

Retention and Deformation of Cobalt-Chromium and High-Impact Polyamide Clasps

Kobalt-Krom ve Yüksek Etkili Poliamid Kroşelerin Deformasyonları ve Retantif Kuvveti

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Keywords

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Abstract

Objective: The use of metal clasps especially in anterior region may cause aesthetic problems. Polyamide resin has been suggested as an alternative aesthetic denture clasp material. This study compared the retentive force and deformation of cobalt-chromium and polyamide clasps after 36 months of simulated clinical use.

Materials and Methods: The retentive force for clasp removal was measured in distilled water using a custom-made apparatus with intervals corresponding to 0, 6, 12, 18, 24, 30 and 36 months of simulated clinical use. The distance (mm) between the retentive and reciprocal clasp tips was measured using a microscope before and after the insertion-removal procedures.

Results: Significant difference was observed in distance between clasp tips for metal clasps between baseline and 36 months for molars and premolars ($p<0.05$). Likewise, retentive force showed significant difference ($p<0.05$) for cobalt-chromium between baseline and 36 months, while polyamide clasps did not show significant difference ($p>0.05$).

Conclusion: Polyamide clasps could be alternative to metal clasps particularly on premolars with reliable retention and deformation.

Öz

Amaç: Metal kroşelerin kullanımları özellikle anterior bölgede ise estetik problemlere yol açabilir. Poliamid rezinin yeni bir tipi alternatif estetik bir dental kroşe materyali olarak kullanılmaya başlamıştır. Bu çalışmanın amacı kobalt-krom kroşeler ile poliamid kroşelerin 36 aylık kullanım periyodu sonunda retantif kuvvetlerinin ve deformasyonlarının karşılaştırılmasıdır.

Gereç ve Yöntemler: Kroşelelerin retantif kuvvetleri distile su içerisinde, özel tasarlanmış, yerleştirme-çıkarma mekanizmasıyla çalışan bir test aparatı yardımıyla ölçüldü. Klinik uygulamanın simülasyonu elde edilip bu aparat yardımıyla 0, 6, 12, 18, 24, 30 ve 36. aylarda ölçüm yapıldı. Yerleştirip çıkartma testinden önce ve sonra bir mikroskop yardımıyla kroşenin retantif ve resiprokal kolları arasındaki mesafe mm cinsinden ölçüldü.

Bulgular: Otuz altı ayın sonunda premolar ve molarlarda metal kroşe tiplerinin kendi aralarındaki karşılaştırmalarında resiprokal ve retantif kollar arasındaki mesafede

önemli ölçüde farklılıklar gözlemlendi. Ek olarak yine molar ve premolar dişlerde 36 ay sonunda metal kroşelerin retantif kuvvetinde önemli değişim gözlenirken, poliamid kroşelerde hiçbir retantivite farkı gözlenmedi.

Sonuç: Poliamid kroşeler özellikle premolarlarda kobalt-krom kroşelere alternatif olabilir.

Introduction

Numerous treatment options exist to restore the missing teeth in partially edentulous patients. Removable partial dentures (RPDs) are an effective and affordable treatment modality to restore function and aesthetics. Several types of polymers and metal alloys could be used in the construction of RPDs (1). The most commonly used alloys for RPDs are cobalt-chromium (Co-Cr), gold and titanium alloys, although they are not aesthetically pleasing. Since their commercial launch 80 years ago, Co-Cr alloys have undergone several modifications. There has been an increase in the use of such alloys and they are currently the most current material of choice for RPD metal frameworks (2-4).

Clasps are the most commonly used direct retainers for the RPDs and they are frequently made from the same alloy as the metal framework. The flexible clasp tip engages the undercut of the abutment in order to provide retention. The components of any clasp assembly must fulfil at least six biomechanical requirements, namely retention, stability, support, reciprocation, encirclement and passivity. In addition, the clasp assembly must ideally not affect aesthetics adversely (1). For this purpose, researchers have been investigating alternative materials in order to overcome the unaesthetic appearance of alloy clasps especially when they are placed on the anterior teeth. The methods to overcome this aesthetic dilemma have included, covering clasps with tooth-colored resin (3,5), the use of lingually positioned clasps (6,7), and the engagement of mesial rather than distal undercuts (8).

Recently, some new types of polymers have been proposed as denture base materials with the purpose of achieving favourable aesthetic outcome, biocompatibility especially for patients who are allergic to conventional metals and resin monomers, higher elasticity than conventional heat-polymerizing resins, sufficient strength for use as a denture base material. One such polymer fulfilling these requirements is polyamide. With its higher elasticity and moulding precision as opposed to heat-

polymerized denture base resins, such polymers facilitate denture retention. Thus, when metal clasps could be eliminated from denture bases, problems associated with metal clasps, such as excessive stress on abutment teeth, aesthetic compromise, and metal allergy could be reduced (9,10).

Due to the many variables involved in clinical evaluation, in *in-vitro* investigations some confounding clinical parameters could be eliminated (11). Some of these studies were performed under constant load (12-19) or displacement. (13,20-24) The long-term effectiveness of retention of clasps and their effect on the abutment teeth have been previously studied (22-24) where clasp arm design was shown to produce less stress and thereby delivered predictable long-term use of an RPD. In fact, three factors affect the design of clasp arm, namely, material, form, and amount of undercut (12). Moreover, fatigue properties of a denture clasp are dictated by the repeated deflection of the clasp over the undercuts of the teeth during insertion and removal of the RPD (1).

The objectives of this study therefore were to compare the retentive force and deformation of Co-Cr and polyamide clasps after long-term simulated clinical use.

Materials and Methods

In this study, pink, transparent polyamide resin (Deflex, Nuxen SRL, Buenos Aires, Argentina) and a conventional dental Co-Cr alloy (Co 64%; Cr 28%; Mo 5%; Dentorium, New York, NY, USA) were evaluated (Table 1). Impressions of a maxillary first premolar and first molar were made from a phantom model

Table 1. Types, brands and manufacturers of the materials tested in this study

Type	Brand	Manufacturer
Cobalt-Chromium	Dentorium	Dentorium, New York, NY, USA
Transparent polyamide	Deflex	Nuxen SRL, Buenos Aires, Argentina
Pink polyamide	Deflex	Nuxen SRL, Buenos Aires, Argentina

(Model 1362, Dentoform, Columbia Dentoform Corp, New York, NY, USA) using reversible hydrocolloid impression material (Speedex, Coltene/Whaledent Inc, Cuyahoga Falls, OH, USA). Then duplicate wax (Casting wax, Dentalwachse, Karl Berg GmbH, Engen, Germany) models were prepared. The wax molar tooth was fixed in the center of a wax plate (1.2 cm x 4 cm x 3 mm) and trimmed on a surveyor (APF400, Amann Dental Equipment, Koblach, Austria) achieving mesial (8 mm) and lingual guide planes (6 mm) while creating a 0.25 mm undercut area on the distobuccal surface. An occlusal rest seat of 2 mm depth was prepared on the mesio-occlusal surface. Small amounts of wax were placed on the distobuccal and distolingual line angles of the tooth in order to standardize the location of the tips and the lengths of both retentive arms (premolar: 8 mm; molar: 12 mm) and reciprocating arms. The same procedure was followed while obtaining premolar models with 0.25 mm undercuts. Each wax model was duplicated (Lab putty, Omega GmbH, Bliedersdorf, Germany) and poured with casting wax. Ten identical sets of wax models were obtained for the molar and premolar specimens. Twenty wax models were invested in single casting rings (Bego GmbH & Co.KG, Bremen, Germany) and cast with a Co-Cr alloy (Dentorium), following the manufacturer's recommendations. Finally, the specimens included 10 premolar clasps with 0.25 mm undercut, and 10 molar clasps with 0.25 mm undercut. The specimens were then trimmed, airborne-particle abraded, finished, and electro polished (Elropol SL, Bego GmbH & Co.KG, Bremen, Germany). The guide planes were evaluated for parallelism and slight inaccuracies were adjusted using a milling machine (APF400, Amann Dental Equipment, Koblach, Austria). Thereafter impressions of each metal model were made in regular-body silicone impression material (Lab putty) with custom impression trays. Each impression was poured with die investment material (Wirovest, Bego, Lincoln, RI, USA) to make 1 refractory cast for Co-Cr clasps, with type IV dental stone (Cere Rock, GC Germany GmbH, Munich, Germany) and 2 refractory casts for the polyamide clasps.

For Co-Cr clasps, preformed half round standard (1.2 mm thickness) clasp patterns with occlusal rests, retentive and reciprocal arms (Klammern Clasp, Dentaurum, Ispringen, Germany) were adapted on

the refractory investment cast. A wax plate (4x7x3 mm³) was attached to the minor connector parallel to the path of insertion (Figure 1). The plate was used later for maintaining the clasp in the testing machine. The cast and pattern assembly were then invested (Wirovest) according to the manufacturer's instructions and cast in Co-Cr alloy. The clasp was trimmed, airborne-particle abraded, finished and electropolished using standardized procedures.

For polyamide clasps, the same preformed half round standard (1.2 mm thickness) clasp patterns were adapted on the refractory cast. For fabrication of the polyamide clasps, the occlusal rest, retentive and reciprocal arm of the clasp was adapted on the refractory die using straight semi-circular clasp pattern (Megadental Vertrieb GmbH, Bidingen, Germany). The previously described, similar-sized wax plate was attached to the minor connector parallel to the path of insertion. Polyamide clasps were prepared according to the manufacturer's instructions where injection was performed at 6 bar pressure for 30 sec following plasticization (280 °C for 15 min).

All the clasp groups (20 transparent polyamide, 20 pink polyamide, 20 Co-Cr) were divided into 2 subgroups (n=10), according to the type of tooth (molar or premolar). Prior to the retention testing, the clasps were placed in acrylic resin (Meliodent, Heraeus Kulzer GmbH & Co. KG, Hanau, Germany) blocks (2.5 cm x 4 cm x 5 mm). The distances between the tips of the retentive and reciprocal arms of the clasps were measured with a microscope (Toolmaker

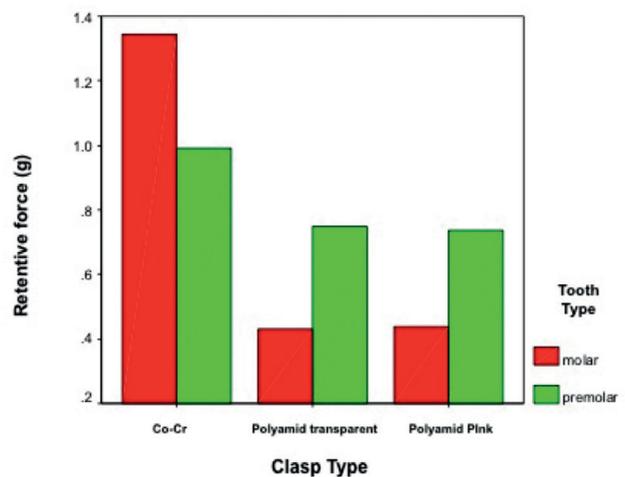


Figure 1. The mean retentive force (g) at baseline for the types of clasp materials tested
Co-Cr: Cobalt-chromium

TM-505, Mitutoyo Ltd, Kawasaki, Japan) and recorded to the nearest 0.005 mm. The retention testing of the clasps was conducted using a custom-made insertion removal apparatus (FESTO AG & Co. KG., İstanbul, Turkey). The apparatus allowed the insertion of the clasp to its predetermined terminal position and its subsequent removal from the metal model. The retentive force of the clasp in grams (g) was measured during removal.

The clasp attached to the testing apparatus was placed on the corresponding abutment metal model fixed on a stainless-steel container that was filled with distilled water. Cycles (x4380) of placement and removal of the clasp, simulating 3-years of clinical use (16) were performed along the path of insertion and removal which was determined by preliminary surveying procedures of the abutment metal model. A tensile load was applied (10 mm/min) to the clasp until it was dislodged. The maximum loads required to remove the clasp at 7 different periods of 0, 730, 1460, 2190, 2920, 3650, and 4380 continuous cycles were recorded by the testing apparatus. First, polyamide clasps and then Co-Cr clasps were tested to avoid any possible surface attrition of the models. After fatigue testing, the distance between the tips of the retentive and reciprocal arms of each clasp was measured under a microscope (Toolmaker TM-505, Mitutoyo Ltd, Kawasaki, Japan).

Statistical Analysis

The means and standard deviations of the retentive force magnitudes were recorded for the 7 time periods for dislodgement of each clasp and the distances between the clasp tips measured before and after insertion-removal test. Comparison of the mean values of the retentive force (gram force) of the clasps and the distance (mm) between the clasp tips was statistically analysed using Kolmogorov-Smirnov, paired t-test and independent sample t-test [Statistical Package for the Social Sciences (v.18.0; SPSS Inc, Chicago, IL) (alpha=0.05)].

Results

Comparison of the mean retentive force for different types of clasps at the initial time period is shown in Figure 1, 2 represents the mean values of the retentive force required to cause dislodgement of each clasp from molar and premolar teeth with 0.25 mm undercuts at the initial and 36 months periods.

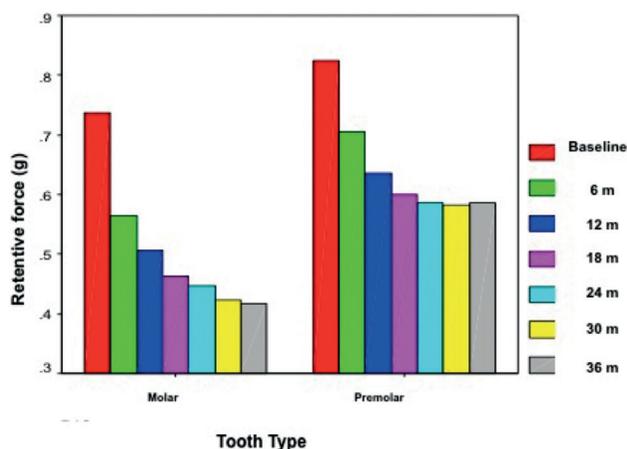


Figure 2. The mean retentive force (g) required dislodging all type of clasps from the molar and premolar teeth at the initial, 6, 12, 18, 24, 30 and 36-months time periods

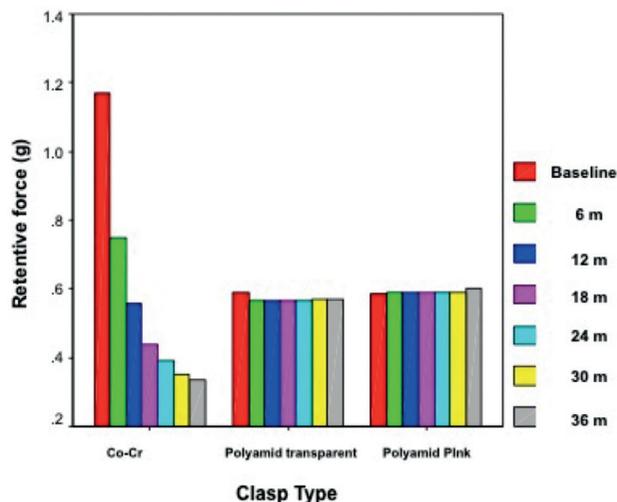


Figure 3. The mean values of the retentive force (g) of polyamide and Co-Cr clasps at baseline and 36-months periods regardless of the tooth type

Co-Cr: Cobalt-chromium

The difference in mean values of tensile load required to dislodge the clasps were not statistically significant between Co-Cr and polyamide clasps ($p < 0.05$). At the end of the testing periods, retentive force for all type of clasps varied from 0.36 ± 0.03 to 0.46 ± 0.01 for molar teeth and from 0.30 ± 0.04 to 0.73 ± 0.08 for premolar teeth (Figure 3).

The highest retentive force required to remove the clasps was for Co-Cr clasps and the lowest for the transparent polyamide resin clasps. At the initial and 36-months periods, the retentive force required to dislodge polyamide clasp from the molar and

premolar teeth was significantly ($p < 0.001$) lower than the retentive force needed for the Co-Cr clasps. The retentive force required for removal of the polyamide resin clasps was also significantly ($p < 0.001$) lower than the retentive force required for removal of the Co-Cr clasps from the molar and premolar teeth. Simulated clinical usage time also affected the results significantly ($p < 0.05$). Metal clasps showed significant difference between baseline and 36 months (1.34 ± 0.13 ; 0.36 ± 0.03) for molar (0.99 ± 0.05) and premolar teeth (0.30 ± 0.04) ($p < 0.05$).

The main effects of material type and tooth type on retention and deformation were significant. These effects were significant for all test periods. Table 2 represents the mean values and statistical comparison for the retentive force required to cause dislodgement of each clasp from molar and premolar teeth at the baseline and 36-months periods. During repeated cycles of placement and removal, the retentive force required to remove the Co-Cr clasps decreased significantly ($p < 0.05$). However, the retentive force required for both types of polyamide resin clasps demonstrated no significant change over the 7 time periods tested (Table 2). The mean retentive force at the first period of testing varied between 0.42 ± 0.08 and 1.34 ± 0.13 . The highest retentive force required to remove the clasps was for Co-Cr clasps, and the lowest for the polyamide resin clasps on molar teeth. The mean retentive force for the 36-months test period varied between 0.30 ± 0.04 and 0.73 ± 0.08 .

After 36 months of simulated clinical use, there was significant increase ($p < 0.05$) in the distance between the tips of Co-Cr clasps but not for both types of the polyamide resin clasps ($p > 0.05$).

Table 2. The mean values for the retentive force (g) required to cause dislodgement of each clasp from molar and premolar teeth

Clasp Material		Molar	Premolar
Cobalt-Chromium	Baseline	1.34 ± 0.13	0.99 ± 0.05
	After 36 m	0.36 ± 0.03	0.30 ± 0.04
Transparent polyamide	Baseline	0.42 ± 0.08	0.74 ± 0.06
	After 36 m	0.41 ± 0.08	0.72 ± 0.06
Pink polyamide	Baseline	0.43 ± 0.01	0.73 ± 0.08
	After 36 m	0.46 ± 0.15	0.73 ± 0.08

Discussion

Current problems associated with the use of metal clasps such as poor aesthetics resulting from metal exposure and the risk of metal allergy yielded to search for new materials (9). In the meantime, polyamide resins gained popularity and acceptance as clasp materials in clinical practice due to their flexibility and highly elastic nature that eventually decreases stress on the abutment teeth. Polyamide resin (DEFLEX) is marketed for the direct retainers attached to a Co-Cr RPD framework and to support the components of RPDs. However, in dentistry, because of its inherent flexibility, it has been used primarily for flexible mucosa born partial dentures. Such polymers do not have sufficient strength to be used as occlusal rest seats and they would not maintain vertical dimension when used in direct occlusal forces, but the studies were controversial in this regard (6-14).

In the present study, the retentive force and deformation of Co-Cr and polyamide clasps (pink and transparent) were compared after 36 months of simulated clinical use in distilled water. The retentive force of a clasp also depends on the frictional coefficient between the abutment and the clasp that was reported to be approximately 0.2 in the presence of saliva. Frictional coefficient values in wet condition with water are nearly the same as the values in saliva (25).

This study was designed to compare clasps on molar and premolar teeth with 0.25 mm undercut. The 0.25 mm undercut was selected as it represents the undercut commonly used for Co-Cr clasps. The stiffness of Co-Cr clasps makes them unsuitable to be placed in larger undercuts due to possible unacceptable stresses on the abutment teeth (22). Polyamide clasps may also be advantageous in clinical situations in which aesthetics and/or periodontal health are of importance (24).

The results of the present study showed that polyamide resin clasps in both colours on both type of teeth (premolar and molar) had significantly low retentive forces than those of Co-Cr clasps. In previous studies, Ahmad et al. (20) found that 4.77 N retention was required to dislodge a Co-Cr clasp from a 0.25 mm undercut, while another study concluded that 300 to 750 g (2.94 N to 7.35 N) is sufficient for the retention of a bilateral distal extension RPD (13). The

flexibility of a clasp arm affects the retention and the function of an RPD. If a clasp is too flexible, the clasp may not provide adequate retention for the RPD when the framework design is based on the recommended principles for Co-Cr alloys (2).

The polyamide resin clasp should be thicker and shorter than a standard clasp and engage a deeper undercut for better retention. This is due to the greater flexibility of the polyamide resin when compared to Cr-Co alloy. The polyamide resin clasps exhibited greater retentive forces when placed on premolar teeth due to the shorter length of the clasp arms. In the present study, the results demonstrated that the retentive force for a polyamide resin clasp might be sufficient for RPDs.

The results of this study also indicated that polyamide resin clasps are resistant to deformation and may offer a clinical advantage over the conventional metal clasps in that the retentive forces of both types of polyamide resin clasps did not decrease after the cycling periods. Under the conditions of the present study, Co-Cr clasps lost retentive force within 730 cycles of placement and removal that decreased during the remaining testing period. Earlier studies have indicated loss of retention because of permanent deformation of the Co-Cr clasps (12,16,25). The results of the present study showed a significant deformation of Co-Cr clasps after 36 months of simulated clinical use. On the other hand, neither type of polyamide resin clasps showed significant deformation after 36 months of simulated clinical use. One limitation of this study was that the duration was limited to 36 months. Prolonged use of clasps may yield to further deformation.

The advantage of non-metal clasp dentures is their flexibility. With these characteristics, ISO standards for the evaluation of non-metal clasp denture materials need to be established with complementary tests. Despite the advantages, polyamide resin materials are more difficult to adjust, and polish compared to Co-Cr. Furthermore, for sufficient retention, they should be prepared in a bulky form which may eventually cause food accumulation. Further research is needed on the clinical efficacy of the polyamide resin clasps in order to determine whether such materials could substitute the Co-Cr clasps.

Ethics

Ethics Committee Approval: The ethics committee approval was not necessary since the study was *in vitro*.

Peer-review: Externally and internally peer-reviewed.

Authorship Contributions

Surgical and Medical Practices: Ö.K., T.A., Y.K.Ö., Concept: Ö.K., T.A., Y.K.Ö., Design: Ö.K., T.A., Y.K.Ö., Data Collection or Processing: M.Ö., Ö.K., Analysis or Interpretation: M.Ö., Ö.K., T.A., Literature Search: M.Ö., Ö.K., T.A., Writing: M.Ö., Ö.K., T.A.

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