Original article

Effect of acetyl resin retentive arms on the retentive force of circumferential clasps: An in vitro study

Érica Miranda de Torres DDS, PhD[a], Iane Inarde de Siqueira Damasceno DDS[b],
Bruna Aguiar do Amaral DDS, MSc[b], Renata Cristina Silveira Rodrigues DDS, PhD[c],
Adriana da Fonte Porto Carreiro DDS, PhD[b], Ricardo Faria Ribeiro DDS, PhD[c],*

[a] Department of Stomatological Sciences, School of Dentistry, Federal University of Goiás, Goiânia, GO, Brazil
[b] Department of Dentistry, School of Dentistry, Federal University of Rio Grande do Norte, Natal, RN, Brazil
[c] Department of Dental Materials and Prosthodontics, Dental School of Ribeirão Preto, University of São Paulo, Ribeirão Preto, SP, Brazil

Abstract

Purpose: To compare and to evaluate the stability of the retentive force of cobalt–chromium (Co–Cr) circumferential clasps (control) to those with an acetyl resin retentive arm.

Methods: Sixteen specimens with a couple of circumferential clasps were made using Co–Cr over a metal model providing 0.25 mm undercuts. Eight specimens were fabricated without the anterior retentive arm, which was made later using acetyl resin (Dental D). Insertion and removal simulation test was performed through 7250 cycles. The retentive force was recorded in Newtons (N) for periods corresponding to 0, 1, 2, 3, 4, and 5 years. The data were subjected to ANOVA and Tukey test to compare periods and to Student's t test to compare groups ($\alpha = 0.05$).

Results: Mean (SD) is presented for Co–Cr and resin groups, respectively: 8.09(3.05) and 2.79(1.57) in period 0; 10.48(4.25) and 3.32(1.92) in 1 year; 10.09(4.15) and 3.47(1.81) in 2 years; 9.87(4.30) and 3.46(1.87) in 3 years; 9.46(3.93) and 3.27(1.59) in 4 years; 9.63(3.79) and 3.41(1.59) in 5 years. There were significant differences for Co–Cr between periods of 0 and 1 ($p < 0.001$), 0 and 2 ($p < 0.01$) and 0 and 3 ($p < 0.05$). In the resin group, no significant differences were found between periods ($p > 0.05$). Comparisons between the groups showed statistical differences for all tested periods: 0 ($p = 0.0012$), 1 ($p = 0.0013$), 2 ($p = 0.0019$), 3 ($p = 0.0031$), 4 ($p = 0.0027$) and 5 years ($p = 0.0014$).

Conclusions: Acetyl resin retentive arms, even if only in the anterior clasps, can significantly reduce the retentive force, but this force remained stable after 5 years of simulated use.

© 2011 Japan Prosthodontic Society. Published by Elsevier Ireland. All rights reserved.

Keywords: Dental clasps; Acetyl resin; Removable partial denture; Aesthetics; Fatigue

1. Introduction

Due to the increasing emphasis on aesthetics, dentists have been concerned about providing aesthetics and functional removable partial dentures (RPDs) to their patients. Some strategies can be used to optimize aesthetic results in RPDs, such as attachment systems [1], RPD with a rotational path of insertion [1,2], aesthetic clasp designs [3], and aesthetic materials for making clasps [4–8].

Metal components that are visible when the patient smiles or speaks are a major problem associated with the conventional clasp-type partial denture [3]. A visible clasp may cause patients to be dissatisfied with both their appearance and the RPD. Appearance would be vastly improved if metal direct retainers were eliminated or minimized [5].

Intracoronal and extracoronal precision attachments can provide good aesthetics; however, they present some disadvantages, such as cost, time-consumption, extensive abutment tooth preparation, and technique-sensitive clinical and laboratory procedures [1,5].

Rotational path RPD replaces certain clasp arms by rigid retentive components. If used in combination with specially designed rests, these components make it possible to eliminate some unaesthetic clasp arms without impairing mechanical

* Corresponding author at: Department of Dental Materials and Prosthodontics, Dental School of Ribeirão Preto, University of São Paulo, Av. do Café, s/n, Monte Alegre, CEP: 14040-904, Ribeirão Preto, SP, Brazil.
Tel.: +55 16 3602 4046/3983; fax: +55 16 3633 0999.
E-mail address: rribeiro@forp.usp.br (R.F. Ribeiro).

requirements of support, retention, and stability. This design decreases tooth and tissue coverage by partial denture framework components, minimizing plaque accumulation and adverse periodontal response [2]. One disadvantage of rotational path RPDs is that Kennedy Class I and Class II with anterior modification spaces ordinarily do not lend themselves to a rotational path of placement, because the rigid retainers will usually torque the abutments during rotational movements in function [9].

In order to minimize this torque effect, Belles [3] described the Twin-Flex technique. It is an alternative for anterior retention that maintains excellent aesthetics and consists of a wire clasp soldered into a channel that is cast in the major connector. It uses areas of mesial and distal retention. In general, the only flexible part of the retentive clasp is its extremity. However, the proposed wire clasp in the Twin-Flex is entirely flexible. Therefore, it does not generate as much torque when the distal extension is depressed in Kennedy Class I and Class II. Disadvantages of this technique include greater space between the retentive component and artificial tooth to allow a horizontal movement of the wire, extra thickness of the major connector over the wire clasp, the extra laboratory steps with implied increased costs, and difficulty in repairing the clasp if breakage occurs [3,10].

Technopolymers, also known as acetyl resins, are injection-molded thermoplastics that have been proposed as an aesthetic alternative to metals when fabricating RPD clasps [4–8]. Manufacturers have recommended acetyl resins due to their flexibility, strength, and retentive properties similar to traditional ones, made in cobalt–chromium (Co–Cr) alloys [6].

Acetyl resin clasps can be produced by waxing the desired shape on a master cast, investing the pattern, using the lost wax technique to create a mold, and injecting the heated, softened acetyl resin into the mold using an appropriate machine. One cannot assume that the design principles that apply to alloy clasps are appropriate for acetyl resin clasps, due to fundamental differences in the physical properties of these materials. One would expect that acetyl resin clasps require a different design to achieve adequate retention [4].

The high flexibility of acetyl resin clasps allows the retentive clasp arm to be placed in deeper undercuts on abutments [8]. It could result in better fatigue strength compared to Co–Cr clasps; however it could reduce RPD retentive force. Nonetheless, the few studies that determine these aesthetic materials' properties and suitability are not enough to support their use for RPD clasps.

The objective of this study was to compare the retentive force of Co–Cr alloy circumferential clasps (control) to those with an acetyl resin retentive arm and to evaluate the stability of this force throughout periods of 0, 1, 2, 3, 4 and 5 years of simulated clinical use.

2. Materials and methods

To perform the simulation test, a metal model representing a partially edentulous mandibular right hemi-arch segment (second premolar and second molar abutment teeth and first

Fig. 1. Metal model used in the study.

molar missing tooth) was made in Co–Cr alloy (Remanium GM380, Dentaurum, Pforzheim, Germany). This model provided 0.25 mm undercuts in the test positions established for circumferential clasps. A 2 mm deep occlusal rest seat was prepared on the mesial occlusal surface of the molar tooth and on the distal occlusal surface of the premolar tooth. In addition, mesial and lingual guide planes were prepared on the molar tooth and distal and lingual guide planes on the premolar tooth (two thirds the crown length) to standardize the path of insertion and removal (Fig. 1). A commercial laboratory fabricated the test specimens, as described below, based on the metal model provided by the researchers.

The metal model was positioned in a surveyor, relieved for the correct waxing of the specimens and duplicated using silicon (Elite Double, Zhermack, Rovigo, Italy). The silicon mold was poured with investment (Cromo-o-Cast, Polidental, São Paulo, SP, Brazil) to construct 16 refractory casts.

Each refractory cast was positioned in the surveyor according to the guide planes to ensure identical waxing outcomes. Standard wax patterns of preformed semicircular clasps (GEO molar ande premolar clasps, self-adhesive; Renfert GmbH, Hilzingen, Germany), for retentive and reciprocal arms, and retention mesh (Rewax, Renfert, Hilzingen, Germany) were used. The dimensions of the retentive arms were 12 mm in length and 1.2 mm in diameter for the molar clasps and 8 mm in length and 1.2 mm in diameter for the premolar ones. The retentive arm of each clasp, from the clasp tip to the minor connector was adapted to the refractory casts, with the terminal end of the clasp in the retentive undercut area (0.25 mm undercut).

Eight specimens were waxed without a retentive arm on the buccal aspect of premolar tooth. These missing arms were made later, using acetyl resin (Dental D, Quatrotti, Rovello Porro, Italy). A mechanical retention was waxed in the specimens without a retentive arm in order to connect the acetyl resin arm later.

A pin, 5 mm wide and 60 mm long, was positioned on the retention mesh parallel to the path of insertion and removal. This pin acted as a sprue for casting, and maintained the specimen in the fatigue testing apparatus later.

Fig. 2. View of specimens entirely made in Co–Cr.

Fig. 3. View of specimens with anterior retentive arm made in acetyl resin.

The assemblies (refractory casts and waxed specimens) were invested (Cromo-o-Cast) and cast with Co–Cr alloy (FIT Flex, Talladium do Brasil, Curitiba, PR, Brazil), following the manufacturer's recommendations.

After casting, the specimens were removed from the cast and sandblasted with aluminum oxide (80 psi = 5.62 kgf/cm^2). No polishing procedures were performed to ensure uniformity. Only nodules were carefully removed with tungsten burs under magnification when necessary (Fig. 2).

For making the acetyl resin arms, the metal model was duplicated (Elite Double) again. The new silicone mold was poured with type IV dental stone (Durone IV, Dentsply, Petrópolis, RJ, Brazil) to make 8 refractory stone models.

The Co–Cr specimens without retentive arms in premolar tooth were positioned on the stone models. The same standard circumferential clasp wax patterns (Rewax) were adapted to the models as described above. The wax clasps were sprued and the assemblies (stone models and waxed specimens) were invested in plaster (Herodent, Vigodent, Rio de Janeiro, RJ, Brazil) within injection flasks. The wax was boiled out for 30 min and the flask was steam cleaned.

The flasks were attached singly to the thermo-injection apparatus (MG-NEWPRESS, Quattroti, Rovello Porro, Italy). Two bars of Dental D were placed into the injection cartridge in the oven, which had been heated to 220 °C. The resin was injected into the flask at a pressure of 7/8 atm.

The flasks were allowed to bench cool, and specimens were then deflasked. Only sprues were carefully removed with tungsten burs. No polishing procedures were performed to ensure uniformity (Fig. 3).

Before the retentions test all clasps were checked, using a black silicone indicator paste (Fit Checker, GC Corporation, Tokyo, Japan) for the correct adaptation to the planned position on abutment teeth, assuring the use of 0.25 mm undercut as planned.

The retention test was performed using an insertion-removal apparatus especially designed at the Ribeirão Preto School of Dentistry, University of São Paulo. This apparatus has been used in others studies [11,12]. Some technical details and a brief description of the testing conditions are described as follows.

Fig. 4. Apparatus' container detail ready for simulation test.

The apparatus allowed inserting the specimen in its predetermined terminal position, and its subsequent removal from the metal model, thus simulating the path of insertion and removal of the RPD. The apparatus is connected to a computer to measure retentive force in Newtons (N) using appropriate software (LabVIEW 8.0, National Instruments, USA) during removal of the specimen from the metal model. The load used to insert the specimens was necessary to overcome the frictional retention and to adapt rests and clasps to the model.

Each specimen was attached to the testing apparatus, and the metal model was fixed to a container filled with distilled water at 37 °C, in order to simulate clinical conditions (Fig. 4).

A total of 7205 insertion/removal cycles were performed, simulating 5 years of specimen insertion and removal, estimating 4 complete cycles per day. The test was performed with 41 cycles per minute at a constant speed of 35.79 mm/s.
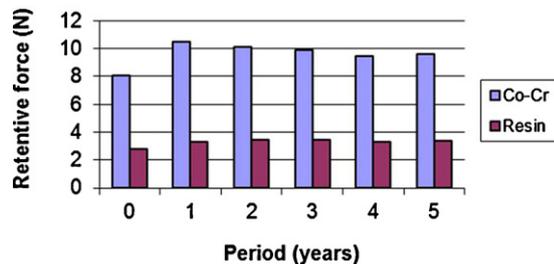
Retentive force mean and standard deviation values were recorded for periods corresponding to 0, 1, 2, 3, 4, and 5 years of simulated clinical use of the specimens. The value established for each period corresponded to the arithmetic average of 10 consecutive cycles.

The data were subjected to repeated-measures ANOVA and Tukey post hoc test to compare retentive force between periods for each group (Co–Cr and Resin). The Student's *t* test was used to compare groups in the same period. *p* values > 0.05 were not considered significant differences. All statistical tests were

Table 1
Mean (SD) retentive force (N) of groups at different test periods.

	Period (simulated years)					
	0	1	2	3	4	5
Resin	2.79(1.57)	3.32(1.92)	3.47(1.81)	3.46(1.87)	3.27(1.59)	3.41(1.59)
Co–Cr	8.09(3.05)	10.48(4.25)	10.09(4.15)	9.87(4.30)	9.46(3.93)	9.63(3.79)

Fig. 5. Mean of retentive force as function of period of specimen simulated clinical use.

performed using GraphPad InStat 3 (GraphPad Software Inc., San Diego, California, USA).

3. Results

Table 1 represents the mean and standard deviation (SD) values of the groups' retentive force at the different studied periods. In the Co–Cr group, there were significant differences between retentive force values related to periods 0 and 1 ($p < 0.001$), 0 and 2 ($p < 0.01$), and 0 and 3 years ($p < 0.05$); period 0 showed the lowest values. No significant differences were observed between periods 1, 2, 3, 4, and 5 ($p > 0.05$). For the resin group, no statistically significant differences were found among all test periods ($p > 0.05$).

Comparisons between the groups revealed significant differences in each tested period; 0 ($p = 0.0012$), 1 ($p = 0.0013$), 2 ($p = 0.0019$), 3 ($p = 0.0031$), 4 ($p = 0.0027$), and 5 years ($p = 0.0014$). Co–Cr group showed the highest retention force values. This can be observed in Fig. 5.

4. Discussion

Very specific equipments are necessary to fabricate acetyl resin clasps. Few laboratories in Brazil have these apparatuses. This may be considered a disadvantage for aesthetic materials compared to conventional alloy for RPD frameworks. As described in the materials and methods session, a commercial laboratory was required to fabricate the tested specimens. It is very important to highlight that the authors oversaw the whole process.

To ensure uniformity, standard wax patterns of circumferential clasps were used, and no polishing procedures were performed. Besides, a single technician waxed and fabricated all specimens. Even so, some differences in the profile of the specimens were observed. The authors assume that this was inherent to the several steps involved in the fabrication of RPD

frameworks. It is a manual process. Therefore, these differences are expected to occur clinically.

RPD clasp retentive arms must be flexible to engage undercuts returning to their original position in order to adequately retain the prostheses [13]. Many studies showed that Co–Cr alloys can be satisfactorily used to fabricate RPD frameworks employing 0.25 mm undercut depth [11,14–16].

On the other hand, acetyl resin clasps have higher flexibility, compared to Co–Cr ones, which can allow the retentive clasp arm to be placed in deeper undercuts on abutments [4,6,8]. Also, this greatest deflection of acetyl resin could be a good property to indicate its use on periodontally compromised teeth [6,17] or where retentive requirements are low [17].

Besides engaging deeper undercuts to have adequate retention, acetyl resin clasps should have a shorter length and a greater cross-sectional area than standard metal clasps [4,18]. According to Turner et al. [4], to obtain stiffness similar to that of a cast Co–Cr clasp measuring 15 mm in length and 1 mm in diameter, a suitable acetyl resin clasp must be shorter (approximately 5 mm) and have a larger cross-sectional diameter (approximately 1.4 mm).

It has been shown that clasps entirely made in acetyl resin require thicker retentive arms. This larger cross-sectional diameter would be considered as a disadvantage, because it would be detrimental to oral health by contributing to plaque accumulation [4,8,18]. It has been suggested that acetyl resin would be a better choice of material since it helps to overcome the poor aesthetics of anterior clasping, besides demonstrating greater flexibility, which would result in reduced loads on the abutment teeth. This assumption may not be completely satisfactory, or, yet, may not be sufficient to imply changes in choosing the material. The lower retention provided by acetyl resin clasps should be considered in clinical use [8].

In the present study, acetyl resin was used only in the retentive arms of anterior clasps, which in clinical conditions would optimize aesthetics without needing larger cross-sectional diameter aesthetic arms. Although there is some evidence that acetyl resin clasps should be placed in deeper undercuts on abutments [4,6,8], 0.25 mm undercuts were used in this study for both Co–Cr and resin group. All specimens were fabricated using standard wax patterns of circumferential clasps to standardize the groups. Therefore, acetyl resin and Co–Cr clasps had the same thickness. This was done because a greater retention force would be expected for acetyl resin clasps in the proposed model since reciprocal arms were made in Co–Cr alloy. It would be a new way to use acetyl resin to make RPD clasps.

Ahmad et al. [14] found that a 4.77 N retention force was required to dislodge a Co–Cr clasp from a 0.25 mm undercut.

This is in agreement with the findings of the present study, because a retentive force of approximately 9.6 N was found over the test periods for specimens with two Co–Cr circumferential clasps.

The retentive force values of specimens with acetyl resin anterior retentive arms (approximately 3.28 N over the test periods) were higher than results obtained by Sykes et al. [6] (1.75 N) and Arda and Arikan [8] (1.2 mm thick clasps, 1.08 N, and 2.0 mm, 1.74 N, respectively). This was expected because, in the present study, the acetyl resin retentive arm was assembled to reciprocal Co–Cr arm and circumferential clasp entirely made in Co–Cr alloy, while in those studies a single clasp was entirely made in acetyl resin. However, the present results showed that retentive arms made in acetyl resin, even only in the anterior RPD clasps, significantly reduced the retentive force compared to those entirely made in Co–Cr.

It has been shown that the retentive force needed to dislodge clasps is significantly lower for molar than premolar teeth due to the shorter length of the premolar clasp arm [8]. This could explain why, in the present study, the retentive force of the resin group was reduced more than half compared to the Co–Cr group. Premolars might be responsible for the major part of the retentive force in this experimental model. Hence, it is expected that this would also happen in clinical use.

Wu et al. [7] compared deformation of acetyl resin and metal alloy RPD direct retainers after repeated dislodgments over a test die for a simulated 3-year period. They took occlusal and facial digital images before and after cycling and found significantly greater deformations for acetyl resin compared to metal alloy in the occlusal view. Therefore, they inferred that acetyl resin direct retainers may lose some of their retentive characteristics.

On the other hand, Arda and Arikan [8] indicated that acetyl resin clasps with 1.2 mm thickness and with 2.0 mm thickness were resistant to deformation. The retentive forces of both types of acetyl resin clasps did not decrease over the 3-year cycling period. The present study confirms these findings, because the retentive force of specimens with acetyl resin clasps remained stable after 5 years of simulated use. During the fatigue test, there was no clasp fracture, and the results obtained for resin and Co–Cr groups indicated no permanent deformation. However, it is important to highlight that the experimental conditions were different from clinical ones, because a periodontal ligament was not present and the insertion path was strictly defined by the testing apparatus and the guide planes of abutment teeth. Therefore, clinical results could differ in terms of deformation.

Contrary to the results of other studies [8,15], there was an increase in retentive force of specimens entirely made in Co–Cr alloy during the first 3 years of simulated clinical use compared to period 0. However, this force remained stable during periods of 1, 2, 3, 4, and 5 years. A similar situation was observed by Rodrigues et al. [11] and according to them, this was probably caused by the clasps' prolonged cold working because the path of insertion was strictly rigid, as reproduced in the present study.

According to Lassila and Vallitu [19], water and artificial saliva can reduce the fatigue strength of Co–Cr alloy by corrosion of the alloy in the wet environment. The insertion/removal test in the present study was carried out in wet conditions, in an attempt to simulate the clinical environment, as done in other reports [8,19]. However, it should be noticed that the tests were performed in a rigid system, which may have increased the force values necessary for inserting and removing the specimens because of greater frictional resistance [11].

Further clinical studies are needed to confirm the present results and to determine whether these aesthetic materials are suitable alternatives for RPD clasps. Besides, this study used only 0.25 mm deep undercuts. This was necessary in this preliminary study because the circumferential clasps should be compared under similar experimental conditions. The unique difference between the specimens was the material of a retentive arm. It could happen that 0.25 mm deep undercuts were enough to provide adequate retentive force for the proposed clasp model. Further research using deeper undercuts, thicker retentive clasp arms and different clasp designs is recommended to provide additional information for acetyl resin RPD clasps.

5. Conclusions

Within the limitations of the methodology used in this in vitro study, and based on the results obtained it is possible to conclude that:

(1) A retentive arm made in acetyl resin significantly reduced the retentive force using circumferential clasps in 0.25 mm undercuts.
(2) The retentive force of specimens with acetyl resin clasps remained stable after continuous fatigue testing cycles.
(3) There was an increase in retentive force of specimens entirely made in Co–Cr alloy during the first 3 years of simulated clinical use compared to period 0. However, this force remained stable along periods of 1, 2, 3, 4 and 5 years.

Conflict of interest

The authors of this study have no conflicts of interest.

Acknowledgement

References

[1] Donovan TE, Cho GC. Esthetic considerations with removable partial dentures. J Calif Dent Assoc 2003;31:551–7.
[2] Jacobson TE. Satisfying esthetic demands with rotational path partial dentures. J Am Dent Assoc 1982;105:460–5.
[3] Belles DM. The Twin-Flex clasp: an esthetic alternative. J Prosthet Dent 1997;77:450–2.

[4] Turner JW, Radford DR, Sherriff M. Flexural properties and surface finishing of acetal resin denture clasps. J Prosthodont 1999;8:188–95.

[5] Chu CH, Chow TW. Esthetic designs of removable partial dentures. Gen Dent 2003;51:322–4.

[6] Sykes LM, Dullabh HD, Chandler HD, Bunn B, Essop ARM. Flexibility of technopolymer clasps compared with cobalt–chromium and titanium clasps. SADJ 2002;57:166–71.

[7] Wu JC, Latta Jr GH, Wicks RA, Swords RL, Scarbecz M. In vitro deformation of acetyl resin and metal alloy removable partial denture direct retainers. J Prosthet Dent 2003;90:586–90.

[8] Arda T, Arikan A. An in vitro comparison of retentive force and deformation of acetal resin and cobalt–chromium clasps. J Prosthet Dent 2005;94:267–74.

[9] Krol AJ, Finzen FC. Rotational path removable partial dentures. Part 2. Replacement of anterior teeth. Int J Prosthodont 1988;1:135–42.

[10] De Rossi A, Abuquerque Jr RF, Bezzon OL. Esthetic options for the fabrication of removable partial dentures: a clinical report. J Prosthet Dent 2001;86:465–7.

[11] Rodrigues RCS, Ribeiro RF, Mattos MGC, Bezzon OL. Comparative study of circumferential clasp retention force for titanium and cobalt–chromium removable partial dentures. J Prosthet Dent 2002;88:290–6.

[12] Rodrigues RCS, Macedo AP, Torres EM, Mattos MGC, Ribeiro RF. Retention force of T-bar clasps for titanium and cobalt–chromium removable partial dentures. Braz Dent J 2008;19:209–13.

[13] Carr AB, McGivney GP, Brown DT. McCracken's removable partial prosthodontics, 11th ed., St Louis: Elsevier; 2004. p. 79–117.

[14] Ahmad I, Sherriff M, Waters NE. The effect of reducing the number of clasps on removable partial dentures retention. J Prosthet Dent 1992;68:928–33.

[15] Kim D, Park C, Yi Y, Cho L. Comparison of cast Ti–Ni alloy clasp retention with conventional removable partial denture clasps. J Prosthet Dent 2004;91:374–82.

[16] Tse ET, Cheng LY, Luk HW, Chu FC, Chai J, Chow TW. Comparison of the retentive characteristics of cobalt–chromium and commercially pure titanium clasps using a novel method. Int J Prosthodont 2006;19:371–2.

[17] VandenBrink JP, Wolfaardt JF, Faulkner MG. A comparison of various removable partial denture clasp materials and fabrication procedures for placing clasp on canine and premolar teeth. J Prosthet Dent 1993;70:180–8.

[18] Fitton JS, Davies EH, Howlett JA, Pearson GJ. The physical properties of a polyacetyl denture resin. Clin Mater 1994;17:125–9.

[19] Lassila LVJ, Vallittu PK. Effect of water and artificial saliva on the low cycle fatigue resistance of cobalt–chromium dental alloy. J Prosthet Dent 1998;80:708–13.