DOI: 10.7860/JCDR/2016/18405.7731

Original Article

Dentistry Section

Comparison of Retention of Clasps Made of Different Materials Using Three-Dimensional Finite Element Analysis

JAGGARI CHANDRAKANTH REDDY[1], SARATH BABU CHINTAPATLA[2], NAVEEN KUMAR SRIKAKULA[3], RAJESH KUMAR REDDY JUTURU[4], SHAMEEN KUMAR PAIDI[5], SATYENDRA KUMAR TEDLAPU[6], PADMAKANTH MANNAVA[7], RUKHAIYA KHATOON[8]

ABSTRACT

Introduction: Retention and esthetics are believed to play a crucial role in deciding the success of removable partial dentures.

Aim: To compare retention of acetal resin and cobalt–chromium clasps.

Materials and Methods: A finite element model was designed with an edentulous space between mandibular right second premolar and second molar. Occlusal rests were placed on distal fossa of the second premolar and mesial fossa of second molar. An undercut depth of 0.01inch was created on the mesiobuccal surface of the premolar and distobuccal surface of second molar. Three dimensional finite element model of clasp assembly was designed and assigned with the properties of two different materials namely acetal resin and cobalt–chromium in successive steps. A horizontal bar was constructed between the occlusal rests of the prosthesis. Later, variable amount of dislodging force, in increasing order, was applied at the centre of the horizontal bar and the force at which the clasp arm gets dislodged was noted with respect to each of the material. The obtained values were noted and then subsequently analyzed.

Results: The amount of force required to dislodge acetal resin and cobalt–chromium clasps was found to be 0.02N and 2N respectively.

Conclusion: The results obtained suggested that acetal resin clasp exhibited less retentive force than cobalt–chromium clasps.

Keywords: Acetal resin, Cobalt–chromium, Occlusal rests, Prosthesis

INTRODUCTION

Since few decades due to the increase in awareness of oral health care, there is a decline in complete edentulous cases and a relative rise in partially edentulous cases and hence there is an increase in partial prosthesis [1]. Even though fixed partial prostheses are available, still removable partial dentures are used in daily practice. Retention through direct retainers is considered as major factor in determining the success of removable partial dentures. Circumferential clasps are most frequently used direct retainers and long term success of removable partial dentures depend on properties of clasps like design of clasp arm, condition of the abutment teeth and rigidity [2].

Mechanical properties of clasps depend on the type of materials used for fabrication like titanium alloys, gold alloys, nickel-chromium alloys and cobalt-chromium alloys (Co-Cr). Co-Cr alloys have replaced noble metal alloys as they possess advantages like better flexibility, lighter weight and cost effectiveness. At the same time they have few drawbacks like failure of retentive arms under stress, frequency of repairs and esthetics [3]. Various methods have been used for esthetic enhancement like lingually positioned clasp, engaging mesial not the distal undercuts, but acetal resin clasps were believed to be a simple and effective way [4].

Acetal resin or Polyoxymethylene (POM) is being used for esthetic purpose for denture base and clasps material and especially in individuals who are allergic to Co-Cr alloys as it has property of biocompatibility [5].

AIM

We conducted this study to compare the load required to dislodge clasps made of Co-Cr alloy to that required to dislodge acetal resin clasps with three dimensional finite element analyses. The aim of the present finite elemental analysis was to compare the retentive capability of the removable partial denture clasps made of acetal resin and Co-Cr alloy.

MATERIALS AND METHODS

Two different materials were tested by finite element analysis method to know the amount of retention for an undercut depth of 0.01inch.

Preparation of master model: A metal model was fabricated with an edentulous saddle between 45 and 47. Occlusal rests were made on distal fossa of the premolar and mesial fossa of molar. An undercut of 0.01 inch was created on the mesio-buccal of the premolar and disto-buccal of molar for the placement of circumferential clasp on both premolar and molar teeth.

Duplication of master model: Shaped block-out was done on the master model and was duplicated in custom made acrylic box of size 6mm x 4mm x 5mm with Unisil silicone duplicating material in 1:1 ratio.

Preparation of refractory cast: Refractory cast was obtained in brevest investment material keeping 210gm: 46ml powder liquid ratio, here 50% of distilled water and 50% of liquid were used. Powder and liquid were mixed thoroughly for 90 seconds. Investment was poured under vibration and was left to set for 20 minutes.

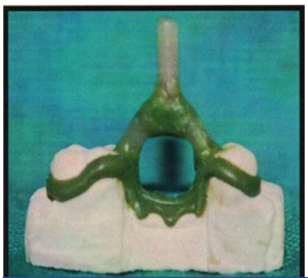
Fabrication of bio-dentaplast cast partial denture frame-work: Performed half round tapered clasp pattern (1.2mm thick) with occlusal rests, and retentive and reciprocal arm (Protek) were adapted on refractory cast on the ledge created during the shaped block-out before the duplication. Sprues of 10mm length were attached on each occlusal rest connecting in the centre [Table/Fig-1]. First, the assembly (stone model and clasp pattern) was invested in a special flask (Muffle-Type 100; Pressing Dental Srl.) with Type III dental stone (GC Fujirock EP, GC) by keeping the assembly 2.5 cm inside the flask. After the flask was set-up, dewaxing of the flask was done by immersing the flask in boiling water. It was reopened and the wax was removed using boiling water. The flask was closed again and placed into an oven at 100°C for 30 min.

Acetal resin granules [Table/Fig-2] were placed into the injection sleeve of the Thermopress machine [Table/Fig-3]. Teflon plunger was placed into the sleeve on top of the resin material and pushed down, and then the sleeve was placed in the injection machine (J-100; Pressing Dental Srl). The parameters of the injection machine were set as follows: pre-injection 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 5 minutes, injection cooling for 60 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.

FINITE ELEMENT ANALYSIS

According to Finite Element Analysis, an object is represented by an analytic model with a finite number of interconnected elements at a finite number of points labelled as nodes. The steps involved in the 3-dimensional Finite Element Analysis were-

1 Designing of three dimensional finite element model.
2 Assigning material properties.
3 Defining the boundary conditions.
4 Application of forces.
5 Execution of analysis and interpretation of results.



[Table/Fig-1]: Wax pattern adapted on refractory cast. **[Table/Fig-2]:** Acetal resin granules.

[Table/Fig-3]: Thermopress -400 injection system.

Designing of Three Dimensional Finite Element Model

1. Pro-Engineer 5 Software was used to make a geometric model from metal model with acetal rein framework and clasp assembly [Table/Fig-4].
2. Hypermesh 10 Software was used to convert the geometric model into finite element model which had 86,753 nodes and 55,022 tetrahydral elements [Table/Fig-5, 6].

RESULTS

Material parameters: Modulus of elasticity and yield strength were the parameters used. Measurements that were constant in our study were undercut depth (0.01 inch), length of molar clasp (10 mm), pre molar clasp (7mm) and thickness of the clasp (1.2 mm).

Mechanical properties of tested materials: The modulus of elasticity and yield strength of Co-Cr alloy was higher (230GPa and 610MPa) when compared to polyacetal (2.9GPa and 87MPa).

Boundary conditions: The load imposed on the structures under study and the area of the model which was restrained represents the boundary conditions in Finite element models.

The finite element method in the process of deflection analysis of retentive clasp arms: ANSYS 13 software system was used for analysis. Initially with a Kennedy's Class III model (Co-Cr) and a clasp assembly (acetal resin and Co-Cr in successive steps) a three dimensional finite element model was designed. Between the occlusal rests of the prosthesis, a horizontal bar was designed and at its center variable amount of dislodging force in increasing order was applied and the force at which the clasp arm gets dislodged was noted for each material. The obtained values were noted and then subsequently analyzed. The results obtained were tabulated [Table/Fig-7] and retentive force for dislodgement of clasp was greater for cobalt-chromium material (2N) than acetal resin (0.02N).

	Cobalt Chromium	Acetal Resin	Undercut Depth
Retention force	2 N	0.02 N	0.25 mm

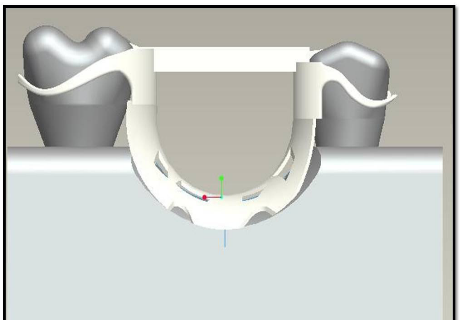
[Table/Fig-7]: The retentive force required for dislodgement of the clasps of Co-Cr and acetal resin from an undercut depth of 0.25 mm/0.01 inch.

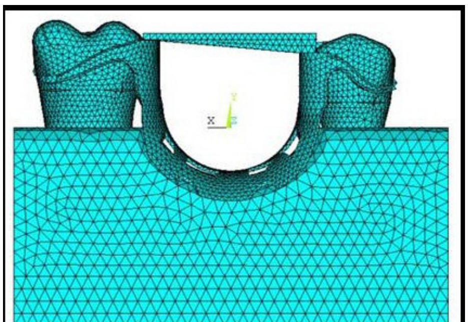
Direction of displacement	Maximum displacement produced
x-axis	0.104918
y-axis	0.642951
z-axis	1.76

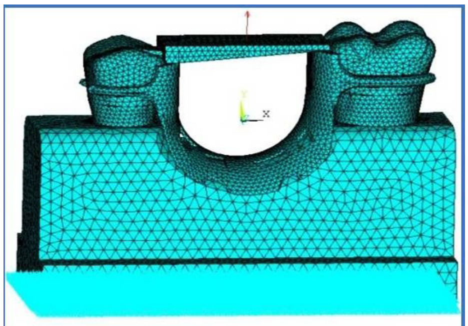
[Table/Fig-8]: Represents the maximum displacement produced in the clasp made of Co-Cr material in three different directions upon application of pulling retentive force of 2N.

Direction of displacement	Maximum displacement produced
x-axis	0.88629
y-axis	0.51686
z-axis	1.393

[Table/Fig-9]: Represents the maximum displacement produced in the clasp arm of acetal resin material in three different directions upon a pulling retentive force of 0.02N







[Table/Fig-4]: Geometric model of Kennedy's Class III from metal model with acetal resin framework and clasp assembly. **[Table/Fig-5]:** Mesh model of Kennedy's Class III and circumferential clasp using Hypermesh 10 Software. **[Table/Fig-6]:** Boundary condition of the mesh model.

Maximum displacement was observed for Z axis (1.76mm) and (1.393mm) for Co-Cr and acetal respectively. Least amount of displacement observed for y-axis in case of Co-Cr and x-axis in case of acetal. Whereas the values were intermediate for x-axis and y axis in cases of Co-Cr [Table/Fig-8] and acetal resin [Table/Fig-9] respectively.

DISCUSSION

Since their inception in 1930, Co-Cr alloys are being used in removable partial denture clasp fabrication. Success of removable partial denture depends on mechanical properties of alloys like elastic modulus, yield strength, density, elongation and fatigue resistance [6]. Elastic modulus indicates rigidity of a material and it should be as higher as possible so that applied forces get dissipated to the supporting tissues. Yield strength of materials used as a partial denture clasp should be minimum of 415 MPa to resist permanent deformation, the yield strength of base metal alloys were found to be greater than 600 MPa. Density of cast base metal alloy is usually 7 to 8 gm/cm^3 which is about half that of most dental gold alloys. Clasps made of materials like Co-Cr which had high elongation did not fractured frequently than materials with low elongation. Fatigue resistance signifies the number of cycles required for fracturing a material like clasp and Co-Cr was found to possess higher resistance than titanium and gold alloys [7-10].

Apart from mechanical properties, esthetics also plays a vital role in removable partial dentures. Many alterations were made to improve esthetics of Co-Cr clasps like coating clasps with tooth colored resin, designing clasps lingually, etc. But the most simple and effective way of esthetic improvement was introduction of thermoplastic materials like acetal resin and hence their use has increased significantly nowadays [11, 12].

Fitton et al., showed that elasticity of acetal resin is due to high proportional limit and its little viscous flow. They also stated that even though acetal resin clasps may be sufficiently resilient in order to engage undercuts for retention of removable partial dentures, but due to its low flexural modulus it requires that the resin be used in larger cross sectional area than metal alloys in order to attain retention. The resultant increased bulk of the framework acts as a platform for plaque accumulation leading to gingival and periodontal problems. Mechanical properties of acetal resins were found to be inferior when compared to Co-Cr alloys [9, 13, 14]. Chu et al., regards acetal resins as a simple and effective means of esthetic enhancement of removable partial denture esthetics [15]. Few authors suggested using acetal resins clasps in patients who are allergic to Co-Cr [16, 17].

Arda and Arikan in their study used an undercut of depth 0.01 inch as it corresponds to the undercut generally used for Co-Cr clasp [7]. In another study, Rodrigues et al., used same depth undercut and an additional undercut of 0.02 inch depth [18]. Edward et al., in their study used 0.01 inch, 0.02 inch and 0.03 inch undercut [19]. Mohamed et al., suggested that Co-Cr clasps due to their rigidness are not suitable for placement in larger undercuts and result in greater stress on the abutment teeth leading to reduction in bone height and bone density [16]. Taking view of all these studies, we used an undercut depth of 0.01 inch. Turner et al., compared stiffness of Co-Cr and acetal resin clasps and found that when all other variables were kept constant, Co-Cr clasp of 15mm long and 1mm diameter has same stiffness as 5mm long and 1.4mm diameter acetal resin clasp [2]. The constant values in the present study were depth of the undercut, length of the clasp and width and thickness of clasp. Undercut of 0.01inch depth and length of 10mm for molar clasp, 7mm for pre molar and a thickness of 1.2mm were taken in to consideration. The variable values in the present study were elastic modulus of the materials used for fabrication of removable partial denture clasps (Co–Cr was 230GPa and acetal resin was 2.9GPa).

The results of the present study showed that acetal resin clasps exhibited significantly lower retentive force of 0.02N compared to 2 N of retentive force showed by Co-Cr clasps. Edward T. et al., found that retentive forces of Co-Cr clasps at undercut depths of 0.25mm, 0.50mm, and 0.75mm were 2.34 ± 0.23 N, 4.65 ± 0.35 N, and 7.56 ± 0.50 N respectively [10]. Arda et al., found that that retentive force of acetal resin clasp was 0.11 N and 1.75N at undercut depths of 0.25mm and 0.50 mm depth respectively. These diverse results might be due to varied situations in different studies [7].

Fitton et al., stated that to gain adequate retention from acetal resin clasps, the clasp should cover a greater cross-sectional area than a metal clasp, which may result in plaque accumulation [9]. Our study confirms these findings. Acetal resin clasp in order to achieve adequate retention should be thicker and shorter than a standard clasp due to its superior flexibility and also must engage a deeper undercut as suggested by Arda and Arikan who found that the retentive force of acetal resin clasps was greater when undercut depth was 0.02 inch when compared with 0.01 inch [7].

Our results showed that Co-Cr clasps had high retentive force than acetal resin. As retention depends on several factors like type of clasp, number and condition of abutment teeth, undercut depth and framework as a whole, all these factors were kept constant in this study. Further studies are required in which varying undercuts, and other parameters can be used.

We found acetal resin to be a better clasp material due to its superior esthetics than Co-Cr alloys especially for anterior prosthesis and as it has greater flexibility than Co-Cr alloys the resultant load on abutment teeth will be lesser. Major disadvantage of acetal resins to Co-Cr alloys is its lower retention. More research should be carried out regarding properties of acetal resin clasps to determine the suitability of this material for fabrication of removable partial denture clasps.

LIMITATIONS

The present study was carried out on a rigid system and hence results obtained may not be replicated to the patients due to the presence of periodontal ligament in natural teeth. Patients may not use the same path of insertion and removal of removable partial dentures every time. This may generate greater loads on the abutment, thus affecting clasps effectiveness over a period of time.

Therefore, we suggest further studies with different clasp materials in conditions simulating natural oral cavity clinical situations as retention is the most important property that determines the success of removable partial dentures. Different clinical conditions like number of teeth remaining, nature of abutment etc., require clasps of different materials and design. Finite element analysis now-a-days is commonly used to analyse the retention elements of removable partial dentures. With this model one can know about the retention properties of clasp material and define optimal shape and design of clasps in different clinical conditions and on different teeth like premolars and molars.

CONCLUSION

The aim of the study was to compare the retentive capability of the removable partial denture clasps made of acetal resin and Co-Cr alloy with finite element analysis. Within the limitations of the study, it was found that Co-Cr clasp had a greater retention force than acetal resin clasp.

REFERENCES

[1] Jayesh R, Jasheel A, Nayar S. Comparative evaluation of retention force and porosity for titanium and cobalt-chromium clasp assemblies-an in vitro study. *World Appl. Sci. J.* 2014; 30(6):757-61.

[2] Turner JW, Radford DR, Sherriff M. Flexural properties and surface finishing of acetal resin denture clasps. *J Prosthodont*.1999; 8(3):188-95.
[3] Jiao T, Chang T, Caputo L. Load transfer characteristics of unilateral distal extension removable partial dentures with polyacetal resin supporting components. *Aust Dent J*. 2009; 54(1):31-37.
[4] FAA Taleb, IR Eltorky, MM. ElSheikh, SA Moula. Patient satisfaction and radiographyical evaluation of acetal resin retentive clasp arm versus conventional clasp on abutment teeth in upper unilateral removable partial dentures. *J Am Sci*. 2013; 9(5):425-32.
[5] Lekha K, Savitha NP, Roseline M, Nadiger RK. Acetal resin as an esthetic clasp material. *J Inter Dis Dent*. 2012;2(1):11-14.
[6] Sato Y, Yuasa Y, Akagawa Y, Ohkawa S. An investigation of preferable taper and thickness ratios for cast circumferential clasp arms using finite element analysis. *Int J Prosthodont*. 2012;8(4):392-97.
[7] 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(3): 267-74.
[8] Aras MA, Chitre V. Direct retainers: esthetic solutions in the smile zone. *J Indian Prosthodont Soc*. 2005; 5(1):4-9.
[9] Fitton JS, Davies EH, Howlett JA, Pearson GJ. The physical properties of a polyacetal denture resin. *Clin Mater*. 1994;17(3):125-29.
[10] Edward, Y.Cheng, Y Henry W K. Comparison of the retentive characteristics of cobalt-chromium and commercially pure titanium clasps using a novel method. *Int J Prosthodont*. 2006;19(4):371-72.
[11] Rehmann P, Orbach K, Ferger P, Wöstmann B. Treatment outcomes with removable partial dentures: a retrospective analysis. *Int J Prosthodont*. 2013; 26(2):147-50.
[12] Jorge JH, Giampaolo ET, Vergani CE. Clinical evaluation of abutment teeth of removable partial denture by means of the priotest method. *J Oral Rehabil*. 2007;34(3):222-27.
[13] Fitton JS, Davies EH, Howlett JA, Pearson GJ. The physical properties of a polyacetal denture resin. *Clin Mater*.1994; 17(3):125-29.
[14] Srirekha A, Bashetty K. Infinite to finite: an overview of finite element analysis. *Indian J Dent Res.* 2010; 21(3): 425-32.
[15] Chu CH, Chow TW. Esthetic designs of removable partial dentures. *Gen Dent*. 2003; 51: 322-24.
[16] Mohamed T, Abdulmoneam BO, Badawy M. Comparison between acetal resin and cobalt-chromium removable partial denture clasps: effect on abutment teeth supporting structures. *IJOPRD*. 2011; 1(3):147-54.
[17] Ming–lun Hsu and Chich-Liin Chang. Application of finite element analysis in dentistry. *Eur J Prosthodont Restor Dent*. 2011; 13(3): 119-22.
[18] Rodrigues RC, Ribeiro RF, DeMattosMla G, Bezzon OL. Comparative study of circumferential clasp retention force for titanium and cobalt-chromium removable partial dentures. *J Prosthet Dent.* 2013; 88(3): 290-96.
[19] 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(4):371-72.

PARTICULARS OF CONTRIBUTORS:
1. Consultant Prosthodontics, Department of Prosthodontics, Partha Dental Hospital, Secunderabad, Telangana, India.
2. Reader, Department of Prosthodontics, Aditya Dental College & Hospital, Beed, Maharashtra, India.
3. Senior Lecturer, Department of Prosthodontics, CKS Teja Institute of Dental Sciences, Tirupathi, Andhra Pradesh, India.
4. Reader, Department of Prosthodontics, Lenora Institute of Dental Sciences, Rajahmundry, Andhra Pradesh, India.
5. Senior Lecturer, Department of Prosthodontics, Gitam Dental College & Hospital, Vishakhapatnam, Andhra Pradesh, India.
6. Senior Lecturer, Department of Prosthodontics, Gitam Dental College & Hospital, Vishakhapatnam, Andhra Pradesh, India.
7. Reader, Department of Periodontics, Triveni Institute of Dental Sciences, Hospital & Research Center, Bilaspur,Chattisgarh, India.
8. Dental Surgeon, SmileTime Dental & Maxillofacial Center, Nizampet, Hyderabad, Telangana, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:
Dr. Sarath Babu Chintapatla,
Reader, Department of Prosthodontics, Aditya Dental College & Hospital, Beed-431122, Maharashtra, India.
E-mail: faizshukt4@gmail.com

FINANCIAL OR OTHER COMPETING INTERESTS: None.

Date of Submission: **Dec 18, 2015**
Date of Peer Review: **Feb 03, 2016**
Date of Acceptance: **Mar 18, 2016**
Date of Publishing: **May 01, 2016**