no existence of interest conflicts identified by the authors that might impact the work presented in this study.

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