An in vitro comparison of retentive force and deformation of acetal resin and cobalt-chromium clasps

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Statement of problem. The use of metal clasps on anterior teeth may cause esthetic problems. Recently, acetal resins have been used as an alternative tooth-colored denture clasp material to improve esthetics. However, there are few studies to support acetal resin use.

Purpose. The purpose of this in vitro study was to compare the retentive force and deformation of acetal resin and cobalt-chromium clasps after 36 months of simulated clinical use.

Material and methods. Forty clasps each of acetal resin (1.2 or 2.0 mm thick) and cobalt-chromium (Dentorium)(1.2 mm thick) were fabricated using half-round standard prefabricated clasp patterns. The groups were further subdivided (n = 10) into the type of tooth ( premolar or molar metal model) and undercut (0.25 mm or 0.50 mm). The retentive force of the clasps was measured in distilled water by a specially designed insertion-removal testing apparatus with intervals corresponding to 0, 6, 12, 18, 24, 30, and 36 months of simulated clinical use of a removable partial denture. The distance between the clasp tips (mm) was measured with a microscope before and after the insertion-removal testing procedure. Comparison of the mean values of the retentive force (gram force) of the clasps and the distance (mm) between the clasp tips was conducted with 3-way analysis of variance and a Least Significant Difference (LSD) multiple range test (α=.05).

Results. The mean values of tensile load required to dislodge acetal resin clasps with 1.2-mm thickness (111.6 g or 0.11 N) and with 2.0-mm thickness (178.4 g or 1.75 N) was significantly lower than that to dislodge Co-Cr clasps (694.1 g or 6.81 N) (P<.001). The retentive force needed to dislodge all 3 types of clasps was significantly lower for the molar than premolar models and also lower for the models with 0.25-mm undercuts than for those with 0.50-mm undercuts (P<.001). After 36 months of simulated clinical use, there was evidence of deformation in the cobalt-chromium clasps but no deformation noted for the acetal resin clasps. The retentive force of cobalt-chromium clasps (297.4 g or 2.91 N) after deformation remained significantly higher (P<.001) than the retentive force of acetal resin clasps that were 1.2 mm (110.7 g or 1.08 N) and 2.0 mm thick (177.5 g or 1.74 N), respectively.

Conclusion. Within the limitations of this study, the results suggest that both thicknesses of acetal resin clasps evaluated required less force for insertion and removal than Co-Cr clasps over a simulated 36-month period. (J Prosthet Dent 2005;94:267-74.)

CLINICAL IMPLICATIONS
The results of this in vitro study demonstrate that the retentive force for an acetal resin clasp may not be sufficient for removable partial dentures (RPDs) due to the significantly low retentive force required for removal. Flexibility of acetal resin clasps would allow for the retentive clasp arm of RPDs to be placed in deeper undercuts on abutments rather than Co-Cr, because acetal resin is not as stiff as Co-Cr alloy. Although low retentive force is required for removal of these clasps, the flexibility and the long-term retentive resiliency of the clasp suggest that acetal resin clasps may be suitable for RPDs where esthetics or periodontal health is a primary concern.

Restoration of esthetics is an important factor to consider in the fabrication of a removable partial denture (RPD). Several types of polymers and metal alloys have been used in RPD construction. Frequently, RPD clasps made from the same alloy as the metal framework. The most common alloys used for clasps are cobalt-chromium (Co-Cr) alloy and gold and titanium alloys, although these may be unesthetic. The methods to overcome this esthetic dilemma have included covering clasps with tooth-colored resin, using lingually positioned clasps, and engaging mesial rather than distal undercuts. While RPDs with precision attachments
may be esthetically satisfying, however, they are expensive and more difficult to fabricate.8,9

Polyoxymethylene (POM), also known as acetal resin, has been used as an alternative denture base and denture clasp material since 1986 and was promoted, primarily, for superior esthetics.10 Acetal resins are formed by the polymerization of formaldehyde.11 The homopolymer (POM) is a chain of alternating methyl groups linked by an oxygen molecule.11 Because of its biocompatibility, it was considered as an RPD framework material for patients with allergic reactions to Co-Cr alloys.10 It is reported to have a sufficiently high resilience and modulus of elasticity to allow its use in the manufacture of retentive clasps, connectors, and support elements for RPDs.10,11

Several investigations have determined the properties of the materials used to fabricate RPD clasps.12-25 In view of the many variables involved with clinical evaluation, most of the studies on clasp materials and designs have been in vitro investigations.26 Some of the studies of clasps were performed under a constant load12-19 or a constant displacement.19-24 Investigators have considered the long-term effectiveness of the clasps and the effects that the clasp might have on the abutment teeth.22-24 A clasp arm design producing less stress is important for predictable long-term use of an RPD. Three factors—clasp material, clasp form, and the amount of undercut—affect the design of a clasp arm.12 Clasp form involves the elements of length, curvature, cross-sectional dimension, and taper. Among these, the first 2 elements are determined by the abutment tooth contour, and the latter 2 elements are under the control of the dentist or technician. Furthermore, clasp form is associated with stress distribution, which affects fatigue and permanent deformation.25 Poor fit may cause the decrease of retention and failure of RPD function.27 However, the mechanical properties of a clasp material are generally determined by the alloy used.28

 Metals and metal alloys undergo permanent deformation and fatigue when exposed to repeated stress.29 The fatigue of a denture clasp is based on the repeated deflection of the clasp during insertion and removal of the RPD over the undercut of the teeth.2 Although extensive work has been performed to determine the properties of a variety of materials used for RPD clasps,17,18,22-24 little is known about how acetal resin functions in this application.

In this study, the tensile load required to dislodge acetal resin clasps with 2 different thicknesses (for a molar or premolar) and 2 different amounts of undercut was investigated after repeated cycles of placement and removal simulating 0, 6, 12, 18, 24, 30, and 36 months of clinical use. Furthermore, the magnitude of tensile load required to dislodge clasps made of a conventional dental Co-Cr alloy was also compared to that required to dislodge acetal resin clasps. The permanent deformation of the clasps was also determined after 36 months of simulated clinical use.

**MATERIAL AND METHODS**

White acetal resin (Polyoxymethylene; Pressing Dental Srl, San Marino, Italy) and a conventional dental Co-Cr alloy (Co 64%; Cr 28%; Mo 5%; Dentorium, New York, NY) were evaluated in this investigation. Impressions of a maxillary first premolar and first molar from a Dentoform (Model 1362; Columbia Dentoform Corp, New York, NY) were made with reversible hydrocolloid (Speedex; Coltene/Whaledent Inc, Cuyahoga Falls, Ohio), and 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 with dimensions of $1.2 \times 4 \times 3$ mm and trimmed on a surveyor (APF400; Amann Dental Equipment, Koblach, Austria) to provide mesial (8 mm) and lingual guide planes (6 mm) and to create a 0.25-mm undercut area on the distobuccal surface. An occlusal rest seat 2 mm deep was prepared on the mesial occlusal surface. Small amounts of wax were placed on the distobuccal and distolingual line angles of the tooth as reference points to standardize location of the tips and lengths of both retentive arms (8 mm for premolar, 12 mm for molar) and reciprocating arms. The same procedure was used to make molar models with a 0.50-mm undercut and premolar models with 0.25-mm and 0.50-mm undercuts. Each wax model was duplicated (Lab putty; Omega GmbH, Bliedersdorf, Germany) and poured with molten casting wax to make 10 identical sets of wax models for the molar and premolar, each with different-sized undercuts. Forty wax models were invested singly in casting rings (BEGO, Bremen, Germany) and cast with a Co-Cr alloy (Dentorium), following manufacturer recommendations. The specimens included 10 premolar clasps with 0.25-mm undercut, 10 premolar clasps with 0.50-mm undercut, 10 molar clasps with 0.25-mm undercut, and 10 molar clasps with 0.50-mm undercut. The specimens were then trimmed, airborne-particle abraded, finished, and electropolished (Eltropol SL; BEGO). The guide planes were evaluated for parallelism, and slight inaccuracies were adjusted using a milling machine (APF400; Amann Dental Equipment). Next, impressions of each metal model were made in regular-body silicone impression material (Lab putty; Omega GmbH, Bingen, Germany) with custom impression trays. Each impression was poured with die-investment material (Wirovest; BEGO) to make 1 refractory cast for Co-Cr clasps and, with Type IV dental stone (Cere Rock; GC Germany GmbH, Munchen, Germany), to make 2 refractory casts for the acetal resin clasps.
For Co-Cr clasps, preformed half-round standard (1.2 mm thick) clasp patterns with occlusal rests, and retentive and reciprocal arms (Klammern Clasp; Dentaurum, Ispringen, Germany) were adapted on the refractory investment cast. A wax plate (4 × 7 × 3 mm) was attached to the minor connector parallel to the path of insertion (Fig. 1). The plate was used later for maintaining the clasp in the testing machine. The assembly (cast and pattern) was invested (Wirovest; BEGO) 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.²⁹

For the acetal resin clasps, the same preformed half-round standard (1.2 mm thick) clasp patterns were adapted on the refractory cast. For fabrication of the 2.0-mm-thick acetal resin clasps, the occlusal rest, and retentive and reciprocal arms of the clasp were adapted on the refractory die by using a straight semicircular clasp pattern (Megadental Vertrieb GmbH, Budingen, Germany). The previously described, similar-sized wax plate was attached to the minor connector parallel to the path of insertion (Fig. 1). First, the assembly (stone model and pattern) was placed at a distance of approximately 2.5 cm from the injection opening of the special flask (Muffle-Type 100; Pressing Dental Srl) with Type IV dental stone (Marble Stone; Pressing Dental Srl). One cylinder of the acetal resin was placed into the injection tube, and then the tube was placed in the injection machine (J-100; Pressing Dental Srl). Once in the injection machine, the parameters of the machine were set as follows: preinjection time with the material maintained at 220°C (melting temperature) for 20 minutes, post-injection time with the temperature maintained at the desired level of 220°C for 3 minutes, and injection pressure of 4 bar. At the end of the process, the flask was removed from the initial position, and the clasp was deflasked. The clasp was polished with rubber points (Pressing Dental Srl), followed by using polishing paste for acetal and acrylic resins (Universal polish; Pressing Dental Srl). Each of 40 acetal resin clasps, 1.2 or 2.0 mm thick, and Co-Cr clasps with 1.2-mm thickness (Fig. 2) were divided into 4 subgroups (n = 10) according to the type of tooth (molar or premolar) and amount of undercut (0.25 mm or 0.50 mm).

Prior to the retention testing, the clasps were placed in acrylic resin blocks (Meliodent; Heraeus Kulzer, Hanau, Germany) (2.5 × 4 × 5 mm) to standardize the measurements with a microscope. The distances between the tips of the retentive and reciprocal arms of the clasps were measured with a microscope (Toolmaker TM-505; Mitutoyo Ltd, Singapore) and recorded to the nearest 0.005 mm. The retention testing of the clasps was conducted using a specially designed insertion-removal apparatus (Festo AG & Co, KG, Istanbul, Turkey). The apparatus allowed the placement (insertion) of the clasp to its predetermined terminal position and its subsequent removal from the metal model. The retentive force of the clasp (g) was also measured during removal (Fig. 3).
Table I. Comparison between mean forces required to dislodge clasp at first period of cycles using 3-way ANOVA

| Source                        | Type III sum of squares | df | Mean square | F      | Sig.  
|-------------------------------|-------------------------|----|-------------|--------|-------
| Material                     | 8129100.217             | 2  | 4064550.108 | 7890.670 | <.001 |
| Tooth                        | 107341.008              | 1  | 107341.008   | 208.385  | <.001 |
| Undercut                     | 247611.675              | 1  | 247611.675   | 480.698  | <.001 |
| Material × Tooth             | 13459.717               | 2  | 6729.858    | 13.065  | <.001 |
| Material × Undercut          | 212570.150              | 2  | 106285.075  | 206.335  | <.001 |
| Tooth × Undercut             | 4025.208                | 1  | 4025.208    | 7.814   | <.001 |
| Material × Tooth × Undercut  | 7413.117                | 2  | 3706.558    | 7.196   | .001  |
| Error                        | 55631.700               | 108| 515.108     |         |       |
| Total                        | 21690513.000            | 120|            |         |       |
| Corrected total             | 8777152.792             | 119|            |         |       |

Difference significant at P < .05.

Material, 1.2-mm- or 2.0-mm-thick acetyl resin clasp or Co-Cr clasp; Tooth, molar or premolar; Undercut, 0.25 mm or 0.50 mm.

Table II. Pairwise comparison of retentive force values (g) and SDs for clasps at first period of simulated clinical use

<table>
<thead>
<tr>
<th>Material</th>
<th>0.25 mm</th>
<th>0.50 mm</th>
<th>0.25 mm</th>
<th>0.50 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetal resin (1.2 mm)</td>
<td>Mean ± SD</td>
<td>P</td>
<td>Mean ± SD</td>
<td>P</td>
</tr>
<tr>
<td>Acetal resin (2.0 mm)</td>
<td>Mean ± SD</td>
<td>P</td>
<td>Mean ± SD</td>
<td>P</td>
</tr>
<tr>
<td>Acetal resin (1.2 mm)</td>
<td>Mean ± SD</td>
<td>P</td>
<td>Mean ± SD</td>
<td>P</td>
</tr>
<tr>
<td>Co-Cr</td>
<td>Mean ± SD</td>
<td>P</td>
<td>Mean ± SD</td>
<td>P</td>
</tr>
<tr>
<td>Acetal resin (2.0 mm)</td>
<td>Mean ± SD</td>
<td>P</td>
<td>Mean ± SD</td>
<td>P</td>
</tr>
<tr>
<td>Co-Cr</td>
<td>Mean ± SD</td>
<td>P</td>
<td>Mean ± SD</td>
<td>P</td>
</tr>
</tbody>
</table>

Table III. Pairwise comparison of retentive force values (g) and SDs for clasps after 36 months of simulated clinical use

<table>
<thead>
<tr>
<th>Material</th>
<th>0.25 mm</th>
<th>0.50 mm</th>
<th>0.25 mm</th>
<th>0.50 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetal resin (1.2 mm)</td>
<td>Mean ± SD</td>
<td>P</td>
<td>Mean ± SD</td>
<td>P</td>
</tr>
<tr>
<td>Acetal resin (2.0 mm)</td>
<td>Mean ± SD</td>
<td>P</td>
<td>Mean ± SD</td>
<td>P</td>
</tr>
<tr>
<td>Acetal resin (1.2 mm)</td>
<td>Mean ± SD</td>
<td>P</td>
<td>Mean ± SD</td>
<td>P</td>
</tr>
<tr>
<td>Co-Cr</td>
<td>Mean ± SD</td>
<td>P</td>
<td>Mean ± SD</td>
<td>P</td>
</tr>
<tr>
<td>Acetal resin (2.0 mm)</td>
<td>Mean ± SD</td>
<td>P</td>
<td>Mean ± SD</td>
<td>P</td>
</tr>
<tr>
<td>Co-Cr</td>
<td>Mean ± SD</td>
<td>P</td>
<td>Mean ± SD</td>
<td>P</td>
</tr>
</tbody>
</table>

The clasp attached to the testing apparatus was placed on the corresponding abutment metal model fixed on a stainless steel container. The container was filled with distilled water. Cycles (4380) of placement and removal of the clasp, simulating 3-years of clinical use, were performed along the path of insertion and removal determined by preliminary surveying procedures of the abutment metal model. A tensile load was applied at a crosshead speed of 10 mm per minute to the clasp until it was dislodged. The sensor (Spider SW; Mettler-Toledo, Inc, Columbus, Ohio) connected to the load cell detected the magnitude of the tensile load applied at the moment the clasp was removed from the metal model. 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 computer (Inspiron 8600; Dell Inc, Round Rock, Tex) connected to the sensor. First, acetal resin 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 surfaces was measured with a microscope (Toolmaker TM-505; Mitutoyo Ltd) and recorded.

The mean values and SDs of the retentive force magnitudes were recorded for the 7 periods for dislodgement of each clasp. The distances between the clasp...
results

Comparison of the mean retentive force with the 3-way ANOVA for each of the different type of clasps at the initial period is shown in Table I. The main effects for the 3 factors studied, namely, material type, tooth type, and undercut type, were significant. The main effects for the 3 factors were significant for all test periods.

Tables II and III represent the mean values of the retentive force required to cause dislodgement of each clasp from molar and premolar teeth with 0.25-mm and 0.50-mm undercuts and the ANOVA comparison of mean values of each group at the initial and 36-month periods. The mean retentive force at the first period of testing in the test groups varied from 85.3 ± 2.4 to 858.2 ± 28.2 g (0.84 N to 8.41 N). The greatest retentive force required to remove the clasps was for Co-Cr clasps, and the lowest retentive force was for the 1.2-mm-thick acetal resin clasps. The mean retentive force for the 36-month test period varied from 84.7 ± 2.6 to 340.9 ± 19.9 g (0.83 N to 3.33 N). At the initial and 36-month periods, the retentive force required to dislodge 1.2-mm-thick acetal resin clasps from the molar and premolar teeth with both 0.25-mm and 0.50-mm undercuts was significantly lower (P < .001) than the retentive force needed for the 2.0-mm-thick acetal resin and Co-Cr clasps. The retentive force required for removal of the 2.0-mm-thick acetal resin clasps was also significantly lower (P < .001) than that for removal of the Co-Cr clasps from the molar and premolar teeth with 0.25-mm and 0.50-mm undercuts.

During repeated cycles of placement and removal, the retentive force required to remove the Co-Cr clasps decreased significantly from the initial to the 6-, 12-, and 18-month cycles (P < .001). Also at 30 and 36 months, the retention for these clasps was significantly less than the retention at 18 and 24 months. However, the retentive force required for both thicknesses of acetal resin clasps demonstrated no significant change over the 7 periods tested (Table IV).

Table V represents the mean values of the distances between clasp tips measured before and after testing and comparison of the data with the ANOVA. After 36 months of simulated clinical use, there was significant increase (P = .022) in the distances between the tips of Co-Cr clasps, but not for both thicknesses of the acetal resin clasps. The difference between the distances of the tips from the models for both types of acetal resin clasps measured before and after fatigue testing was significantly lower (P < .001) than the distances of Co-Cr clasps (Table VI).

**DISCUSSION**

Retentive clasp arms must be capable of flexing and returning to their original form and should retain an RPD satisfactorily. The tooth should not be unduly stressed or permanently distorted during service and should provide esthetic results. The clinical experience of loss of retention of the RPD after the prosthesis is worn for some time raises the question of whether constant deflection of the clasp during insertion and removal of the denture fatigues the clasp. Acetal resin is marketed for the direct retainers attached to a Co-Cr RPD framework, as well as the supportive components of RPDs. As purported by the manufacturer, acetal resin is available in 20 color shades matching the Vita shade guide (Vitapan; VITA Zahnfabrik, Bad Sackingen, Germany).

Acetal resin has a relatively high proportional limit with little viscous flow, enabling it to behave elastically over a large enough range to be used as a material for clasp fabrication. Turner et al. found that if all other variables were equal, a 15-mm-long Co-Cr clasp of 1-mm diameter would exhibit the same stiffness as an acetal resin clasp, 5 mm in length and 1.4 mm in diameter. For this reason, thicker acetal resin clasps were used for comparison in the present study.

### Table IV. Mean values ± SDs of average retentive force (g) of clasps on molar and premolar with 0.25- and 0.50-mm undercut and comparison at different test periods using LSD multiple range test

<table>
<thead>
<tr>
<th>Cycle</th>
<th>Acetal resin (1.2 mm)</th>
<th>Acetal resin (2.0 mm)</th>
<th>Co-Cr (1.2 mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>111.6 ± 20.9</td>
<td>178.4 ± 37.5</td>
<td>694.1 ± 121.5</td>
</tr>
<tr>
<td>730 (6 mos)</td>
<td>111.3 ± 20.8</td>
<td>178.4 ± 37.4</td>
<td>538.2 ± 124.0</td>
</tr>
<tr>
<td>1460 (12 mos)</td>
<td>110.8 ± 21.1</td>
<td>178.2 ± 37.5</td>
<td>433.9 ± 87.0</td>
</tr>
<tr>
<td>2190 (18 mos)</td>
<td>110.7 ± 20.8</td>
<td>178.1 ± 37.3</td>
<td>393.2 ± 79.3</td>
</tr>
<tr>
<td>2920 (24 mos)</td>
<td>110.7 ± 21.0</td>
<td>177.8 ± 37.5</td>
<td>355.5 ± 68.6</td>
</tr>
<tr>
<td>3650 (30 mos)</td>
<td>110.6 ± 21.0</td>
<td>180.2 ± 44.2</td>
<td>322.3 ± 54.0</td>
</tr>
<tr>
<td>4380 (36 mos)</td>
<td>110.7 ± 20.9</td>
<td>177.5 ± 37.4</td>
<td>297.4 ± 44.8</td>
</tr>
</tbody>
</table>

*Differences significant at P < .05.

### Table V. Mean values ± SDs of distances (mm) between clasp tips before and after simulated clinical use*

<table>
<thead>
<tr>
<th>Material Type</th>
<th>Clasp (1.2 mm)</th>
<th>Clasp (2.0 mm)</th>
<th>Co-Cr (1.2 mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetal resin</td>
<td>6.3 ± 1.0</td>
<td>6.3 ± 1.1</td>
<td>6.1 ± 1.0†</td>
</tr>
<tr>
<td>Acetal resin</td>
<td>6.3 ± 1.0</td>
<td>6.3 ± 1.1</td>
<td>6.7 ± 1.0†</td>
</tr>
<tr>
<td>Co-Cr</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*36 months, 4380 cycles. †Differences significant at P < 0.05.
The study was designed to compare clasps in function in 2 different amounts of undercuts. The 0.25-mm undercut was selected because it represents the undercut commonly used for Co-Cr clasps. With the increased requirements of esthetics, more patients are requesting that dentists conceal RPD clasps by placing them closer to the gingival, where the undercuts tend to be larger. The stiffness of Co-Cr clasps makes them unsuitable for placement in larger undercuts due to unacceptable stresses on the abutments. One property of acetal resins that has created interest for use in RPDs is the low modulus of elasticity, which allows for their use in larger retentive undercuts than recommended for Co-Cr alloys. This may be advantageous in clinical situations in which esthetics and/or periodontal health are priorities. The second undercut condition (0.50 mm) was chosen to determine whether fabrication of clasps from acetal resin would be a possible alternative to the metal clasps in large undercuts. Greater than 0.50-mm-undercut conditions were not considered because Co-Cr clasps in a deeper undercut may be difficult to repair.

Abutment condition includes the shape of the abutment and the frictional coefficient between the abutment and the clasp. The frictional coefficient between a tooth and cast metal clasp metals has been reported to be approximately 0.2 in the presence of saliva. Sato et al reported that frictional coefficient values in wet conditions with water are nearly the same as values in wet conditions with saliva. In the present study, the insertion and removal test was performed in wet conditions with distilled water.

The results of the present study showed that acetal resin clasps of both dimensions had significantly lower retentive force (111.6 g or 1.09 N and 178.4 g or 1.74 N, respectively) than Co-Cr clasps (694.1 g or 6.80 N). Ahmad et al found that 4.77-N retention was required to dislodge a Co-Cr clasp from a 0.25-mm undercut. Frank and Nicholls concluded that 300 to 750 g (2.94 N to 7.35 N) represented an acceptable amount of retention for a bilateral distal extension RPD. 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. In the present study, the results demonstrate that the retentive force for an acetal resin clasp might not be sufficient for RPDs because of the significantly low retentive force required for removal. It should be noted that other factors, in addition to the type of retentive clasp and depth of undercut, influence the retention of an RPD. For example, the presence of a guiding plane on the proximal surface increases the retention. Clinical experience indicates that ineffective reciprocation may result in denture instability and lack of retention. The number and distribution of the abutment teeth, the amount of wax block-out, and the fit of the framework are other factors that influence the amount of retention obtained. The experimental design of this study tested a single-clasp system. When 2 or 3 acetal resin clasps are used in the fabrication of an RPD and all other mentioned factors are also considered, acetal resin clasps may be sufficient for clinical use.

The mean retentive force of the 1.2-mm-thick acetal resin clasps was lower than that of 2.0-mm-thick acetal resin clasps. Not surprisingly, the greatest retentive force for acetal resin clasps was found in the 2.0-mm-thick clasps designed to engage the 0.50-mm undercut area of the premolar. The acetal resin clasps exhibited greater retentive forces when placed in both 0.25-mm and 0.50-mm undercuts of the premolar due to the shorter length of the clasp arms. Turner et al suggested that in clinical use, acetal resin clasps should have a shorter length, a relatively larger cross-sectional area, and engage deeper undercuts to have adequate retention. Fitton et al stated that to gain adequate retention from acetal resin clasps, the clasp should have a greater cross-sectional area than a metal clasp. The present study confirms these findings. The acetal resin clasp must be thicker and shorter than a standard clasp and engage a deeper undercut to achieve clinically acceptable retention. This is due to greater flexibility of the acetal resin (Elastic modulus; 2.9 to 3.5 kN/mm²).
when compared to Cr-Co alloy (Elastic modulus: 22.43 kN/mm²).²⁹ It could be argued that a larger, bulkier clasp design would be detrimental to oral health by contributing to plaque accumulation. However, if plaque control is established and the patient presents for regular recall visits, there is no evidence suggesting that any harm will result.²⁹ Further study using deeper undercuts and thicker retentive clasp arms is recommended to provide additional information for using acetal resin clasps.

The results of this study indicate that acetal resin clasps with 1.2-mm thickness and with 2.0-mm thickness are resistant to deformation and may offer a clinical advantage over the conventional metal clasps. The retentive forces of both types of acetal resin clasps did not decrease over the cycling periods. Under the conditions of the present study, Co-Cr clasps lost retentive force within 730 cycles of placement and removal and continued to lose retentive force during the remaining testing period. Past studies have indicated that there was a loss of retention because of permanent deformation of the Co-Cr clasps.¹²,¹⁵,²⁵ The attrition of the inner surface of the Co-Cr clasps and/or the surface of the model may be other potential causes of the reduction of the retention. This possibility could not be completely eliminated in this study because there was no quantitative evaluation of the specimen surface characteristics. However, no attrition on these surfaces was observed visually.

Although the retentive force of the Co-Cr clasps decreased in the test cycles, it was still greater than that of both types of acetal resin clasps at the end of the test period. The greater load generated by the Co-Cr clasp was attributed to a higher stiffness or modulus of elasticity than acetal resin. With this study design, in which the shapes and dimensions of the abutments were standardized, the retention magnitude of the clasps should be closely related to the elastic modulus of the clasp material.

Bates¹² showed that a 10-mm-long Co-Cr clasp would display a tip deflection of 0.15 mm at the proportional limit. Morris et al¹³ suggested that permanent deformation of a clasp tip by more than 0.025 mm may be significant. The results of the present study showed a significant deformation of Co-Cr clasps after 36 months of simulated clinical use. However, neither type of acetal resin clasps showed significant deformation after 36 months of simulated clinical use (Table VI).

Suggesting that acetal resin is a better material because it assists in overcoming the poor esthetics of anterior clasping and demonstrates greater flexibility resulting in reduced loads on the abutment teeth may not be adequate to change the choice of the material. The lower retention provided by acetal resin clasps should be considered in clinical use. Further research on the clinical efficacy of the acetal resin clasps is needed to determine whether these materials are suitable alternatives for RPD clasps.

**CONCLUSIONS**

Within the limitations of this study, the following conclusions were drawn:

1. The mean retentive force required to remove the 1.2-mm- and 2.0-mm-thick acetal resin clasps was found to be significantly lower ($P<.001$) than those required for removal of the Co-Cr clasps.
2. The retentive force required for 1.2-mm- and 2.0-mm-thick acetal resin clasps demonstrated no significant change over the 7 periods tested.
3. Co-Cr clasps lost significant amounts of retentive force from the initial to the 6-, 12- and 18-month periods ($P<.001$) and continued to lose the retentive force during the remainder of the test.
4. Although the mean retentive force of the Co-Cr clasps decreased in the test cycles, it remained significantly greater ($P<.001$) than that of both types of acetal resin clasps at the end of the 36 months of simulated clinical use.
5. The 1.2-mm- and 2.0-mm-thick acetal resin clasps tested did not show significant deformation after 36 months of simulated clinical use.
6. Co-Cr clasps showed significant deformation ($P=.022$) after 36 months of simulated clinical use.

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