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Evaluation of Retention Force of Polyetheretherketone (PEEK) and Cast Cobalt-Chromium Circumferential Clasps: A comparative study

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Abstract

Aims: This in-vitro study aimed to compare the retention force of Polyetheretherketone (PEEK) and Cobalt-Chromium (Co-Cr) clasps by mechanical cycling test simulating ten years of use. **Materials and Methods**: 72 clasps samples were fabricated on a standardized e-max upper right first premolar, it is divided into 24 Co-Cr clasps, and 48 PEEK clasps which were subdivided into 24 clasps (2.4mm width), and 24 clasps (3.00mm width).Each group was further subdivided (n=8 clasps) into amounts of abutment undercut 0.25mm, 0.50, and 0.75mm undercuts. Mechanical cycling of each clasp was performed 15000 times on its specific abutment crown. The retention force of each clasp in newton was measured every 1500 cycles by applying a tensile force using a universal tensile machine. R**esults**: The retention force of Co-Cr clasps was higher significantly than the PEEK clasps retention force for the three undercuts. Deeper undercuts showed a significantly higher retention force for both materials. All subgroups (except 0.75mm Co-Cr group) exhibit an increase in retention force after the first 1500 cycles followed by the gradual decrease till the end of 15000 cycles. **Conclusions**: The retention force of PEEK clasps with both widths along 15000 cycles of insertion/removal was lower than Co-Cr clasps but still sufficient for clinical use at 050, and 0.75mm undercut but not enough at 0.25mm undercut.

الخلاصة

الاهداف: تهدف هذه الدراسة المختبرية الى مقارنة قوة ثبات مشبك الطقم الجزئي المعدني(كروم كوبالت) مع غير المعدني(بولي ايثر ايثر كيتون) بعد الاستخدام الافتراضي لمدة عشرة سنوات. **المواد وطرائق العمل**: تم تحضير (٧٢) مشبك على الضاحك العلوي الايمن المصنع من الايماكس, قسمت العينات الى (٢٤) مشبك كروم كوبالت, (٤٨) مشبك بولي ايثرايثر كيتون والتي قسمت الى (٢٤)مشبك بعرض (٢,٤مم) و(٢٤)مشبك بعرض (٣,٠٠مم). كل مجموعة تم تقسيمها (٨مشبك) حسب حجم منطقة الثبات على الضاحك ٠,٢٥مم,٠,٥٠مم, و٠,٧٥مم. تم انجاز التدوير الميكانيكي لكل مشبك (١٥٠٠٠دورة) على الضاحك المخصص. تم قياس قوة ثبات المشبك باستخدام جهاز الشد العام كل (١٥٠٠دورة).**النتائج**: قوة ثبات مشابك الكروم كوبالت تفوق قوة ثبات مشبك البوايثرايثركيتون بشكل كبيرذات دلالة احصائية. منطقة الثبات الاعمق اظهرت قوة ثبات اكبر احصائيا لكلا المادتين. كل المجاميع (ماعدا مجموعة مشابك الكروم كوبالت مع منطقةالثبات بعمق ٠,٧٥مم) اظهرت زيادة في الثبات اول ١٥٠٠ دورة ثم انخفاض تدريجي للثبات حتى نهاية ١٥٠٠٠ دورة. **الاستنتاجات**: قوة ثبات مشابك البولي ايثر ايثر كيتون اقل من مشابك الكروم كوبلت لكنها كافية للاستعمال السريري في مناطق الثبات الكبيرة ٠,٥٠,٠,٧٥مم وغيركافية في منطقة الثبات ٠,٢٥مم.

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INTRODUCTION

Beauty, attractiveness, and function must be restored by removable partial dentures (RPDs) to guarantee psychological agreement of the patient [1]. RPDs are most commonly made from Co-Cr alloy and eventually, the clasp [2] Esthetic problem and the probability of patient's metal sensitivity are the main drawbacks of the metal alloys [3]. Newly, thermoplastic resins have been used instead of metal alloys to resolve these drawbacks [4].

Thermoplastic PEEK is biomedical, with a modulus of elasticity similar to dentin, and non-allergic proposed to be used in dentistry [5, 6]. Little information is found about PEEK clasps performance, its retention force at a long-term use.

The purpose of this study was to estimate the retentive force of PEEK clasps with two widths retentive arms at three different undercuts after recurrent placement and removal on the first upper premolar tooth and to compare it with Co-Cr clasps as a control group. The null hypothesis was that there would be a difference in retentive force between PEEK clasps and cast Co-Cr clasps.

MATERIALS AND METHODS

Natural beige PEEK (peekMED, Dental Direkt, Germany) and a conventional dental Co-Cr alloy (Co 63%; Cr 29%; Mo 6.5%; Magnum H60, MESA, Italy) were tested in this study.

A. Abutment Fabrication

The first upper right anatomical premolar (acrylic resin tooth) (Jining Xingxing Medical, China) was fixed within type IV stone cylindrical template (Synarock XR, DFS Diamon, Germany). Distal and lingual guide planes, two thirds of the crown length were milled, blocking useless undercuts at the cervical area, generate 0.25mm (1), 0.50mm (2), and 0.75mm (3) retentive undercut, and setting an occlusal rest, 2.5mm long, 2.5mm wide, and 2mm deep were performed by a milling machine (DENTAURUM GmbH & Co. KG, USA).

The exact position, length, and end of the clasp parts was predetermined by placing a composite border (Tetric N-Ceram, Ivoclar Vivadent, Germany) at the cervical third of the crown all-around the abutment except for the mesial surface.

A-silicone impression material (Elite P&P, Zhermack, Italy) was used to take an impression of the abutment for each undercut measurement by using a tray with stoppers and then poured by type IV stone according to manufacture instructions. Three stone models were produced for the three amounts of undercuts, sent to the dental technician to fabricate an IPS e-max press (Ivoclar Vivadent, Germany) abutment. IPS e-max was supposed to have a similar attrition to enamel [7].

B. Clasp Design and Fabrication

Resurveying the IPS e-max abutments to assure parallel guide planes and detect the retentive undercuts, and then scanned by the 3D dental scanner (Dental Expert, Georgia). Designing of a traditional circumferential clasp (1.5mm widthx1.0mm thickness retentive arm) was completed by Zirkonzahn.modellier software and milled by a 5-axis milling machine (imess-icore GmbH, Germany), into wax which was processed into Co-Cr clasps by technician according to manufacturer's instructions.

PEEK clasps were designed similarly with different dimensions for the retentive arm, 1.5mm thickness with either 2.4mm (f) or 3.00mm (w) widths which converge to 1.2mm and 1.5mm respectively the tip of the arm. PEEK clasps were easily milled from PEEK discs by a 5-axis milling machine.

A total of 72 clasps were produced, forming nine groups, including 3 control groups of Co-Cr for 3 amounts of undercut (Co-Cr1, Co-Cr2, and Co-Cr3), and 6 study groups of PEEK, 3 for each width for 3 amount of undercut (Pf1, Pf2, Pf3, Pw1, Pw2, and Pw3)

C. Mechanical Cycling

A jelenko surveyor (QD, England) was modified to be similar to a chewing simulator tool connected to a digital counter (4DRCM, China). The e-max tooth with its resin base was retained on the table of the surveyor in parallelism to a path of insertion. The clasp was held in the locking device of the surveying beam. The clasp was removed and reinserted at a speed of 10mm/s simulating the placement and removal of RPD by a denture user (figure1). The study was completed in dry condition and at room temperature (25^{O}C).

Figure (1): The Clasp on Abutment Fixed on Cycling Machine.

D. Retention Measurements

A total of 15000 cycles were executed, matching the simulated insertion and removal of RPD over ten years, supposing that the patient would execute four complete cycles per day [8, 9]. The retention forces (in newton) of clasp were estimated by a universal testing machine which performs a tensile force at a constant speed of 5mm/min till the clasp separated from the abutment teeth and the mean of the peak forces of ten tests was reported as the retentive force of each specimen [10,11].

RESULTS

The average retentive force registered in newton's unit (N), standard deviation from zero to tenth cycles for nine groups of both clasps' materials are analyzed using the SPSS program (version19). Table (1) illustrated the mean in all groups with the higher means in the Co-Cr control group at all amounts of the undercut.

Table (1): Means and Standard Deviations of Clasps Retention (N) For Ten Mechanical Cycles of Co-Cr and PEEK Clasps with Three Undercuts.

Material	Undercut(mm)	N	Mean(N) ± SD
Co-Cr Control groups	0.25	8	10.744±1.651
	0.50	8	12.409±1.442
	0.75	8	12.922±1.907
PEEK, fine retentive arm Pf	0.25	8	1.956±0.218*
	0.50	8	5.555±0.392*
	0.75	8	7.352±0.371*
PEEK, wide retentive arm Pw	0.25	8	2.655±0.209*
	0.50	8	6.154±0.718*
	0.75	8	8.804±0.634*

*Significant difference from the control groups at $p \leq 0.01$, N: number of the samples.
SD: standard deviation.

Table (2) shows one-way analysis of variance (ANOVA) for comparison of the retentive force of Co-Cr clasps at each abutment undercut. Results showed that there was a significant difference in retentive force of all groups at p≤0.01 with the Co-Cr groups having higher values than PEEK clasps groups with both widths of the retentive arm. As well the wider retentive arm PEEK clasps showed significantly higher retention force than PEEK clasps with a fine retentive arm. However, Abutment undercut showed a significant effect on clasps retention, 0.75mm undercut exhibit greater retention than 0.50mm undercut, and 0.25mm undercut provide less retention for all groups.

All clasps groups except Co-Cr clasps with 0.75mm undercut showed initial raise in retention at the first cycle and then gradually reduced along with the remaining cycles.

Table (2): One Way Analysis of Variance (ANOVA) of the Retention Force (N) for Three Undercuts Groups Using Co-Cr and PEEK Clasps.

Undercut Type	Source of Variance	Sum of Squares	df	Mean Square	F	Sig.
Undercut 0.25	Between Groups	4198.580	2	2099.290	2.234	0.000*
	Within Groups	245.286	261	0.940		
	Total	4443.866	263			
Undercut 0.50	Between Groups	2536.422	2	1268.211	1.383	0.000*
	Within Groups	239.414	261	0.917		
	Total	2775.836	263			
Undercut 0.75	Between Groups	1469.538	2	734.769	527.226	0.000*
	Within Groups	363.743	261	1.394		
	Total	1833.280	263			

df: degree of freedom. , * Significant difference existed at $p \leq 0.01$.

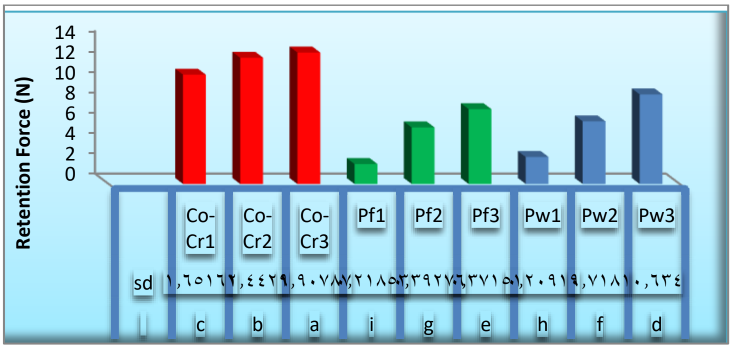
DISCUSSION

The data obtained from this in vitro study showed that Co-Cr clasps had significantly higher retention force than PEEK clasps. Therefore, the null hypothesis that there would be the difference in retentive force between cast Co-Cr clasps and PEEK clasps has been accepted.

The factors affecting clasp retention are tooth undercut and flexibility of clasp material but also affected by other factors such as clasp design, surface topography, angle of gingival convergence (12), and friction coefficient between the abutment teeth and the clasp (13).

Thermoplastic resins clasps have to be thicker and wider than a metallic clasp to produce efficient retention, due to their high proportional limit and low elastic modulus (14).Other authors claimed that the resin clasps arm must be shorter with bigger cross-sectional diameter and engage deeper undercuts to get sufficient retention(15). The results of the present project following these findings, the 3.00mm wide retentive arm of PEEK clasp that engages 0.75mm undercut provides the greatest retentive force.

Figure 2 showed that the highest amount of retention was obtained by Co-Cr clasps then the wide retentive arm PEEK clasps and the lowest retention was PEEK clasps with a fine retentive arm. This is due to low elastic modulus of PEEK material (4.0GPa) which renders PEEK more flexible with low rigidity in comparison to Co-Cr alloy (240GPa) which is rigid with low flexibility (16,17).



*Duncan's Multiple Range Tests: Means with different letters are statically significant at $p \leq 0.01$.

Figure (2): Mean ± Standard Deviation and Duncan's Multiple Range Tests for Means of Retention Force of the Nine Groups

Retention of 2.94-7.35N is substantial in clI RPD to protect against removal during chewing [(18)]. Other authors claimed that a retentive force of 5N is suitable for functioning RPD [(19)]. The results of the present study showed that PEEK clasps provide sufficient retention for 0.50mm and 0.75mm undercut even with fine arm along ten years of use theoretically.

The initial raise in retentive forces for Co-Cr clasps with 0.25 and 0.50mm undercut after first cycle can be attributed to strain hardening of the plastically deformed Co-Cr clasps which occur as a result of accumulated dislocations within the material as it passes over the height of contour of the tooth which makes material entangled decreasing its capability to mobilize generating a hardening of CO-Cr material [(20)].

Co-Cr clasp with 0.75mm undercut attitude was not harmonious with the aforementioned groups; this was because of the big amount of strain undergone as it was evicted from the undercut. The high modulus of elasticity of Co-Cr predetermines its use in an undercut smaller than 0.50mm [(21)].

The subsequent decrease in retention force Co-Cr clasps along with the rest cycles because of the successive attrition of the inner surface of the clasps and outer surface of the abutment crowns which produce plastic clasp distortion leading to progressive reduction in frictional resistance [(22, 23)].

The initial rise in retention for PEEK clasps in the first cycle attributed to enhance the fitness of the clasps to the abutment crowns which subsequently cause more friction, and then the retention reduced progressively during the remaining cycles due to fatigue deformation which reduces the friction [(24)].

Authors' similar studies on Co-Cr clasps mentioned that a severe decrease in retentive force had been inspected [(22, 25)], other study remembered a raise in retention force along five years of simulated use [(8)].

Tannous F. et al., 2012 study showed a similar initial raise in force for Co-Cr and resin clasps using Co-Cr abutment and claimed that there is no significance between initial and final retention forces at the end of 15000cycles [(9)].

An in vitro study compared the retentive force of circumferential clasps made of Co-Cr and PEEK on lithium di-silicate crowns revealed initial raise then progressive reduction in retentive force along 15000cycles, but the abutment undercut was not remembered [(24)].

CONCLUSIONS

The PEEK clasps can be used in an undercut 0.50mm and 0.75mm that is contraindicated for Co-Cr clasps. PEEK clasps can be used in case of tilted or malposed abutment and in case of abutment with periodontal problems, without exerting a harmful force to the supporting tooth and provide sufficient retention force.

Limitation of the study:

The limitation of this study was that it was performed in a dry environment -without saliva- and that may influence the retentive force, so the retentive force may be diverse in a realistic -oral cavity- environment.

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