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# Comparative study of some mechanical properties of conventional cobalt chromium and poly ether ether ketone thermoplastic removable partial denture clasps. (An In-vitro Study)

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## Abstract:

**The 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).

**Methods:** sixteen models were fabricated, each one having lower 1st molar. Models were divided into two groups according to materials, group I for cobalt chromium (Co-Cr) and group II for PEEK. Each testing models and its clasps were mounted inside universal testing machine. Each clasp and its model were mounted in a 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

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months of simulated clinical use of a RPD) to simulate the fatigue resistance test.Deformity was measured before and after each cycleing 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, 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.

## Introduction

Removable Partial Dentuers (RPDs) are considered one of the most important way for replacement of missing natural teeth.RPDs must be have Sufficient retention, flexability and easthetics which are considered as the most important factors affecting their clinical success. The most common metal alloy used for construction of the direct retainers of RPDs is a cobalt-chromium (Co-Cr) alloy, also other alloys as gold, titanium alloy and round wrought wire can be used for fabrication of the direct retainer (1). 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 (2) . Recently thermoplastic resins have been introduced into the market, direct retainers fabricated in a tooth-colored material and constructed from polyoxymethylene (POM), also the polyetheretherketon (PEEK) and polyetherketonketon (PEKK) have been used to enhance the esthetic of metal direct retainer assemblies of RPD(3) . Polyetheretherketone (PEEK) is a synthetic, tooth colored polymeric material that has been used as a biomaterial in orthopedics for many years (4,5) . Poly ether ether keton 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 (6) . 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 (7).

The fatigue of a denture clasp is based on the constant deflection of the clasp 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 (8-11,14,15).

Also the fatigue behavior of clasps made from PEEK may differ from that of clasps made from Co-Cr alloy (12,13). In spite of the thermoplastic resin direct retainer is more flexible than the conventional Co-Cr direct retainer there is little data available regarding the long-term performance of such direct retainers (8-17). As an increased awareness of aesthetics in dentistry has resulted in the need for removable partial dentures that reveal little or no metal supporting structures or retentive elements. It will beneficial to conduct this study to compare 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: Group I (GI): Co-Cr (Kera C, Eisenbacher Dentalwaren ED GmbH, Germany) and Group II (GII): PEEK (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 (Dupliflex, Protechno, Spain). On the investment models, cast Co-Cr alloy and PEEK material frameworks with Aker 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. After that a small piece of wax (15 mm in length, 3 mm in height, and 6 mm in width) was fixed on the superior surface of the investment cast with 2 mm away from the distal surface of the abutment, by using softened wax. This wax piece was placed parallel to superior surface of the investment cast. It was connected with the wax pattern of the clasp by wax. A small cylindrical plastic piece of wax sprue (20 mm in length and 3 mm in diameter) was fixed at 90 degree to the piece of wax (to produce a testing column of the framework) and away 3 mm from the minor connector of the wax pattern framework. 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 (GI) were constructed as conventional manner, then finished and polished.

For GII the following steps of the injection molding process of the PEEk Aker clasps were carried out:

- The ring that was used for this injection process composed of two separate parts and three holes
- One part of the ring was filled with extra hard stone. The main hole of the flask was filled with wax through which PEEK injection process was carried out.
- Investment of wax pattern in mold using investing material in special silicone ring after attaching the wax pattern with spurs to the ring base. Then another metal ring with slightly smaller diameter is inserted inside the silicone ring. Each ring poured was allowed to set for half an hour .
- Wax elimination: The ring contained mold and investment plunger were placed in burn out oven up to 350 degrees for 5 minutes then 850 degrees for 1 hour. Then decrease the temperature to 400 degrees for half hour according to manufacture instruction .
- Peek granules were weighted in a ratio 3:1 of the wax then placed in the hot ring (400 degree) and placed in the burn out oven for 20 minutes to allow fusing of the peek material.
- After that, the ring is removed from oven with a metal holder and the plunger is placed in the ring and placed in the pressing device (for 2 press) under 4.5 bar pressure and vacuum for 3 inutes and pressure without vacuum for about 35 minutes .
- After that, the ring is divested and sand blasted (110 micron) then finished and polished.

For GI and GII, the frameworks 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).

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 servomotor (Model ACH-09075DC-T, AD-TECH TECHNOLOGY CO., LTD., GERMANY) was used. Each clasp specimen was then placed on the corresponding abutment crown and fixed to the upper part of machine with vertical rod. The test conditions were maintained at room temperature (25 ± 2°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) to simulate the fatigue resistance test .

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 0.001mm. 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.

## Results

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

### 1-Retention and Fatigue Resistance

Table 1 show PEEK group the retention mean values were decreased significantly from baseline to 24 months evaluation time as indicated by one-way ANOVA test (p=<0.0001<0.05). Pair-wise Tukey's post-hoc test showed non-significant (p>0.05) difference for Co-Cr between (baseline and 3 months), (baseline and 6 months) and (3 months and 6 months). Also group the retention mean values were decreased significantly from baseline to 24 months evaluation time as indicated by one-way ANOVA test (p=<0.0001<0.05). Pair-wise Tukey's post-hoc test showed non-significant (p>0.05) difference between (baseline and 3 months. Regarding to % change, totally the difference between PEEK and Co-Cr groups was statistically non-significant (p=0.0980>0.05) where (metal>PEEK). Regarding to % change, totally the difference between PEEK and Co-Cr groups was statistically non-significant (p=0.0980>0.05) where (Co-Cr >PEEK).

| 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 |
| | 24 months | 4.531875 | 1.202503 | 2.7025 | 6.2 |
| Co-Cr | 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 |

**Table (1) : Descriptive statistics of retention results for both groups as function of evaluation time.**

### 2-Deformation results

Table 2 show PEEK group the deformation

mean values 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).

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

| 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 |

**Table (2): Descriptive statistics of deformation results for both groups as function of evaluation time.**

## 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,CoCr 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, CoCr alloy served as the metal group while PEEK served as the thermoplastic group.

One laboratory custom made a metallic mold (30 mm in length, 20 mm in width, and 25 mm in height) was used for fabrication the testing models .A small piece of wax was fixed on the superior surface of the Acrylic block to provide space between the testing model and framework. Then, a small hole was made at its distal end to provide a positive stop. This stop and occlusal rest of the clasp provided positive location of the framework during finishing, testing and measuring the retention force (9,10). The unwanted proximal undercuts were blocked out by using softened wax to eliminate its effect on the retention force and then trimmed by means of the wax trimmer of the dental surveyor.

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 360,730,1080,1440,2116,2880) 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 (polyetheretherketon (PEEK), polyetherketonketon (PEKK) and polyoxymethylene) and cobalt–chromium (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 thr 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).

In the present study the the PEEK clasp group subjected to deforamtion

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

## Conclusion

In accordance with the limitations of this study, it could be concluded that the PEEK clasps (1.0 mm in cross section diameter) engage 0.50 mm undercut provide sufficient retention nearly similar that of Co-Cr clasps.

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