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Comparative study between removable partial dentures frameworks fabricated using PEEK and using Co-Cr alloy: clinical study

Nariman Maraka[1], Alaa'a Salloum[2], Mamdouh AlMohareb[3]

Postgradguated student (PhD degree) - Department of Removable Prosthodontics- Faculty of Dentistry- Damascus university, Syria[1]
Professor in the Department of Removable Prosthodontics- Vice Dean For Scientific Affairs Faculty of Dentistry - Damascus University, Syria[2]
Department of Oral Histology and Pathology- Faculty of Dentistry- Damascus University , Syria[3]

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ABSTRACT

Aim To conduct a clinical study to evaluate the fit accuracy of the removable partial denture (RPD) frameworks fabricated by 3D printing computer-aided design/computer-aided manufacturing (CAM-CAD) method and the conventional method using CS. Ten patients with partial tooth loss of a maxillary Kennedy class I were divided into two groups: in the first group, the RPD frameworks were fabricated from chromium-cobalt using CS casting technique in the second group, the RPD frameworks were fabricated from poly ether ketone (PEEK) using Milling technique. The fabricated frameworks were injected with polyvinyl siloxane (PVS) and were put inside the patient's mouth, and then the rubber laminas were weighted. The results of Student T- test showed that there were statistically significant differences in the average weight of the rubber laminas in the two groups, where $P<0.05$. The gap in the group of CS frameworks was larger than that in the group of CAM-CAD (Milling) frameworks which achieved the best fit accuracy. The RPD frameworks fabricated from PEEK using CAM-CAD (Milling) technique achieved the best fit accuracy compared with the frameworks of Cr-Co fabricated using CS technique, where the accuracy was affected by the fabricating technique used.

1. INTRODUCTION

The need for RPD frameworks increases due to the increase in the population and the average age, in addition to the spread of partial tooth loss [1], [2]. Partial tooth loss has been estimated at more than 20% in some regions [3], and the number of partial tooth loss is expected to increase to more than 200 million individuals in the United States over the next few years [4]. The rate of partial tooth loss for adults over the age of twenty years in the United States was estimated at 43.7%, while the rate of remaining teeth for those over the age of sixty-five years was estimated at 18.9% [5], [6]. In a study on dental health in the United

States in (2009), it was found that one out of five adults has a partial or complete removable framework [7] knowing that 6% of them have a complete framework and 13% of them have a partial framework with the presence of natural teeth. The development of means of maintaining oral health contributes to decrease the tooth loss that leads to treatment ability using partial framework [8], [9]. On the other hand, many patients aspire to have prostheses for their missing teeth using frameworks that provide them with an aesthetic appearance, improve their chewing function, prevent unwanted tooth movement (elongation - tilt) and improve speech. Removable prostheses have special advantages as they are cheap compared to prostheses by dental implants, and they can be used as temporary prostheses. They are easy to clean, and have excellent biomechanical properties if designed correctly. They are a suitable prostheses solution for the loss of three adjacent teeth, where fixed prostheses are not appropriate in such cases [2], [10], [11]. RPD frameworks are considered the best treatment in many clinical cases, especially in the case of loss of bony and tissue support [2], [10]. It is likely that RPD frameworks will remain a treatment option compared to the more expensive alternatives [12]. To date, Cr-Co alloys are considered one of the most popular metal alloys used in the fabrication of removable partial denture frameworks. This is due to their high hardness, excellent resistance to corrosion and oxidation, lower price compared to gold alloys, and their thermal conductivity [13], [14]. However, despite the advantages of Cr-Co alloy, it has some defects, such as inflammatory reactions to the oral tissues, the existence of a metallic taste, and the failure to meet the patient's aesthetic requirements in cases where the retainers of the clasps appear [15], [16]. The medical literature has also reported numerous cases of inaccurate fit of the different components of removable partial denture frameworks fabricated from Cr-Co alloys, which can range from minor which requiring minor adjustments in the clinic, to large enough which requiring the fabrication of a new metal frameworks. This unfit reflects the dimensional change that occurs in the different stages of fabricating metallic frameworks [17].

The question of searching for a material with ideal properties for fabricating the removable partial denture (RPD) frameworks remains a matter of concern to researchers. Therefore, many thermoplastic materials have been introduced in clinical practice and the poly ether ketone (PEEK) appeared, which was first marketed in (1980) [18]. Because of the properties of PEEK which include chemical and physiological stability, bio-acceptance, wear resistance, and resistance to radiation damage and stability at high temperatures, PEEK may be an alternative to Co-Cr alloys. Furthermore, its distinctive properties make it an interesting material for use in dentistry with potential using it according to CAD-CAM technique. The PEEK has been modified with 20% ceramic addition to be suitable for fabricating the bases of the RPD frameworks [19], [20]. So far, there is no evidence on how these materials behave under the influence of different forces when used in RPD frameworks, in addition to the lack of studies evaluating the clinical behavior of these materials [21]. Thus, in order to know the behavior of these materials under the influence of different forces when used in partial devices, it is necessary to conduct a research in addition to laboratory and clinical experiments to compare this material with Cr-Co alloys that are the commonly used in RPD frameworks.

2. Materials and Methods

The research includes ten patients who come to the Department of Removable Prosthodontics at the Faculty of Dentistry at Damascus University. They suffer from upper partial teeth loss of Kennedy class I, as similar as possible within the conditions of inclusion and exclusion. They are distributed into two groups equally, where each group includes 5 patients:

1. In the first group: a framework of Cr-Co alloys was fabricated using the CS casting method for each patient.
2. In the second group: a framework of PEEK was fabricated using Milling method for each patient.

2.1 The conventional method used to fabricate the RPD framework from Cr-Co alloys using the CS casting was as follows

The primary impressions were taken using alginate (Hygedent Inc., China) and plastic stamps (Solo, Syria). Then the impressions were casted with dental stone (Ruthenium, Dental Manufacturing, Italy) to get the preliminary cast. Then The preliminary cast was studied and plotted with a diagram (Ney Gold, The J.M. Company, USA). The essential patient's mouth preparations were made to receive the partial framework according to the selected design. The master impression was taken with alginate Hygedent. The final (master) cast was obtained by casting the gypsum cast. The metal frameworks design was made using the master gypsum cast. The master cast was configured and prepared for duplicating to obtain a master cast-resistant. The components of the partial framework were set (major connectors - minor connectors - clasps - direct retainers - indirect retainers) [2], [22]. The master cast-resistant was coated using wax (Tenatex Type 1 Soft, Kemdent, UK), and then the crucible was placed in the furnace (Realloy-Germany) so that the wax evaporated, and thus the metal framework fabricated from Cr-Co was obtained.

2.2 The method used to fabricate the RPD framework from PEEK using Milling method was as follows

The same steps used in fabricating the Cr-Co framework were followed to get the master gypsum cast. Then a 3D model was produced using the design program (Exocad), Computer-aided designing (CAD). After that, the master gypsum cast was scanned using the scanner (CS. Ultra Pro). Then the design obtained in the first step was transmitted to the STL format. Then the printing file was transferred to the 3D printer (Roland-Dw510). The PEEK block (China™-PEEK) was installed in the place designated for it in the printer, and the printer milled it. Thus, we obtained the RPD framework fabricated from PEEK using Milling method [10].

2.3 The method of studying the accuracy of major connector

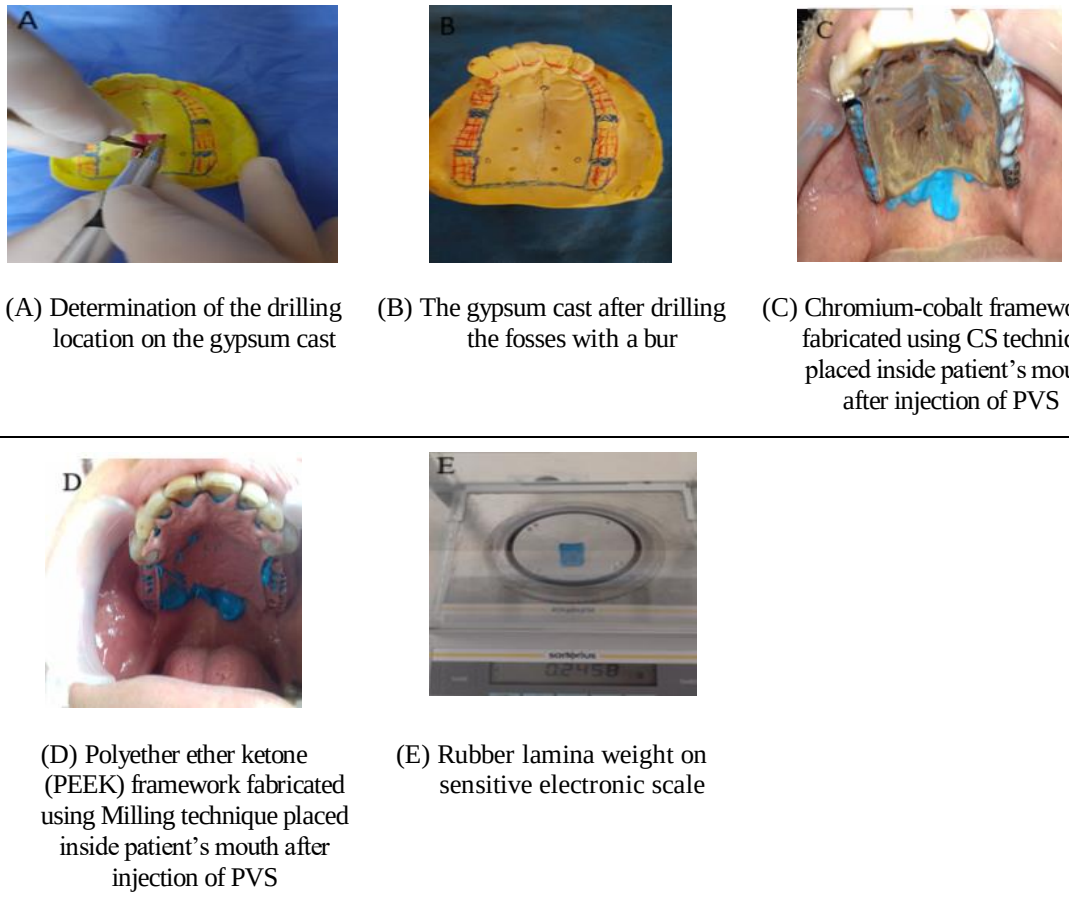
A similar method to [23], [24] was used to check the fit accuracy of the major connector for upper RPD frameworks at the stage where the master cast was obtained. The middle line of the palatine dome is drawn on the master cast, and a flexible numbered plastic piece with 1 cm wide and 2 cm long is placed at a distance of 5 mm from the back edge of the framework, so that it applies to the palatine dome, and its center line applies to the center line of the palatine dome. Then six points were drawn by a pencil: a point at each corner of the plastic piece, and a middle point on each side at a distance of 1 cm from the points at the corners of the piece as in the Figure (1-A). After that, six fosses corresponding to the six points were drilled with a depth of approximately 0.5 mm using a metal bur (HM 1SQL, Bego, Germany) with a diameter of 0.8 mm as in Figure (1-B). Then the metal framework was fabricated from Cr-Co alloys, with a palatine lamina of about 0.5 mm thickness. This thickness was used by many researchers to make the palatine lamina of the Cr-Co alloys [25- 27]. The manufacturer's instructions were followed during the processes of coating, casting and finishing.

Whereas, to design the frameworks fabricated from PEEK using Milling technique, the master gypsum cast was scanned after drilling fosses on the casts.

The casts were then immersed in water for 10 minutes, and dried with napkins. After that, an amount of polyvinyl siloxane (Hydrorise Extra Light Body, Zhermack, Italy) was injected on the inner surface of each of two frameworks Cr-Co and PEEK) using the injector (Ivoclar). Each one was placed inside its own patient's mouth, making sure that the spurs and clasps were correctly in place. Then a pressing with the thumb was done in the center of the palatal dome until the soft rubber was completely hardened, as shown in Figure (1-C-D). Then the framework was taken from the patient's mouth.

A piece of polyvinyl siloxane was cut using a sharp scalpel (Maped) around the impressions of the six fosses. Then a precise cut using a scalpel and a metal ruler was made to the piece containing the six fosses depending on the six fosses where the cutting line was tangent to the outer boundaries of the impressions of the fosses.

The cutting rubber lamina was kept in a closed container, and then weighed using a sensitive electronic balance (Sartorius, AG Gottingen, Germany) as shown in Figure (1-E).



(A) Determination of the drilling location on the gypsum cast

(B) The gypsum cast after drilling the fosses with a bur

(C) Chromium-cobalt framework fabricated using CS technique placed inside patient's mouth after injection of PVS

(D) Polyether ether ketone (PEEK) framework fabricated using Milling technique placed inside patient's mouth after injection of PVS

(E) Rubber lamina weight on sensitive electronic scale

Figure (1)

3. Results

Student T-test was conducted for the independent samples to study the significance of the differences between the average weights of rubber laminas (in gram). The results were as follows:

Table (1) shows the average, the standard deviation, and the standard error of the weight of the rubber lamina (in grams) in the samples of fit accuracy study according to the type of framework used.

Studied variable	Type of framework used	Number of frameworks	Average (gram)	Standard deviation	standard error	p value	Statistical significance
weight of rubber lamina	Framework fabricated from Cr-Co alloys using CS	5	0.194640	0.018033	0.008064	0.003	statistically significant

(gram)	Framework fabricated from PEEK using CAM-CAD	5	0.150900	0.014157	0.006331		

The table shows that the value of the significance level 0.003 is smaller than 0.05. This means at the 95% confidence level, there are statistically significant differences in the average weights of rubber laminas in the group of frameworks fabricated from Cr-Co alloys using CS and the group of frameworks fabricated from PEEK using CAM-CAD. In addition, the table shows that the average weights of rubber laminas in the frameworks fabricated from Cr-Co alloys using CS were greater than those fabricated from PEEK using CAM-CAD in the sample of the accuracy study.

According to the above-mentioned study, the research hypothesis is accepted, which states that there are statistically significant differences in the average weight of the rubber lamina (in grams) between the group of frameworks fabricated from Cr-Co alloys using CS technique, and the group of frameworks fabricated from PEEK using CAM-CAD technique in the sample of the accuracy study. The best accuracy is in the PEEK group using CAM-CAD technique. Figure (2) shows the differences in the average weights of rubber laminas:

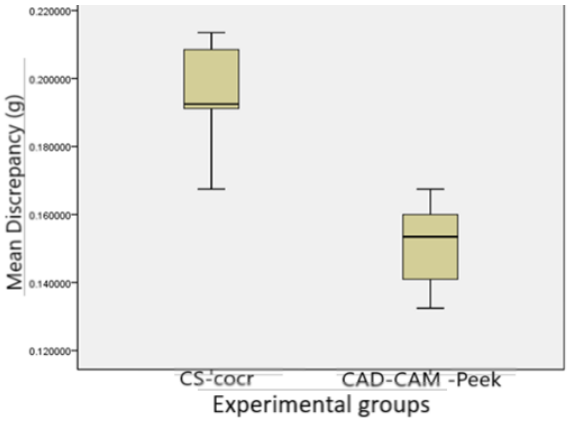


Figure (2) The difference in the weight of the rubber lamina in the sample of the fit accuracy study

4. Discussion

In this study, Kennedy Class I upper RPD frameworks were fabricated using two different methods: CS casting method, and CAM-CAD method. Then the fit accuracy of the frameworks inside the patient's mouth was evaluated through injecting PVS on the framework and placing it inside the patient's mouth. The results of the study shows that there is a clear difference in the fit accuracy between the two groups, and thus the null hypothesis is rejected. The gaps in the Cr-Co frameworks using CS technique were larger than frameworks fabricated from PEEK using CAM-CAD technique, where the average weight of PVS in the Cr-Co frameworks was 0.194640 which is larger than the average weight of PVS in the PEEK frameworks 0.150900, and thus the latter technique achieved the best fit.

The explanation for these results is due to all stages of fabricating in the CS casting method are manual, where there are fluctuations in temperature that cause metal shrinkage in addition to the trimming and finishing operations that affect the fit accuracy of fabricated frameworks. Whereas, the RPD frameworks fabricated from PEEK using Milling technique have unparalleled accuracy in finishing. It provides surface textures with smoothness that were not available previously using any conventional method. The fabrication using computer-aided design/computer-aided manufacturing (CAD-CAM) simplifies the fabricating prosses

where stages are achieved automatically, and, unlike the CS casting method, it does not require the trimming and finishing operations. This study agreed with [28], where it was found that the RPD frameworks fabricated from PEEK using Milling technique have better fit accuracy than those fabricated from Cr-Co using CS technique.

5. Conclusions

Based on the results of this study, the following conclusions were drawn:

1- The fit accuracy of the RPD frameworks fabricated from PEEK using Milling technique was better compared to RPD frameworks fabricated from Co-Cr using CS technique.

2- Cr-Co frameworks fabricated using CS technique were less accurate compared to frameworks fabricated from PEEK using Milling technique. This was due to the deformation (shrinkage) of the metal accompanying the fabricating process.

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