



Comparative study of some mechanical properties of cobalt chromium and polyether ether ketone thermoplastic removable partial denture clasps: an In-vitro Study

Estudo comparativo de algumas propriedades mecânicas dos grampos parciais removíveis termoplásticos removíveis termoplásticos de cobalto cromo e éter cetona: um estudo in vitro

Rady EL-BAZ¹, Mostafa FAYAD², Mohamed ABAS³, Ahmad SHOEIB⁴, Mohammed Moustafa GAD⁵, Mohamed Ahmed HELAL⁶

- 1 - Removable Prosthodontics Department - Faculty of Oral and Dental Medicine - Al-Azhar University - Cairo – Egypt.
- 2 - Removable Prosthodontics Department - Al-Azhar University - Faculty of Oral and Dental Medicine - Cairo – Egypt. Substitutive Dental Science Department, College of Dentistry, Taibah University, Saudi Arabia.
- 3 - Dental Biomaterials Department - Al-Azhar University - Faculty of Oral and Dental Medicine - Cairo – Egypt.
- 4 - Removable Prosthodontics Department - Al-Azhar University - Faculty of Oral and Dental Medicine - Cairo – Egypt.
- 5 - Substitutive Dental Sciences Department, College of Dentistry, Imam Abdulrahman Bin Faisal University, Dammam, Saudi Arabia.
- 6 - Removable Prosthodontics Department - Faculty of Oral and Dental Medicine - Al-Azhar University - Cairo – Egypt.

ABSTRACT

Objective: was to evaluate the retentive force, fatigue resistance and deformity of clasps made from two materials cobalt chromium and poly ether ether ketone (PEEK). **Material and Methods:** sixteen models were fabricated, each one having lower 1st molar. Models were divided into two groups according to materials, group I (GI) for cobalt chromium (Co-Cr) and group II (GII) for PEEK. Each testing models and its clasps were mounted inside universal testing machine, the retention was measured by applying withdrawal force to it by this machine at 5 mm/min. The Fatigue resistance is measured by the reduction in retention through repeated insertion and removal cycles using robota chewing simulator. Removal and insertion cycling of clasps was carried out for 360, 730, 1080, 1,440, 2,116 and 2,880 cycles (corresponding to 3, 6, 9, 12, 18 and 24 months of simulated clinical use of a RPD) to simulate the fatigue resistance test. Deformity was measured before and after each cycling using a digital micrometer. Statistical analysis was done by 2-way-ANOVA test to detect significance effects of each variable. **Results:** Retention and fatigue resistance, after 360,

RESUMO

Objetivo: o objetivo foi avaliar a força de retenção, a resistência à fadiga e a deformidade dos grampos fabricados com dois materiais diferentes: cromo-cobalto (Co-Cr) e poliéter-éter-éter-cetona (PEEK). **Materiais e métodos:** dezesseis modelos foram confeccionados, cada um com 1^o molar inferior. Os modelos foram divididos em dois grupos de acordo com o material: grupo I Co-Cr e grupo II para PEEK. Cada modelo de teste universal e seus grampos foram montados em uma máquina de teste universal. A retenção foi medida aplicando força de retirada por esta máquina a 5 mm/min. A resistência à fadiga foi medida pela redução na retenção através de ciclos repetidos de inserção e remoção usando um simulador do ciclo de mastigação. O ciclo de remoção e inserção dos grampos foi realizado por 360, 730, 1080, 1.440, 2.116 e 2.880 ciclos (correspondendo a 3, 6, 9, 12, 18 e 24 meses de uso clínico simulado de um RPD) para simular teste de resistência à fadiga. A deformidade foi medida antes e após cada ciclo, usando um micrômetro digital. A análise estatística foi realizada pelo teste ANOVA de 2 fatores para detectar os efeitos de significância de cada variável. **Resultados:** A retenção e a resistência à fadiga após 360, 730, 1080, 1.440, 2.116 e 2.880

730, 1080, 1,440, 2,116 and 2,880 cycles totally the difference between Co-Cr and PEEK groups was statistically non-significant ($P = 0.0980 > 0.05$) where (Co-Cr > PEEK). Deformation results, regardless to evaluation time, Co-Cr group recorded statistically significant higher deformation mean value than PEEK group ($P = 0.008 < 0.05$). Regardless to material group, deformation mean value changed non-significantly by time ($P = 0.2882 > 0.05$). **Conclusion:** PEEK clasps (1.0 mm in cross section diameter) engage 0.50 mm undercut provide sufficient retention nearly similar that of Co-Cr clasps.

KEYWORDS

Flexible clasps; polyether ether ketone, PEEK; thermoplastic resin; Partial Denture.

ciclos entre os grupos Co-Cr e PEEK não mostrou diferença estatisticamente significativa ($p = 0,0980 > 0,05$), onde (Co-Cr > PEEK). Para os resultados da deformação, independentemente do tempo de avaliação, o grupo Co-Cr registrou um valor médio de deformação maior, com diferença estatística significativa, quando comparado com o grupo PEEK ($p = 0,008 < 0,05$). Independentemente do grupo de material, o valor médio da deformação foi alterado de forma não significativa pelo tempo ($p = 0,2882 > 0,05$). Conclusão: os grampos PEEK (1,0 mm de diâmetro da seção transversal) engatam 0,50mm retenção quase semelhante à dos grampos Co-Cr.

PALAVRAS-CHAVE

Fechos flexíveis; Poliéter-éter-cetona (PEEK); Resina termoplástica; Prótese Parcial.

INTRODUCTION

Removable Partial Dentures (RPDs) are considered one of the most important way for replacement of missing natural teeth. RPDs must be have Sufficient retention, flexibility and esthetics which are considered as the most important factors affecting their clinical success. The retentive clasp arms of the direct retainers must be flexible and should retain the RPD satisfactorily without not unduly stress abutment teeth or be permanently deformed during service. Direct retainers of the RPD that were constructed from elastic materials demonstrated a higher resistance to retention loss [1].

The most common metal alloy used for construction of the direct retainers of RPDs is a Co-Cr, also other alloys as gold, titanium and round wrought wire can be used for fabrication of the direct retainer [2]. Metallic RPD has a big esthetic problem many methods have been carried out to overcome this problem such as etching the clasp arm and coating it with a layer of tooth-color resin, and lingual retention design [3]. Recently thermoplastic resins have been introduced into the market, direct retainers fabricated in a tooth-colored material and

constructed from polyoxymethylene (POM), also the PEEK and polyetherketoneketon (PEKK) have been used to enhance the esthetic of metal direct retainer assemblies of RPD [4]. Polyetheretherketone (PEEK) is a synthetic, tooth colored polymeric material that has been used as a biomaterial in orthopedics for many years [5,6]. PEEK can be used for patients allergic to metals, or who dislike the metallic taste, and the unpleasant metal display of the denture framework and retentive clasps [7].

The fatigue of a denture clasp is based on the its constant deflection during insertion and removal of the RPD. Clasp fatigue adversely affected the retentive properties of RPDs, the permanent deformation of clasps can cause loss of retention [8-11].

The fatigue behavior of the direct retainer is affected by its flexibility so the fatigue behavior of clasps made from PEEK may differ from that made from Co-Cr alloy [12,13].

The long-term retentiveness of metal and the thermoplastic resin clasps were not clear [8-17], and detailed analysis of the fatigue behavior of these clasps seems appropriate. Therefore, this

report was conducted to compare the retentive forces, fatigue resistance and deformation of PEEK clasps and Co-Cr clasps.

MATERIALS AND METHODS

For this study sixteen natural lower first molar teeth were collected, cleaned and examined to ensure that only intact non-carious non-mottled enamel was present. Laboratory custom made metallic mold (30 mm in length, 20 mm in width, and 25 mm in height) was used for fabrication the testing models. The testing models were made from self-cure acrylic resin (Acrostone ,Egypt) blocks with a natural tooth embedded in each model vertically. The testing models were divided into two groups according to the tested material: GI having Co-Cr clasps (Kera C, Eisenbacher Dentalwaren ED GmbH, Germany) and GII having PEEK clasps (Bio-HPP, Bredent, Senden, Germany). The abutment of the testing model was surveyed to ensure that there were adequate undercuts 0.02 inch. Tooth preparation was performed to provide rest seat. The laboratory models were duplicated into investment models (Calibra-M, Protechno, Spain) by using silicone duplicating material (Duplifix, Protechno, Spain). On the investment models, cast Co-Cr alloy and PEEK material frameworks with Ackers clasps were constructed as following:

Half-round cross section (with 1.0 mm in thickness) Aker clasp wax pattern (Polywax, Bilkim, Izmir, Turkey) was used to construct the wax patterns of the frameworks. According to the clasp and framework material each group was divided into two groups, each group contained eight testing models, GI for Co-Cr clasp material and GII for PEEK clasp material.

Cast Co-Cr alloy frameworks with Aker clasps of GI were constructed as conventional manner, then finished and polished.

For GII the steps of the injection molding process of the PEEK were carried out usual maner to construct the PEEK Aker clasps and frameworks.

After that the frameworks of GI and GII were tried on the models and were considered to be suitable for testing when the occlusal rests fit well in their rest seats, the retainers were in contact with the abutments, and the positive part of the framework rested on the testing model. Each clasp and its model were mounted on a Universal testing machine (Instron® 3345, Instron (4)Co. Ltd, Norwood, MA) as shown in Figure 1.

Retention of each clasp at pre-test (Baseline) was measured by applying withdrawal force to it by this machine at 5 mm/min. To perform the fatigue test, through removal and insertion cycling, ROBOTA chewing simulator integrated with thermo-cyclic protocol operated on servo-motor (Model ACH-09075DC-T, AD-TECH TECHNOLOGY CO., LTD., GERMANY) was used. Each clasp specimen was then placed on the corresponding abutment and fixed to the upper part of machine with vertical rod. The test conditions were maintained at room temperature ($25 \pm 2^\circ\text{C}$) and wet condition. Removal and insertion cycling of clasps was carried out for 360, 730, 1,080, 1,440, 2,116 and 2,880 cycles (corresponding to 3, 6, 9, 12, 18 and 24 months of simulated clinical use of a RPD) [9,15] to simulate the fatigue resistance test (Figure 2).

For studying deformity the distance between 2 reference points on the tips of the retentive and reciprocal arms of each clasp was measured before and after each removal cycles using a digital micrometer (Digimatic Micrometer Mitotoyd, Japan) with a resolution 0.001 mm. The data of the retentive force magnitudes at different intervals, , fatigue resistance and deformity were tabulated and subjected to statistical analysis. Data analysis was performed in several steps. Initially, descriptive statistics for the results of each group. 2-way-ANOVA test and multi-factorial ANOVA test was performed to detect significance effects of each variable (material group, tooth support and mechanical aging). Also Paired t test and unpaired t test was done between subgroups. Statistical analysis was performed using Graph Pad InStat (Graph

Pad, Inc.) for Windows. P values ≤ 0.05 are considered to be statistically significant in all tests.

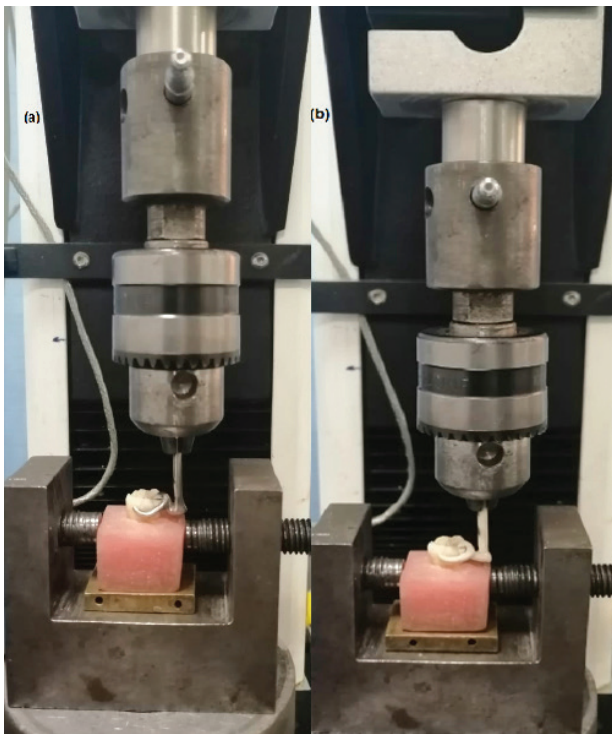


Figure 1 - Each clasp and its model were mounted on the universal testing machine, (a) Co-Cr clasp, (b) PEEK clasp.

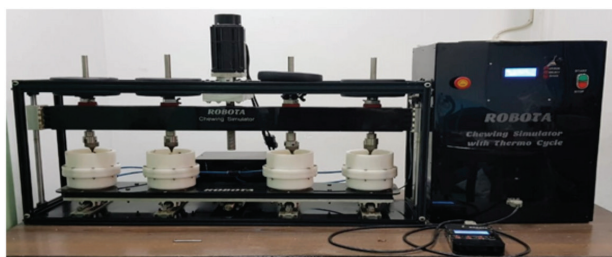


Figure 2 - Each clasp and its models were mounted on the chewing simulator device.

RESULTS

The results were analyzed using Graph Pad InStat (Graph Pad, Inc.) software for windows. A value of $P \leq 0.05$ was considered statistically significant. Continuous variables were expressed as the mean and standard deviation.

Retention and Fatigue Resistance

Table I shows the retention mean values of GI were decreased significantly from baseline to 24 months evaluation time as indicated by one-way ANOVA test ($P < 0.05$). Pair-wise Tukey's post-hoc test showed non-significant ($P > 0.05$) difference only between baseline and 3 months. Also the retention mean values of GII were decreased significantly from baseline to 24 months evaluation time as indicated by one-way ANOVA test ($P < 0.05$). Pair-wise Tukey's post-hoc test showed non-significant ($p > 0.05$) differences only between baseline and 3 months, baseline and 6 months, and 3 months and 6 months. Regarding to % change, totally the difference between GI and GII was statistically non-significant ($P = 0.0980 > 0.05$) where ($GI > GII$).

Table I - Descriptive statistics of retention results for both groups as function of evaluation time

Group	Time	Mean	SD	Minimum	Maximum
PEEK	Baseline	22.6875	2.467374	19.9725	26.625
	3 months	21.83644	1.103969	20.3205	23.66
	6 months	20.75	0.128695	20.5675	20.9325
	9 months	14.31438	1.586558	11.775	16.125
	12 months	11.19875	0.665219	10.075	12.0175
	18 months	7.6825	1.133814	6.225	9.575
Co-Cr	24 months	4.531875	1.202503	2.7025	6.2
	Baseline	36.0405	1.098187	34.1025	37.512
	3 months	34.27	0.401189	33.595	34.745
	6 months	25.89475	1.080684	24.1695	27.36875
	9 months	23.2275	0.719953	21.95	23.9375
	12 months	15.65438	0.177689	15.325	15.8275
	18 months	11.275	1.542968	9.25	13.825
	24 months	8.60625	0.959997	7.15	10.175

Clasp Deformation results

Table II shows the deformation mean values of GI were changed significantly from baseline to 24 months evaluation time as indicated by one-way ANOVA test ($P = 0.0478 < 0.05$) where the highest mean value recorded after 6 months (1.27675 mm) while the lowest recorded after 3 months (0.353 mm).

Also the deformation mean values of GII were changed non-significantly from baseline to 24 months evaluation time as indicated by one-way ANOVA test ($P = 0.05$) where the highest mean value recorded after 24 months (1.158403 mm) while the lowest recorded after 6 months (0.195972 mm).

Totally regardless to evaluation time, GI recorded statistically significant higher deformation mean value than GII as demonstrated by two-way ANOVA ($P = 0.008 < 0.05$). Totally regardless to material group, deformation mean value changed non-significantly as demonstrated by two-way ANOVA ($P = 0.2882 > 0.05$).

Table II - Descriptive statistics of deformation results for both groups as function of evaluation time

Group	Time	Mean	SD	Minimum	Maximum
PEEK	Baseline	0.459583	0.123003	0.265	0.617778
	3 months	0.532792	0.70402	0.026667	1.8945
	6 months	0.195972	0.181033	0.05	0.545
	9 months	0.956944	0.645036	0.222222	1.87
	12 months	0.835	0.444994	0.18	1.55
	18 months	0.267986	0.160135	0.044444	0.45
	24 months	1.158403	0.546744	0.322222	2.0225
Co-Cr	Baseline	1.172778	0.236185	0.8125	1.5475
	3 months	0.353	0.235201	0.045	0.772
	6 months	1.27675	0.690932	0.0595	2.1
	9 months	0.881623	0.42837	0.081111	1.268438
	12 months	0.957188	0.554238	0.115	1.72125
	18 months	1.259722	0.298895	0.85	1.7
	24 months	0.775	0.25	0.3	1

DISCUSSION

The demand for esthetic dental restorations has been increased due to an importance on physical appearance in modern society. Materials for clasps and frameworks of (RPDs) need to have enough flexibility for the clasps and rigidity for other framework components. Therefore, Co-Cr is the most popular alloy for the frameworks of RPDs. The biggest disadvantage of CoCr clasps is their poor esthetic appearance. Tooth colored clasps made of thermoplastic resins have been developed to overcome the aesthetic problems. In this study, Co-Cr alloy served as the metal group while PEEK served as the thermoplastic group.

It was found that metal group recorded higher retention mean value than PEEK group at base line, 3, 6, 9, 12, 18 and 24 months (corresponding to 360, 730, 1,080, 1,440, 2,116, 2,880) cycles, which is in agreement with the results of Tannous et al. [11], who compared the retentive force of clasps made from three thermoplastic resins PEEK, PEKK, POM and CoCr alloy by the insertion/removal test simulating 10 years use. Based on the results of this study, the retention forces of the PEEK clasps showed values clearly inferior to those of Co-Cr alloy which agree with the results of the others [12,13].

Also these results support the using of the PEEK clasps (1.0 mm in cross section diameter) to engage 0.50 mm undercut to provide sufficient retention nearly similar that of Co-Cr clasps.

However Abd-Elrahman et al. [12], stated that "the PEEK clasps should be thicker more than 1.0 mm (in cross-sectional diameter) when engage a deeper undercut (0.50 mm) to gain the stiffness of the cast CO-Cr clasps 1 mm in cross sectional diameter and to obtain a clinically acceptable retention".

As the clasps undergone a constant deformation due to the movements of insertion and removal of the prostheses. Previous studies showed how the fatigue strength of Co-Cr clasps concludes with the loss of retention because of the permanent deformation of the metal. In Sara study, two Co-Cr clasps were fractured by fatigue and deformation while PEEK clasps she did not

break [14,15]. According to Arda et al., although the Co-Cr clasps exhibit deformation and not the clasps of acetalic resins, the retention force of the Co-Cr clasps after their deformation remains higher than that of the acetal clasps, although these latest requirements less force of insertion and removal [16]. Loss of retention of the clasps due to fatigue resistance test was considered as a good indicator of permanent deformation of the clasps [17].

At the end of cycling of the present study there was no significant difference in the retention force between the Cr-Co clasp group and the PEEK clasp group however there was increase in the amount of clasp deformation in the Cr-Co clasps more than the PEEK clasps, these may be due to the amount of wear that might be occurred to the retentive arm of PEEK clasp that led to loss of its retention and non-significant statistical difference between the groups.

CONCLUSION

In accordance with the limitations of this study, it could be concluded that:

due to lack of statistical difference, it should be considered that PEEK clasps (1.0 mm in cross section diameter) engage 0.50 mm undercut provide the same retention as Co-Cr clasps.

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Prof. Dr. Mohamed Helal (Corresponding address)

Al-Azhar University, Faculty of Dentistry, Department of Removable Prosthodontics, AlmokhyamAldaem St., Nasr Road, 11884 Nasr City, Cairo, Egypt.
E-mail: mhelal@azhar.edu.eg

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