Comparison of fit of poly (etheretherketone) and cobalt-chromium removable partial denture frames: an in-vitro study

Ary Yaqoub Putros [(1)] Jawad Mohammed Mikaeel [(1)]

Background and objective: the adaptation of the Removable partial denture (RPD) is a key factor in the success of the treatment outcome. This study aims to compare the fit of Poly (etheretherketone)(PEEK) and cobalt-chromium (Co-Cr) frames through the rest seat adaptation

Methods: Ideal typodont model of the maxillary partially edentulous case (Kennedy Class III), four rest seats were prepared on abutment teeth afterwards, and the cast was turned into a metal master cast to serve as a reference cast. Twenty RPD samples were made, ten samples for the Co-Cr group and ten for the PEEK group. A Vinyl Polysiloxane Impression Material (VPS) is used to paint the intaglio surface of the rest, and the frame samples are held in place with finger pressure on the master cast. Eighty VPS samples were made to present the gap between rest and rest seats; these samples were measured using a digital micrometre under a microscope with a magnification of 40x. The data were analysed using SPSS programs with an independent T-test.

Results: comparison between the two groups revealed that the PEEK groups had a better fit in one tooth #17 with a mean of (147.2 µm) than the Co-Cr group (252.6 µm), which is statically significant with a P value of (0.000). The other three abutments showed no significant difference.

Conclusion: RPD frames made from PEEK showed a slightly better fit than Co-Cr frames.

Keywords: fit accuracy, laboratory research, removable partial denture framework

[(1)]Department of Prosthodontic Dentistry, College of Dentistry, Hwler Medical University, Erbil, Iraq.
Correspondent Name:-Ary Yaqoub Putros
Email: aryjacop@gmail.com

Introduction

A removable partial denture (RPD) is "a removable denture that replaces some teeth in a partially edentulous arch; the removable partial denture can be readily inserted and removed from the mouth by the patient"[(1)]. Despite recent advancements in dental implantology, RPD is still one of the most viable options in treating a partially edentulous patient. [1,2]

The conventional RPDs are generally fabricated with metal. However, the biocompatible Co-Cr alloy is the contemporary metal of choice for RPD frameworks. The supremacy of metal-based frameworks over acrylic resin is that they are used in thin sections and are less bulky, provide high strength and stiffness, conduct heat and cold for a more natural experience, and are resistant to corrosion. [3] RDPs are usually manufactured of a Polymethyl methacrylate (PMMA) base with acrylic or ceramic teeth in combination with (CoCr) clasps. The tried and tested CoCr clasps show excellent mechanical properties, such as good long-term stability and reliability. [4]

The drawbacks of metal RPDs include esthetic issues with the metal display, oral galvanism, adverse tissue reactions, osteolysis of abutment teeth, and biofilm production. Even if cobalt-chromium is widely considered the best material for a denture framework, the material's physical properties are

not ideal. [5]
In recent advancements, titanium alloys have been used as metal frame replacements for chrome-cobalt alloys. The use of titanium to form RPDs has increased and is often recommended for large RPDs. Although titanium has become a proven biocompatible metal, it can cause inflammatory reactions in an estimated 0.6% of patients.[6,7]
Other materials used are resins and polymers are used Because of the drawbacks of metal-based frameworks, the use of metal-free materials, including high-performance polymers such as PEEK, polyethene glycol, polymethyl methacrylate, and aryl-ketone polymers, has been investigated. Some advantages of polymer-based frameworks over those made of metal are that they improve esthetics because of their translucency and colour, are more cost-effective, have higher elasticity, and are straightforward to produce, as well as lightweight, have low water sorption and solubility, and are easily repaired and reproduced. [8,9]
PEEK materials are at present employed for a wide range of restorations in prosthetic dentistry, from dental implants, abutments, FDPs, and frameworks of RDPs to clasps or telescopic prostheses. [10] Flexible PEEK frameworks can reduce overloading masticatory pressures in implant restorations due to a lack of proprioception. [11]
PEEK restorations can be produced "employing the conventional lost-wax technique by pressing from pellets or granules or computer-aided design and manufacturing (CAD/CAM) by milling from blanks". Furthermore, using CAD/CAM allows for an entirely digital workflow that entails numerous advantages like raised material homogeneity and the ability to reproduce fillings, for example, when elderly patients misplace their prostheses. [12]
The Fitting of a removable partial denture RPD framework is one of the most crucial requirements for the success of the prosthesis. Any misfit might cause discomfort, preventing many patients from wearing their prostheses. Also, the improper fit may result in the movement of the associated teeth. [13]
Few studies examined the mechanical properties of PEEK to determine the clinical outcome of its use and especially in CAD/CAM milled PEEK frames and 3D printed resin frames; therefore, this study aims to examine and compare the fit of the PEEK and compare it to Co-Cr frame through rest seat adaptation.

Methods

Preparation of the metal master cast:

An Ideal typodont model (kaykay, India) of the maxillary partially edentulous case (Kennedy Class III) employed for educational purposes has been selected as a master model replicating the anatomical features of the teeth. Missing teeth are the second premolar and first molar on both sides. Four rest seats were prepared adjacent to the edentulous spaces. The model was surveyed to ensure parallel guiding planes and to provide them with a block-out relief. A ledge of 0.25mm undercut was created on the premolars and on the molars to ensure a correct position of the retentive clasp tips. An occlusal rest seat of 2mm in depth is prepared. The position of the rest and its size is made to the rule that the rest seat should occupy one-third to one-half the mesiodistal diameter of the tooth and approximately one-half the buccolingual width of the tooth measured from cusp tip to cusp tip. The alveolar ridges will be smoothly planned to ensure the passive fit of frame samples during the insertion and removal procedure, Figure 1.

After the preparation of the typodont, the cast is scanned using an intraoral scanner (Care Stream CS3600, USA) to make a digital impression of the cast. Then the impression is 3D printed to a metal master cast utilizing a metal sintering printer (Riton D100); this metal cast will serve as the final cast that is made of metal which will not be going to change by duplication and testing procedure, Figure 2.

Figure 1: Typodont cast

Figure 2: The reference metal cast

Sample design and fabrication

Two groups of RPD framework are fabricated, ten frames for the Cr-Co group and ten frames for the PEEK group, the design of the RPD samples is made the same for both groups. Using digital designing software (EXO-cad, Germany) to make sure the samples are standard for both groups.

The design made for Kennedy class III was as follows; a single palatal strap as a major connector with a thickness of 1.5mm, a minor connector and saddle that are connected to 4 Aker clasps, two on the premolars and two on the molars with their respective rests, the diameter of retentive arm and reciprocal arm were made the same 1.2mm to 0.8mm at from the minor connector to the tip of the clasp.

For the Cr-Co frame fabrication, the digital design is 3D printed to pattern resin with a 3D printing device (UnionTech, shanghai/ china) utilizing that can be invested and turned into a Cr-Co frame using the conventional casting method, Figure 3. The PEEK frames are milled from prefabricated PEEK discs (95mm×25mm, ceradirect,

Figure 3. the finished Co-Cr sample

Figure 4. The finished PEEK sample

Hongkong). The STL file was transferred to a milling machine (Zirkonzhan m5, Germany) to be milled; then, after the milling was complete, the samples were fished and polished, Figure 4. This process was repeated ten times to make ten samples.

Figure 5. The VPS sample under the microscope.

The fit test

The fit test was performed using of rest seat adaptation measurement. A vinyl polysilicon light body impression material (VPS impression/pro clinic, CHL, Italy) is used as a measurement, the impression material is placed in the rest-seat of the master metal cast, and the frame is fitted on the cast with finger pressure until the material is completely set. The excess is removed with a sharp surgical blade (size 11) with precision under a digital microscope (Koolertron 7-inch LCD Digital USB Microscope) to make sure that all the light body specimens are the same for all the 20 frames The light body additional silicone specimens are measured from the mesial and distal side for all the rest seats, and the mean of the two is selected as the final measurement. A digital micrometre (INSIZE digital outside micrometre 0.001mm resolution, Germany) is used to make the measurements under the microscope magnification, Figure 5. The statistical analysis is done using SPSS through an independent T-test.

Result

The distance between the rest of the frameworks and their respective rest seats was represented by a total of 80 VPS specimens, each with four rest zones with ten samples for both groups (chrome and PEEK). The significance cut-off was established at 0.05.

Co-Cr group

According to Table 1, the results discovered that the best-fitted zone in the Cr-Co group was in the tooth #27 rest zone (147.500 µm), followed by the #14 zone (246.200 µm) and the #17 zone (252.600 µm). At the same time, the tooth #24 rest zone indicated the worst fit with the highest mean value (255.900 µm), with significantly increased gap distance compared to the #27 rest.

PEEK group

The findings of the PEEK group in Table 2 show that tooth #27 rest (145.000 µm) was the best-fitted zone in the PEEK technique group, followed by tooth #17 rest (147.200 µm) with no considerable difference with tooth #17 rest, and tooth #14 rest (256.100 µm). As opposed to the #27 and #17 rest seats, tooth #24 rest seats showed the weakest fit with the greatest mean value up to (263.600 µm) and a substantially larger gap distance, Figure 3.2.

Table 1: Descriptive Statistics of Co-Cr group.

Tooth #	N	Mean	Std. Deviation	95% Confidence Interval for Mean		Min.	Max.
				Lower Bound	Upper Bound		
#24	10	255.900	35.319	230.634	281.166	201.000	299.000
#14	10	246.200	24.675	228.549	263.851	214.000	286.000
#27	10	147.500	35.924	121.802	173.198	105.000	196.000
#17	10	252.600	24.052	235.394	269.806	215.000	281.000
Total	40	225.550	54.358	208.165	242.935	105.000	299.000

Comparison between PEEK and Cr-Co

The objective of the present study was to compare each rest affected by the materials, and the goal is to find which material created fewer gap distances at each rest. Independent T-Test was carried out, and in line with the below output in (Table 3), Co-Cr material seemed to have a better fit where it had smaller mean values at teeth #14 and #24; since the difference mean value of gap distances were small with 9.900 µm and 7.700 µm respectively, yet they showed no significant difference with p-values larger than 0.05. Regarding tooth #27 rests, PEEK showed a better fit with a 2.5 µm difference, also not significant (p=0.874). However, the mean difference of 105.400 µm showed at tooth #17, and this means that PEEK material created less gap distance than CHROME with 105.400 µm and hence significant.

Table 2: Descriptive Statistics of PEEK group.

Tooth #	N	Mean	Std. Deviation	95% Confidence Interval for Mean		Min.	Max.
				Lower Bound	Upper Bound		
#24	10	263.600	33.514	239.626	287.574	212.000	299.000
#14	10	256.100	27.400	236.499	275.701	205.000	297.000
#27	10	145.000	33.263	121.205	168.795	101.000	193.000
#17	10	147.200	42.814	116.573	177.828	101.000	196.000
Total	40	202.975	66.606	181.673	224.277	101.000	299.000

Table 3: Between Groups Comparison Test result (Independent T-Test)

Tooth #	t	Sig. (2-tailed)	Mean Difference (µm)	95% Confidence Interval of the Difference	
				Lower	Upper
#24(Co-Cr/PEEK)	-0.849	0.407	-9.900	-34.397	14.597
#14(Co-Cr/PEEK)	-0.500	0.623	-7.700	-40.047	24.647
#27(Co-Cr/PEEK)	0.161	0.874	2.500	-30.027	35.027
#17(Co-Cr/PEEK)	-6.787	0.000	105.400	138.026	72.774

Discussion

The replacement of missing teeth or teeth is still a challenge despite the advancement of materials and machinery in this fast-paced time. Restoring function and aesthetics are primordial key factors in the treatment outcome. [3,5] RPDs are yet a viable option to treat the missing teeth depending on the case selection and the patient's socioeconomic status. [14]

The selection of PEEK as the choice material to compare it with Cr-Co came from the recent advancements made to the properties of this material, as the surging of digital dentistry into prosthodontics cannot be undone. The new studies that examined PEEK showed promising results and a bright future for PEEK to take the throne from Cr-Co alloy. [15] The digitally made prosthesis showed a very good result while being tested, especially CAD/CAM-made PEEK RPD frames.

The fit of the RPD is the factor of success because, without fit, there is no retention; achieving a precise fit is seemingly impossible while using the conventional casting techniques due to curing shrinkage of high fusing metal alloys compared to the alloy of gold. [16] Many manufacturers have tried to enhance the properties of the Cr-Co material throughout the years to minimise the shrinkage, but this is not the only factor to take into consideration wax flow increase results in less shrinkage as well as the heat acceleration in wax elimination and the gypsum product expansion all these are primordial factors in the success of well-fitted RPD. [17] The recent advancement of the precise techniques of milling and rapid prototyping led to an increase in digitally fabricated RPDs due to time efficacy and precise control of the design as well as precise manufacture. [18,19]

The measurement of samples showed that tooth #27 has the best fit in the rest seat area for the Cr-Co samples (147.500 µm), while in the PEEK group, two teeth showed a similar fit #27 and #17 (145.000 µm, 147.200 µm) respectively showing slightly better results. On the other hand, the comparison between all the four rest-seat for both groups showed only a statistically significant difference in tooth #17 with a mean difference of (105.400 µm) between Co-Cr from the PEEK group (p= 0.000).

In a similar study by Veljee, 2015 they compared the conventional wax pattern with light cured pattern wax using light-body silicone impression while splitting the rest into four zones (central, buccal, lingual, and marginal); they found that the best-fitted zone was the marginal for both groups with the upper hand for the light cure wax pattern method. Another study in 2019 by Bajunaid et al. found out that the SLM-made metal RPD has a better fit than in the marginal area of the rest in comparison to conventional-made metal RPD.

In this limited study, we found out that the milled PEEK frames have better adaptation in one rest seat in comparison to conventionally made Cr-Co these results come in agreement with two recent studies done by Negm et al. 2019 and Shihabi et al., 2021 both found out that milled PEEK shows better fit compared to conventional made Cr-Co and 3D printed [(20,21)]. This can be explained in the matter of the fabrication technique it's related to the premade blocks of PEEK are dimensionally stable, and the process of milling and finishing and polishing hardly affects the material quality; on the other hand, the casting procedure for Cr-Co frames fabrication undergoes many laboratory processes that led to affect the final outcome of the finished prosthesis. Thus the null hypothesis cannot be rejected due to the significant better fit of PEEK frames in one tooth. [18,22]

Conclusion

With the limitations of our study, even though there were relatively nearly the same results in three rest seats, PEEK showed better adaptation in one tooth which indicates a promising future for this material. In contrast, further research is needed to ensure that its properties match that of the Cr-Co material.

Conflict of interest

The authors report no conflicts of interest.

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