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ORIGINAL RESEARCH

Comparison between Acetal Resin and Cobalt-Chromium Removable Partial Denture Clasp Retention: An *in vitro* Study

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ABSTRACT

Statement of problem: The retention qualities of acetal resin clasps are questionable.

Purpose: To asses the initial retention and after cycling for 1,200 cycles of acetal resin clasps as compared to cobalt-chromium clasps.

Materials and methods: Extracted maxillary first premolars and molars were collected. Each tooth was embedded in acrylic block up to the cementoenamel junction. On each block, partial denture model consisted of Akers clasp, minor connector, cobalt-chromium horizontal plate representing the denture base, and a vertical arm on the horizontal plate was constructed. Models were divided into four groups (five each). Group I had acetal resin clasps on premolars. Group II had cobalt-chromium clasps on premolars. Group III had acetal resin clasps on molars. Group IV had cobalt-chromium clasps on molars. Akers clasps were designed to utilize 0.01 inch undercut. Each model was connected to the universal testing machine through the vertical arm. The model was placed in artificial saliva and a tensile load was applied to measure the initial retention. Then retention was measured after cycling for 200, 400, 600, 800, 1,000 and 1,200 cycles. One-way analysis of variance followed by Duncan's multiple range test was used to test the effect of groups and cycling on tensile load required for clasp dislodgment.

Results: Groups I and III showed no change in retention on cycling up to 1,200 cycles. Group I showed significantly higher retention than group III. Groups II and IV showed significant reduction in retention upon cycling more than 800 cycles. In spite of this reduction in retention, it is still higher than that in groups I and III.

Conclusion: Cobalt-chromium clasps showed higher retention than acetal resin clasps despite the deformation encountered in the former. Acetal resin clasps showed more retention qualities on premolar teeth than that on molar teeth.

Clinical implications: Acetal resin clasps can be used to retain Kennedy's class III partial denture. However, when used on molar teeth, it is recommended to increase the thickness of the retentive clasp arm or to use a deeper undercut.

Keywords: Acetal, Retention, Clasp.

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INTRODUCTION

The retention qualities of acetal resin clasps are questionable.

Acetal resin is a monomer-free thermoplastic technopolymer based on semicrystalline polyoxymethylene and is a product of formaldehyde polymerization. Its characteristics are high elastic memory, high tensile and shock strength, and high abrasion resistance. Because of its elasticity, clasps are able to enter much deeper undercuts as commonly found on premolars and canines. Also, it is used for single pressed unilateral partial dentures, partial denture frameworks, provisional bridges, occlusal splints and even implant abutments.[1]

The effect of repeated stresses on acetal resin direct retainers is unknown. In a study conducted to compare deformation of acetal resin and metal alloy removable partial denture direct retainers, 10 acetal resin and 10 metal alloy removable partial denture direct retainers, fabricated to manufacturers' specifications, were dislodged over a stainless steel die by means of a laboratory test apparatus for a simulated 3-year period (5,000 cycles). Occlusal and facial digital images made before and after cycling were measured in millimeters for direct retainer deformation by using computer-imaging software. Student t-tests were performed for statistical comparisons. It was found that a significant difference in deformation between acetal resin and metal alloy direct retainers occurred in the occlusal view but not in the facial view. Average deformation varied but was greatest in the occlusal view for acetal resin direct retainers compared with that for metal alloy direct retainers. Average facial view deformations revealed no significant differences for metal alloy and acetal resin direct retainers. It was concluded that within the limitations of this *in vitro* study, significantly greater deformation resulted with acetal resin compared with metal alloy direct retainers after 3 years of simulated use.[2]

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. This study was performed to compare the retentive force and deformation of acetal resin and cobalt-chromium clasps after 36 months of simulated clinical use. Forty clasps each of acetal resin (1.2 or 2.0 mm thick) and cobalt-chromium (1.2 mm thick) were fabricated using half-round standard prefabricated clasp patterns. The groups were further subdivided into the type of tooth (premolar or molar metal model) and undercut (0.25 or 0.50 mm). The retentive force of the clasps was measured in distilled water by a specially designed insertion and 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 and 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. The mean values of tensile load required to dislodge acetal resin clasps with 1.2 mm thickness (111.6 g or 1.11 N) and with 2.0 mm thickness (178.4 g or 1.75 N) was significantly lower than that to dislodge cobalt-chromium clasps (694.1 g or 6.81 N). The retentive force needed to dislodge all three 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. 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 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. It was concluded that, within the limitations of this study, the results suggested that both thicknesses of acetal resin clasps evaluated required less force for insertion and removal than cobalt-chromium clasps over a simulated 36-month period.[3]

A study was conducted to examine the flexural properties of acetal resin to determine the appropriate design for an acetal resin removable partial denture clasp. The effectiveness of various acetal resin polishing procedures were also evaluated using scanning electron microscopy. Loads of up to 1,500 g were applied to cylindrical acetal resin specimen lengths of 5, 10 and 15 mm and the degree of deflection of the specimen tip was measured. Specimens were 2 and 1.5 mm in diameter with a round cross-section as well as 2 mm in diameter with a half-round cross-section. Half-round specimens were loaded with their flat surface vertical and then horizontal. Contour plots showing load and deflection for varying lengths of resin were developed for each cross-sectional type based on specimen length, and the stiffness was calculated. Additional acetal resin specimens underwent polishing techniques including tungsten carbide burs, aluminum oxide stones, abrasive impregnated rubber points and 'Polish-D'. Polished specimens were examined with scanning electron microscopy to compare surface roughness. The results showed that, for the 5 mm length specimens, the median stiffness values decreased in the following order: round cross-section with 2 mm diameter > half-round vertical > half-round horizontal > round cross-section with 1.5 mm diameter. The median stiffness values for the 10 and 15 mm lengths followed a similar trend. At each length, the round cross-section with 2 mm diameter specimen was generally at least twice as stiff as other designs. Regarding polishing, the smoothest surface was seen on the specimen that was polished with the rubber point followed by Polish-D. It was found that to have stiffness similar to a cast cobalt-chromium clasp 15 mm long and 1 mm in diameter, a suitable acetal resin clasp must be shorter (approximately 5 mm) with greater cross-sectional diameter (approximately 1.4 mm). To obtain a smooth surface, the acetal resin clasp should be polished with a rubber point followed by a material, such as Polish-D.[4]

MATERIALS AND METHODS

The purpose of this study was to asses the initial retention and after cycling for 1,200 cycles of acetal resin clasps as compared to cobalt-chromium clasps.

Selection and Grouping of the Teeth

Extracted maxillary first premolars and molars were collected. Each tooth was embedded in acrylic block up to the cementoenamel junction. Models were divided into four groups (5 each). Group I had acetal resin clasps on premolars (Pressing di Monticelli Rag Stefano, 47046 Misano Adriatico, Italy). Group II had cobalt-chromium clasps on premolars (METAPLUS VP, Germany). Group III had acetal resin clasps on molars. Group IV had cobalt-chromium clasps on molars.

Models Preparations

Twenty acrylic blocks made of heat-cured acrylic resin (Trevalon, Degu Dent GmbH, Dentsply, Germany) were constructed with 3 cm length, 2.5 cm height and 2 cm width. The bases of the acrylic blocks and their superior surfaces were made parallel to the surveyor table (AF 30, Switzerland). A hole was done at one end of the superior surface of each of the 20 acrylic blocks with suitable length and width to accommodate the roots of the teeth. These holes were filled by self-cured acrylic resin (special tray acrylic resin—Degu Dent GmbH, Dentsply, Germany) and the selected teeth were inserted in these holes in a position perpendicular on the superior surfaces of the acrylic blocks and their long axis were parallel to the analyzing rod of the surveyor. After polymerization of the self-cured acrylic resin the excess were trimmed, finished and polished (Fig. 1).

Surveying of the Samples

Each acrylic block with the corresponding selected tooth was transferred to the surveyor table without tilting. The analyzing rod of the surveyor was parallel to the long axis of the tooth and was used to determine the height of contour of

Fig. 1: Parallelism of teeth

the selected tooth. The undercut gauge of the surveyor was used to measure and locate the undercut depth of 0.01 inch on the buccal surface of the tooth at the retentive clasp tip area. All the selected teeth were having 0.01 inch undercut depth in the gingival one-third of their crowns otherwise it was excluded and replaced by another corresponding tooth. After measuring the 0.01 inch undercut depth, a red pen mark was placed at the planned position for the retentive clasp tip. The unwanted undercuts on the buccal, palatal and proximal surfaces of the tooth were blocked out using softened wax (YETI Dentalprodukte GmbH, Germany) and trimmed by means of the wax trimmer of the dental surveyor. A piece of relief wax of 1 mm thickness was attached to the superior surface of the acrylic block just away from the proximal surface of the tooth. A small hole of square 2 mm was made at the end of the relief wax. The testing model including the acrylic block and the attached tooth was duplicated in investment material (Wirovest, BEGO, Germany) by using of agar-agar duplicating material (Wirodouble, BEGO, Germany) (Fig. 2).

Fig. 2: The relief wax with the small hole representing the tissue stop

Construction of the Clasp Assembly, Base and Vertical Sprue

Half-round cross section Akers clasp wax pattern was used (Yeti Dental GmbH, Germany). The average length of the retentive clasp arm was 7 mm for premolar teeth and 10 mm for molar teeth. The thickness of the retentive clasp arm for all samples was 1 mm at the origin, and 0.5 mm at the retentive clasp tip. A flat piece of wax representing the denture base was attached to the superior surface of the investment model just away from the proximal surface of the tooth and extended to the hole on the superior surface of the investment model representing the tissue stop at the end away from the tooth. This piece of wax was attached to the minor connector of the Akers clasp wax pattern. A rounded vertical plastic sprue 30 mm in length and 3 mm in diameter was attached to the flat piece of wax on the superior surface of the investment model perpendicular on it and away from the minor connector by 3 mm. This distance between the vertical plastic sprue and the minor connector was fixed for all samples. In cases of acetal clasps, the flat piece of wax was in the form of meshwork in the 3 mm area between the vertical plastic sprue and the minor connector of the Akers clasp wax pattern for the mechanical means of retention of the acetal resin clasps. The wax pattern of the Akers clasp assembly, the flat piece of wax, and the vertical plastic sprue were sprued, invested and cast in cobalt-chromium alloy for the second and fourth groups. For the first and the third groups, the wax pattern of the Akers clasp assembly was converted into acetal resin through injection molded process and attached to the cobalt-chromium base and vertical sprue by mechanical means. The Akers clasp (cobalt-chromium or acetal resin), and the metal base with the vertical sprue were tried on the testing model and considered suitable for testing when the occlusal rest was fitting well in its rest seat, when the clasp arms were in contact with the tooth, and when the tissue stop of the metal base was resting on the superior surface of the testing model. Heavy contacts of the cobalt-chromium and the acetal resin minor connectors with the proximal surfaces of the teeth were disclosed and adjusted (Figs 3 to 7).

Measuring the Retention of the Acetal Resin and Cobalt-Chromium Akers Clasps

Twenty acrylic resin cups were made with handles. The handles were used to fix these acrylic cups to the universal testing machine (Lloyd, England). Each testing model with the tooth was attached from its base to the base of one of the acrylic cup by using of self-cured acrylic resin. The occlusal rest of the Akers clasp was fully seated in its rest seat. The tissue stop of the metal base was touching the

Fig. 3: The clasp assembly, base and vertical sprue

Fig. 6: Acetal resin clasp on premolar

Fig. 4: Cobalt-chromium Akers clasp on premolar

Fig. 7: Acetal resin clasp on molar

Fig. 5: Cobalt-chromium Akers clasp on molar

superior surface of the acrylic testing model, and the vertical sprue was attached to the vertical spindle of the universal testing machine. Each acrylic cup was filled with 150 ml of artificial saliva. This artificial saliva was covering the testing model with the tooth and the clasp. Each clasp was initially activated by withdrawal of the clasp over the maximum convexity of the tooth until complete separation of the clasp from the tooth had occurred, and the amount of retention each clasp was able to perform was recorded in gram. The speed of the universal testing machine was adjusted at 0.2 m/min for all clasp samples. The tension load of the machine for each clasp was equal to the initial retention force of that clasp. This equation was fixed for all clasp samples. Retention of the clasps was tested after cycling for 200, 400, 600, 800, 1,000 and 1,200 cycles simulating 1 year service period of the maxillary partial denture inside the patient's mouth (Figs 8 to 11).

One-way analysis of variance at $p \leq 0.05$, followed by Duncan's multiple range test were used to test the effect of groups and cycling on tensile load required for clasp dislodgment.

RESULTS

Groups I and III showed no change in retention on cycling up to 1,200 cycles. Group I showed significantly higher

Fig. 8: Acetal resin clasp attached to the universal testing machine

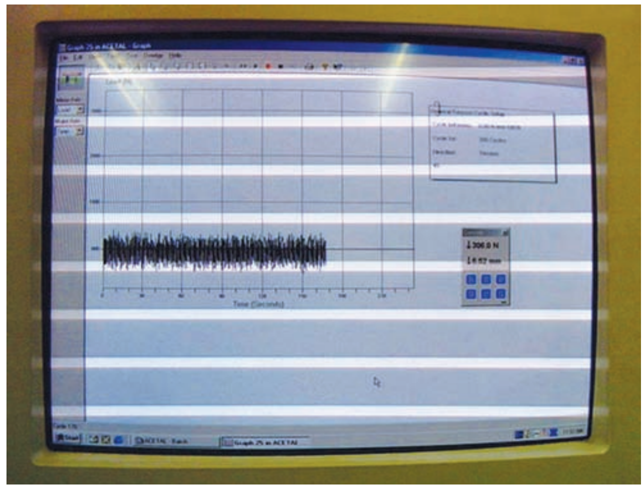

Fig. 11: Clasp cycling

Fig. 9: Cobalt-chromium clasp attached to the universal testing machine

Fig. 10: Universal testing machine

retention than group III. Groups II and IV showed significant reduction in retention upon cycling more than 800 cycles. In spite of this reduction in retention, it is still higher than that in groups I and III. The results of this study were shown in Tables 1 to 6.

DISCUSSION

The means of the retention force (in gram) required for clasp dislodgment at the initial cycle for groups I, II, III and IV were 444.92, 1,467.78, 218.28 and 1,206.66 respectively. In a study made to evaluate the retention qualities of the acetal resin clasp, Arda and Arikan (2005)[3] found that the mean value of the tensile load required to dislodge acetal resin clasps with 1.2 mm thickness was 111.6 gm and with 2.0 mm thickness was 178.4 gm, while that for cobalt-chromium clasps with 1.2 mm thickness was 694.1 gm. In studies made to evaluate the retention qualities of the cobalt-chromium clasp, Soo and Leung (1996)[5] found that the mean value of the tensile load required to dislodge Akers cobalt-chromium clasp was 1,785 gm. Morris et al (1983)[6] mentioned that the cast circumferential clasp with different dimensions and 0.25 mm deflection can generate 970 to 3,140 gm of force under tension. Cameron and Lyons (1996)[7] found it to be 3,085.5 gm, and Firtel (1968)[8] found it to be 1,398 gm. The differences in the retention forces among these studies may be due to differences in the dimensions of the wax pattern from which the clasp was made, amount of deflection, flexibility of the clasp and the type of the testing model. For group I (premolar acetal resin clasp) and group III (molar acetal resin clasp), there was insignificant change in the tensile load required for clasp dislodgment at the different interval of cycles. This finding may be due to flexibility of the acetal resin clasp and it was in agreement with a study made by Arda and Arikan (2005)[3] who mentioned that no deformation noted for the acetal resin clasps over a simulated 36-month period. On the other hand, this finding was in disagreement with a study made by Wu et al (2003)[2] who mentioned that, significantly greater deformation resulted with acetal resin direct retainers after 3 years of simulated use. For group II (premolar cobalt-chromium clasp), there was highly significant reduction in the tensile load from

Table 1: The tensile loads (in gram) required for clasp dislodgment

Number of cycles	*Group I*		*Group II*		*Group III*		*Group IV*	
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
Initial	444.92	32.48	1,467.78	22.92	218.28	26.60	1,206.66	23.81
200 cycles	444.92	32.48	1,467.78	22.92	218.28	26.60	1,206.66	23.81
400 cycles	444.92	32.48	1,467.78	22.92	218.28	26.60	1,206.66	23.81
600 cycles	444.92	32.48	1,459.62	14.60	218.28	26.60	1,206.66	23.81
800 cycles	444.92	32.48	1,426.98	38.91	218.28	26.60	1,190.34	9.94
1,000 cycles	443.50	29.49	1,336.20	29.74	218.28	26.60	1,129.14	48.86
1,200 cycles	442.48	29.35	1,303.56	26.40	218.28	26.60	1,090.38	29.39

Group I: Premolar acetal resin clasp group; Group II: Premolar cobalt-chromium clasp group; Group III: Molar acetal resin clasp group; Group IV: Molar cobalt-chromium clasp group; SD: Standard deviation

Table 2: The effect of number of insertion and removal cycles on the tensile load (in gram) required for clasp dislodgment in premolar acetal resin clasp group (group I)

Differences	*Mean*	*SD*	*p*
Initial—200 cycles	0.000	0.000	NS
200-400 cycles	0.000	0.000	NS
400-600 cycles	0.000	0.000	NS
600-800 cycles	0.000	0.000	NS
800-1,000 cycles	–1.428	3.193	NS
1,000-1,200 cycles	–1.020	2.281	NS
Initial—1,200 cycles	–2.448	3.429	NS

p: Probability level between number of cycles; NS: Not significant

Table 3: The effect of number of insertion and removal cycles on the tensile load (in gram) required for clasp dislodgment in premolar cobalt-chromium clasp group (group II)

Differences	*Mean*	*SD*	*P*
Initial—200 cycles	0.000	0.000	NS
200-400 cycles	0.000	0.000	NS
400-600 cycles	–8.160	18.246	NS
600-800 cycles	–32.640	31.768	NS
800-1,000 cycles	–90.780	17.068	***
1,000-1,200 cycles	–32.640	45.272	NS
Initial—1,200 cycles	–164.220	20.527	***

p: Probability level between number of cycles; NS: Not significant; ***: Highly significant

Table 4: The effect of number of insertion and removal cycles on the tensile load (in gram) required for clasp dislodgment in molar acetal resin clasp group (group III)

Differences	*Mean*	*SD*	*p*
Initial—200 cycles	0.000	0.000	NS
200-400 cycles	0.000	0.000	NS
400-600 cycles	0.000	0.000	NS
600-800 cycles	0.000	0.000	NS
800-1,000 cycles	0.000	0.000	NS
1,000-1,200 cycles	0.000	0.000	NS
Initial—1,200 cycles	0.000	0.000	NS

P: Probability level between number of cycles; NS: Not significant

800 up to 1,000 cycle interval. For group IV (molar cobalt-chromium clasp) there was significant reduction in the tensile load from 800 up to 1,000 and from 1,000 up to 1,200 cycle intervals. Both groups II and IV started to loss retention force at the 800 cycles due to the rigidity of the cobalt-chromium clasp and lack of its flexibility. The higher reduction of the tensile load in group II than that in group IV was due to the greater length of the retentive clasp arm in group IV than that in group II which lead to more flexibility of the cobalt-chromium clasps in group IV. Wear did not seem to be the reason of retention loss in groups II and IV as in a study made by Helal (2004)[9] who mentioned that there was no significant effect of both the wear of different abutment materials and different clasp designs on the retention loss after 16,000 cycles with no wear predicted on the retentive arm of the clasps of all subgroups. Also in studies made by Phillips and Leonard (1956),[10] Bates (1968)[11] and Hebel et al (1984),[12] who mentioned that wear was not a significant problem in 25,000 cycles. The results of this study was in agreement with a study made by Arda and Arikan (2005)[3] who mentioned that, in spite of presence of evidence of deformation in the cobalt-chromium clasps but no deformation noted for the acetal resin clasps, the retentive force of the cobalt-chromium clasps after deformation remained higher than that of the acetal resin clasps that required less force for insertion and removal than cobalt-chromium clasps over the follow-up period.

Table 5: The effect of number of insertion and removal cycles on the tensile load (in gram) required for clasp dislodgment in molar cobalt-chromium clasp group (group IV)

Number of cycles	*Mean*	*SD*	*p*
Initial—200 cycles	0.000	0.000	NS
200-400 cycles	0.000	0.000	NS
400-600 cycles	0.000	0.000	NS
600-800 cycles	–16.320	21.151	NS
800-1,000 cycles	–61.200	52.010	*
1,000-1,200 cycles	–38.760	25.398	*
Initial—1,200 cycles	–116.180	25.602	***

p: Probability level between number of cycles; NS: Not significant; *: Significant; ***: Highly significant

CONCLUSION

Cobalt-chromium clasps showed higher retention than acetal resin clasps despite the deformation encountered in the former. Acetal resin clasps showed more retention qualities

Table 6: The effect of groups on changes in the required tensile loads (in gram)

Number of cycles	Group I			Group II			Group III			Group IV		
	Mean	SD	dt	Mean	SD	dt	Mean	SD	dt	Mean	SD	dt
Initial—200	0.000	0.000	a	0.000	0.000	a	0.000	0.000	a	0.000	0.000	a
200-400	0.000	0.000	a	0.000	0.000	a	0.000	0.000	a	0.000	0.000	a
400-600	0.000	0.000	a	−8.160	18.246	a	0.000	0.000	a	0.000	0.000	a
600-800	0.000	0.000	b	−32.640	31.768	a	0.000	0.000	b	−16.320	21.151	ab
800-1,000	−1.428	3.193	b	−90.780	17.068	a	0.000	0.000	b	−61.200	52.010	a
1,000-1,200	−1.020	2.281	b	−32.640	45.272	ab	0.000	0.000	b	−38.760	25.398	a
Initial—1,200	−2.448	3.429	c	−164.220	20.527	a	0.000	0.000	c	−116.180	25.602	b

dt: Duncan's multiple range test between groups; Means with the same letter within each row are not significantly different at $p \leq 0.05$

on premolar teeth than that on molar teeth, so when used on molar teeth, it is recommended to increase the thickness of the retentive clasp arm or to use a deeper undercut.

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