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Comparative Evaluation of Retention Force and Porosity for Titanium and Cobalt-Chromium Clasp Assemblies-An *In vitro* Study

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Abstract: *AIM:* The aim of this study was to evaluate the porosity and retentive force of cobalt chromium and titanium clasp assemblies. MATERIALS AND METHOD: Using standard die model, one complete metal crown was fabricated for the left mandibular second molar. A total of 20 clasps, Co-Cr alloy (n=10) and CpTi (n=10) were fabricated. Clasps were made to engage retentive undercut depth of 0.3 mm. Each clasp was radio graphically examined for porosity. The force (N) required to remove the clasps was measured using a universal testing machine with a crosshead speed of 10 mm/min for measuring the retentive force. Data were subjected to 1-way analysis of variance (P= 0.05). RESULT: The average retentive force for the cobalt-chromium alloy clasps was 12.18±3.17N and the average retentive force for titanium clasps were 6.68±2.15N.The results also indicated that titanium casting had more porosities than cobalt chromium alloys. CONCLUSION: Within the limitations of the present study, it can be concluded that Cobalt-chromium clasp had more retention than titanium. Titanium casting had more porosities than cobalt-chromium alloy casting.

Key words: Cobalt Chromium Alloy · Titanium · Universal Testing Machine · Industrial X-Ray Unit

INTRODUCTION

Commercially pure titanium (CpTi) has been used in prosthodontics from 1977 [4, 5]. Properties like biocompatibility, corrosion resistance, low cost when compared with gold alloys, have facilitated the widespread use of CpTi [6]. In addition to making light, well-adapted frameworks, the low density of CpTi can allow more castings per unit volume. It has low modulus of elasticity; so larger amount of retentive undercut can be engaged than that allowable for cobalt chromium alloys [2].

Retentive force control of clasp retainers is one of the most essential factors for the successful function of removable partial dentures (RPDs) [8]. Hence, the present study has been undertaken to compare the retentive force of circumferential clasps made of commercially pure titanium and cobalt-chromium alloys with an insertion / removal test.

MATERIALS AND METHODS

The mandibular left second molar in a dentiform was prepared for a complete metal crown. The molar preparation was duplicated using silicone impression material. Impression was poured with improved dental stone and a complete crown was waxed up. With the occlusal plane oriented horizontally, the wax crown was surveyed and the disto-buccal retentive undercut depth was adjusted to 0.3 mm on crown. Crown was modified for use as removable partial denture abutment. Occlusal rest seat, 2.5 mm long, 2.5 mm wide and 2mm deep, was placed on the mesial marginal ridge. Mesial and lingual guide planes, two thirds the length of the crown, were prepared with a surveyor blade (Bego, Germany).

Wax pattern was sprued with 8-gauge sprue and cast in a Co-Cr alloy (Bego, Germany). After checking the fit, the crown was cemented with glass ionomer cement. Cast was surveyed to determine the vertical path of insertion

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for removable partial denture clasps and undesirable undercuts were blocked out. Ledges were carved in the block-out material to standardize position of clasp arms. Terminal one fifth (2 mm) of the clasp engaged the retentive undercut. Tripod marks were added to index cast for future repositioning. Impression of cast with cemented abutment crown was made. Impression was poured to make refractory dies using two different types of casting investments (one for titanium and another for cobalt-chromium alloy). An individual refractory die was poured for each clasp.

Wax circumferential clasp assemblies were fabricated using preformed semicircular clasp patterns (Bego, Germany). The patterns were adapted along ledges formed with block-out material prior to making impression. Clasps were extended to the distal line angle. A round sprue was connected to the residual ridge base parallel to the path of insertion using a surveyor. This sprue was later used to maintain clasp test specimens in the universal testing machine. Each assembly (die and pattern) was invested for casting in the same investment material used to make the dies. Clasp patterns were then cast. Investing and casting materials were used according to the manufacturer's instructions.

Outer surfaces of clasp assemblies were polished using sequential finishing instruments. Clasps were then airborne-particle abraded with 50 μm alumina oxide with 0.4 MPa air pressure for 30 seconds. Ten clasps were fabricated with cobalt-chromium (Bego, Germany) and ten clasps were fabricated with titanium (Tritan, Germany) (Fig. 1 and 2). Test specimens were evaluated for retentive force in Newtons (N) using a universal testing machine with a crosshead speed of 10 mm/min (Fig 3).

Fig. 1: Group -a clasps (cobalt chromium)

Fig. 2: Group- b clasps (Titanium)

Fig. 3: Specimen in Universal testing machine

Evaluation of Porosity: Internal porosity of specimens was examined radio graphically (FCR5000R radiographic unit). The radiographic source (200kV/5 mA) was positioned perpendicular to the film at a cone-to-film distance of 10 cm. Exposure time was 1/60 seconds. In each clasp, porosities were counted regardless of the scale.

The resulting data were subjected to one-way analysis of variance (ANOVA) for comparison of the retentive forces of the Co-Cr and Ti clasps.

RESULTS

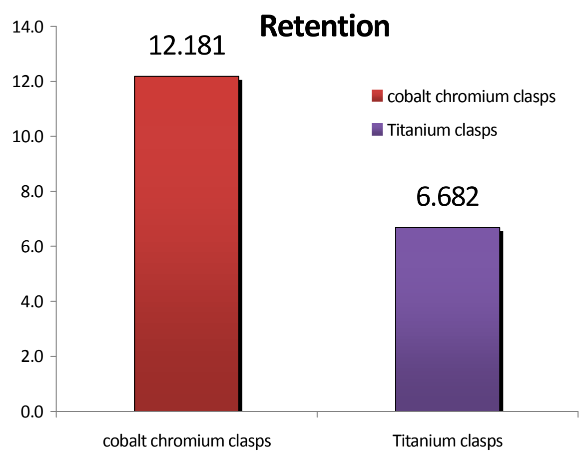
DESCRIPTIVE STATISTICS FOR RETENTION BETWEEN COBALT-CHROMIUM AND TITANIUM CLASPS

	Retention							
					95% Confidence Interval for Mean			
	N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
cobalt chromium clasps	10	12.181000	3.1694705	1.0022746	9.913697	14.448303	9.0100	18.2300
Titanium clasps	10	6.682000	2.1571524	.6821515	5.138866	8.225134	4.7000	10.0400
Total	20	9.431500	3.8626733	.8637200	7.623713	11.239287	4.7000	18.2300

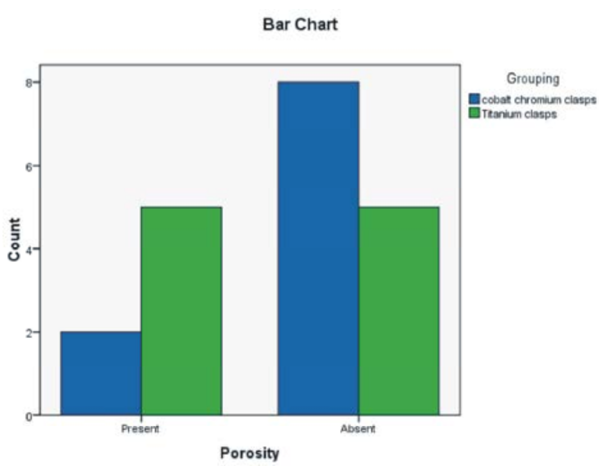
ANOVA F 20.572 p Value :0.000**p Value Significant at the level <0.05

Table: Number of Porosity in Cobalt-chromium and Titanium Clasps
Porosity * Grouping Cross tabulation

			Grouping		
			cobalt chromium clasps	Titanium clasps	Total
Porosity	Present	Count	2	5	7
		% within Porosity	28.6%	71.4%	100.0%
		% within Grouping	20.0%	50.0%	35.0%
	Absent	Count	8	5	13
		% within Porosity	61.5%	38.5%	100.0%
		% within Grouping	80.0%	50.0%	65.0%
Total	Count	10	10	20	
	% within Porosity	50.0%	50.0%	100.0%	
	% within Grouping	100.0%	100.0%	100.0%	



Bar Diagram 1: Retentive Forces for Cobalt-chromium and Titanium Clasps



Bar Diagram 2: Porosity in Cobalt-chromium and Titanium Clasps

Retention Force Analysis: For cobalt-chromium clasps, the mean (± standard deviation) retentive force at 0.3mm undercut was 12.18±3.17N. The corresponding retentive force for titanium clasps was 6.68±2.15N. The test showed that the retentive forces of the clasps made of two materials were significantly different. Results revealed that cobalt-chromium alloy clasps showed more retention than titanium clasps.

Porosity Analysis: In cobalt chromium clasps, 2 porosities were present which was 28.6% and in titanium, 5 porosities were present (71.4%).

DISCUSSION

Among the many different alloys used in removable prosthodontics, cobalt-chromium alloys and titanium alloys find unique application in cast partial denture service. Till the end of last century, cobalt-chromium alloys were the material of choice for cast partial denture work, since gold alloys, due to rising cost, found gradual decrease in usage. Although cobalt-chromium alloys have good rigidity, fit and required strength to withstand forces while being used intra-orally, abutment teeth can be subjected to deleterious forces due to the alloy's rigid nature.

Titanium has been used in implant prosthodontics successfully as it has excellent bio-compatibility, corrosion resistance and osseo-integration. In addition, its modulus of elasticity is nearly one half of that of cobalt-chromium alloys. Titanium is hypoallergenic and has many clinically useful properties similar to those of type-3 and type-4 gold alloys. Of the base metals, titanium and its alloy may be an alternative for a patient who is sensitive to cobalt-chromium alloy and who needs prosthetic devices. Removable partial denture frame-works of titanium can be manufactured by appropriate casting techniques [7]. Although interest in the use of pure titanium and titanium alloys for fabricating removable partial denture started as early as 1980's, casting difficulties and framework imperfection were obstacles to be overcome.

In the present study, ten clasps were fabricated with cobalt-chromium (Bego, Germany) and ten clasps were fabricated with titanium (tritan, Germany).

Retention force values for cobalt-chromium was 12.18N while the same for titanium alloys was 6.68N. This shows that twice the amount of force is required to dislodge a cobalt-chromium clasp than the titanium clasp.

Retentive force for a titanium clasp might just be sufficient, as research has shown that the minimum retention force for removable partial denture clasps is 5N. It should be noted that other factors, in addition to the type of retentive clasp and depth of undercut, influence the retention of a removable partial denture. Appropriate guiding plane on the proximal surface increases the retention. Clinical experience indicates that ineffective reciprocation may result in lack of retention and stability. 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 clasps are used in the fabrication of a removable partial denture and all other mentioned factors are also considered, titanium clasps may be sufficient for clinical use. Still, retention with cobalt chromium alloy clasps is significantly greater.

The results of the present study are in agreement with the study of Renata Christina *et al*. [3]. They suggest that titanium clasps with 0.25-mm undercut demonstrated lower retentive force values than the Co-Cr alloys.

When the specimens were tested for presence of porosity, cobalt-chromium casting had 2 porosities while titanium had 5 porosities. The number of porosities was more in titanium alloy samples, when compared with cobalt-chromium samples. Percentage wise, titanium alloy clasps exhibited 71.4% of porosity while cobalt-chromium clasps exhibited 28.6% of porosity.

Such porosities might have occurred because of the 713 mmHg pressure generated by argon gas in metal, thus favouring the inclusion of pores in the cast metal [9,10]. Another cause may have been the temperature difference between fluid titanium (1700°c) and the mold (400°c), which causes rapid solidification of the metal, lessening the likelihood of gas escaping from the mold. Altogether, such occurrence presents difficulties in casting [10].

Porosity can be generated by many variables such as shrinkage of the alloy and entrapment of gases during solidification. Molten titanium has a strong affinity for hydrogen and oxygen on solidification; as the absorbed gases are expelled, porosity results. Density of the investment also affects gas entrapment and therefore porosity formation. A porous investment facilitates the escape of gases from the mold. Although there is a difference in the metallurgical nature of the commercially pure titanium used in our study and Co-Cr alloy commonly used commercially for removable partial denture frameworks, porosity is not a unique characteristic of titanium, but is also found in Co-Cr alloys.

In the present study, overall porosity in titanium clasps was more than that of chrome-cobalt alloy clasps.

Limitations of the Present Study:

- Retentive force measurements did not include infrabulge clasp designs. Retentive properties of circumferential clasps cannot be extrapolated to infrabulge clasps because of the difference in approaching the undercut area.
- An undercut of one value was used. Perhaps, if the undercut dimensions were increased, there would have been a possibility of titanium clasps showing more retentive force values.
- Another limitation is that this experiment was done in in-vitro situations. Therefore, the results may not be the same in the oral environment.

CONCLUSION

- Clasps fabricated with cobalt chromium alloy and titanium alloy (both types) had sufficient retention force values. (i.e, > 5 Newtons)
- Cobalt-chromium clasp had more retentive force than titanium clasp for the selected undercut.
- Titanium casting had more porosities than cobalt-chromium alloy casting.
- Titanium alloy clasps exhibited 71.4% of porosity while cobalt-chromium clasps exhibited 28.6% of porosity.

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