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Original Article

RETENTION OF CAST CHROME-COBALT VERSUS MILLED CHROME-COBALT TELESCOPIC RETAINER FOR AN IMPLANT SUPPORTED OVERDENTURE: AN IN VITRO STUDY

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Abstract

Aim: The objective of this study was to compare the retention of frameworks using milled versus cast cobalt chromium alloys for implant supported mandibular overdentures using a universal testing machine. **Methodology:** An epoxy resin model of edentulous mandible was constructed and prepared to receive four implants in the intra-foraminal region of the model. Four pre-milled titanium abutments were screwed to them which were considered to be the primary coping. The secondary copings were either Group C (cast cobalt chromium frameworks) or Group M (milled cobalt chromium frameworks). Retention was measured at baseline, after subjected to chewing cycles of 12,500 cycles and then after subjected to chewing cycles of 37,500 using the chewing simulator. **Results:** Both the cast and the milled groups showed a statistically significant decrease in retention when subjected to different cycles. Group C showed a higher non-significant change in retention from baseline to 12500 cycles. While Group M showed a higher non-significant change in retention from 12500 cycles to 37500 cycles and from baseline to 37500 cycles. **Conclusion:** The retention of the milled frameworks is higher than the cast frameworks up to an equivalent period of 1 month, after which the retention of both frameworks became equivalent.

Keywords: implant overdentures, telescopic attachments, retention, cast chrome-cobalt telescope, milled chrome-cobalt, mechanical properties, surface characteristics, microstructure characteristics.

Introduction

Edentulous patients often experience problems with their mandibular complete dentures. Patients with resorbed mandibular ridge often complain of lack of stability and retention of the mandibular denture and decreased chewing ability [(1)]. Mandibular implant overdentures solved many of the problems of conventional mandibular dentures such as; possible decrease in resorption of the residual ridges; improving stability and retention, and possible additional improvement in the patient's quality of life and satisfaction [(2)]. Mandibular two implant overdentures have been recognized as the standard care of treatment for the edentulous patients [(3)].

Different attachment systems were used in implant-supported overdentures; bars, magnets, ball or telescopic attachments. Telescopic retainers consist of primary and secondary copings.

Telescopic attachments have successfully improved the retention and stability of overdentures [(4)].

Several materials were recommended for telescopic crowns such as precious and non-precious metal alloys [(5)]. Materials suggested for use for telescopic retainers include cobalt chromium alloys, zirconium and PEEK.

Cobalt-chromium alloys are the most widely used materials for removable and fixed prosthetic frameworks. Cast cobalt-chromium frameworks have low thermal conductivity, ease of fabrication, high resistance to corrosion, precise fitting, high elastic modulus and mechanical strength when compared to other materials used for frameworks [(6,7,8)]. Recent developments in dental technology provided alternative manufacturing techniques compared to conventional casting for the fabrication of removable partial denture cobalt-chromium frameworks. CAD-CAM technology offered several advantages due to the elimination of casting deficiencies especially internal porosity [(9)].

However, it is still unclear which of the construction method; cast or milled cobalt-chromium, will improve and maintain the retention of the mandibular telescopic overdentures.

The aim of this in vitro study is to compare the change in retention for mandibular telescopic implant-supported overdentures where the primary coping is the pre-milled titanium abutments and the secondary coping is made of either cast or milled cobalt-chromium framework.

Subjects and Methods

The implant system used in this in vitro study was Implant Direct with length 10 mm and diameter/platform 3.5 mm placed in one epoxy resin model of edentulous mandibular arch. Four implants were installed at lateral incisor and first premolar area and the pre-milled abutments used were considered the primary coping for both groups. The primary coping in this study was considered the four pre-milled abutments while the secondary coping used was different in the two groups, Group C was cast cobalt chromium frameworks Group M was milled cobalt chromium frameworks. One epoxy model was used for both groups. Three frameworks for each group were constructed.

The study was designed to be a parallel In vitro study with allocation ratio 1:1.

The sample size calculation was done according to a previous study where the response within each subject group was normally distributed with standard deviation 3.26. If the true difference in the experimental and control means is 6, we will need to study 6 experimental subjects and 6 control subjects to be able to reject the null hypothesis that the population means of the experimental and control groups are equal with probability (power) 0.8. The Type I error probability associated with this test of this null hypothesis is 0.05 [(10)].

The implant system used in this in vitro study was Implant Direct with length 10 mm and diameter/platform 3.5 mm placed in one epoxy resin model of edentulous mandibular arch. Four implants were installed at lateral incisor and first premolar area and the pre-milled abutments used were considered the primary coping for both groups. The primary coping in this study was considered the four pre-milled abutments while the secondary coping used was different in the two groups, Group C was cast cobalt chromium frameworks Group M was milled cobalt chromium frameworks. One epoxy model was used for both groups. Three frameworks for each group were constructed.

An impression of a completely edentulous mandibular jaw using alginate impression was made and then poured to create stone model. The completely edentulous ridge chosen for this study was of sufficient width in the area corresponding to the lateral incisors and first premolars to accommodate implants of diameter 3.5mm and height 10mm.

The stone model was then duplicated using laboratory addition-curing 1:1 duplicating silicone “Ecosil+” to create the acrylic resin (epoxy) model to simulate a clinical condition.

Trial denture base was constructed using self-cure acrylic resin denture base on the epoxy resin model which was used for setting up the acrylic teeth following the conventional guidelines for setting up the teeth of a complete denture followed by marking over the epoxy model between the intra-foramainal area corresponding to the first premolar region and lateral incisor region bilaterally to prepare for the drilling and placement of the four implants.

A wide diameter fissure bur was used to drill for implant installation in the epoxy resin model slightly larger than implants to facilitate installation and parallelism at the first premolar and lateral incisor areas bilaterally following the acrylic resin trial set up of teeth.

The four implants with diameter 3.5 mm and length 10 mm were installed using a surveyor. Soft mix of acrylic resin was placed within corresponding four holes during implant placement to ensure that the implants were well attached within the epoxy resin model.

After placing the implants and setting them on the epoxy resin model, pre-milled titanium cylinder abutments having the same clinical height of 6mm by Implant Direct were screwed to the four installed implants in the model using a torque ratchet at 30N/cm. While the model was placed on the surveying table, a 2 degree taper bur was inserted into a hand piece that was mounted on the surveyor to create the required tapering on the abutments with a chamfer finish line. (Fig 1). The abutments were sprayed using scanning powder and the model was scanned using a benchtop dental scanner. For both groups, the designs of the frameworks and secondary copings were done using exocad software (Fig. 2). One epoxy model was used for both groups. Three frameworks for each group were constructed. All frameworks were constructed to be covering all the abutment surfaces through the defined finish line.

A. Cast Co-Cr framework (Group C)

After the design was ready, it was milled from wax using VHF dental milling machine to form a wax pattern of the framework which was then sprued and put into casting ring and prepared for investment. The sprue was then attached to the crucible former which constitutes the base of the casting ring during investment. The investment ring was placed in the furnace at room temperature and heated to the casting temperature of 700 degree Celsius until burnout was carried and all traces of wax were vaporized. Then casting of Co-Cr was done by forcing the molten alloy into the mold. Once casting was finished, the mold was removed and immersed in cold water. Finishing and polishing of the cast Co-Cr framework was carried out. (Fig. 3). The framework was checked for proper seating on the model using alternate figure pressure technique by manually seating the framework with finger pressure applied over 1 terminal abutment and then the other. Also, fit checker spray was used to check the proper seating of the frameworks by applying it over the framework, then the framework was gently seated on the abutments then removed. Areas that exhibit metal showing through or appear as a bright shiny spot were adjusted and the high spots were removed. The old fit checker spray was then removed, new spray was applied and the framework was tried again till passive seating was obtained. This group was named Group C and the three frameworks were fabricated using the same technique.

B. CAD/CAM or milled Co-Cr framework (Group M)

The same design was milled by VHF milling machine from Co-Cr block by Dentaurum to obtain the milled framework (Fig. 4) which was then checked for proper seating on abutments to be ready for next step. Checking of the proper seating of the frameworks was done similar to Group C. Three frameworks were constructed in this group and named Group M.

After the frameworks were ready, 3 layers of base plate wax was applied over the framework covering all the abutments height. This space of the base plate wax would be later used to create space for the pickup of each framework. The wax was 10 mm in width to accommodate 3 nuts that would further be used to attach the 3 screws for measuring retention using orthodontic wires for better engagement. Duplication was done in order to construct an investment model.

Using the investment model, the metal prosthetic part was waxed up. The top had a horse shoe shape with sufficient width for 3 nuts. At the bottom, there were 3 lingual triangular shaped extensions present at the two terminal abutments bilaterally and one in the midline. The prosthetic part would extend at the terminal implants bilaterally. The waxed up part was sprued, invested and cast over the metallic nuts.

After the casting process of the metallic prosthetic part was done, the lingual area of the cast was indexed using a large parallel shaped bur. A thick mix of stone plaster was placed on the lingual area of the model, the prosthesis was returned to the model while the stone was still soft. Excess stone was removed until the three triangular shaped extensions were flushed at the same level with the stone. This stone index was made on the lingual surface of the epoxy model. (Fig. 5). After the casting process, finishing and polishing for the metal prosthetic parts were done.

The epoxy resin model was painted with a separating medium to prevent the adherence of acrylic of pick up to the epoxy model. After proper seating of the framework over the primary abutments, trial seating of the metal prosthetic part was carried out on the framework. To ensure proper placement of the framework, the lingual triangular shaped extension rests had to properly engage their defined position in the lingual stone index. The framework was then removed and a soft mix of self-cured acrylic resin then placed inside the fitting surface of the metal prosthetic part and then seated over the framework with the lingual triangular shaped extensions properly placed over the stone index. After complete setting of the self-cure acrylic resin, the metal prosthetic part was removed to be checked properly to the picked up framework. This was carried out with all the frameworks of both groups. (Fig. 6).

One epoxy resin model with the frameworks of both groups were subjected to tensile forces using universal testing machine to record the retention at the baseline. Retention was measured in Newton. The epoxy resin model was mounted in Teflon housing and attached to the lower compartment of the universal testing machine by the aid of a hole made in the epoxy model to be fixed to the cast holder by a tightening screw while the upper compartment of the universal testing machine was attached to the metal prosthetic part over the framework. The metal prosthetic part was suspended from the upper movable compartment of the testing machine by triple orthodontic wire loop of height 12 cm and width 0.7 mm through custom-made three hooks fixed to metal prosthetic part. The orthodontic wires were narled over each other and then fixed into the center of the upper compartment of the universal testing machine through a Jacobs chuck. The device was subjected to a slowly increasing vertical load (1mm/min) until total dislodgment of the prosthetic part from their initial position.

The chewing simulator used in this study was the multimodal ROBOTA chewing simulator device integrated with thermo-cyclic protocol operated on servomotor. It consists of four chambers that simulate the horizontal movements of 10mm and vertical movements of 3mm simultaneously in the thermodynamic condition. The rising and forward speeds were 90mm/s while the descending and backward speeds were 40mm/s. the cycle frequency was 1.6 Hz with torque 2.4 Nm and the weight per sample was 3 kg.

Each framework of the two groups was then placed on the corresponding abutment and fixed to Jakobe’s chuck of the upper part of machine through inverted t-shaped auto-polymerizing acrylic resin centrally positioned horizontal bar to facilitate the aligning with the loading axis of machine and proper load distribution.

The test conditions were maintained at room temperature (20±2°C) and wet condition (distilled water) simulating the saliva. The test was repeated 12500 and 37500 times to clinically simulate the one and three months chewing condition respectively, according to previous studies [11]. This test was performed for each framework in each group (Group C and M).

These tests were performed using Bluehill® Lite software installed in the Instron machine. Data were recorded using the computer software. The obtained data was tabulated and subjected to statistical analysis.

Statistical analysis of the data was performed with SPSS 20®13, Graph Pad Prism®14 and Microsoft Excel 2016. All data were explored for normality by using Shapiro Wilk Normality test and presented as means and standard deviation (SD) values.

Comparisons between both groups of the study was performed by using Dependent t-test, Comparison between the studied variable in each group was performed by using Repetitive One-Way ANOVA test followed by Tukey’s Post Hoc test for multiple comparisons to detect the significant value. The significant level was set at $P \leq 0.05$.

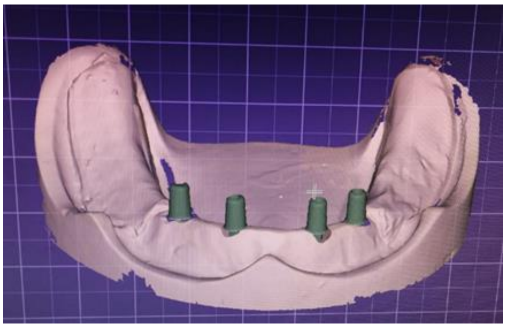

Figure (1) Scanned abutments

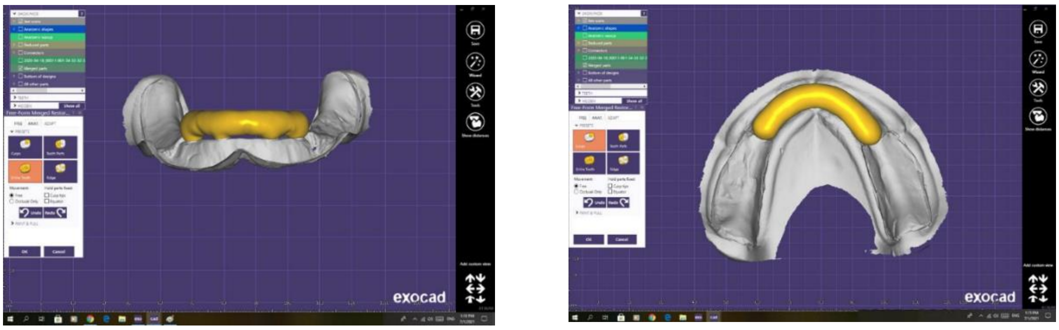

Figure (2) Framework design

Figure (3) Cast Co-Cr framework seated on abutments

Figure (4) Milled Co-Cr framework seated on abutments

Figure (5) Metal prosthetic part

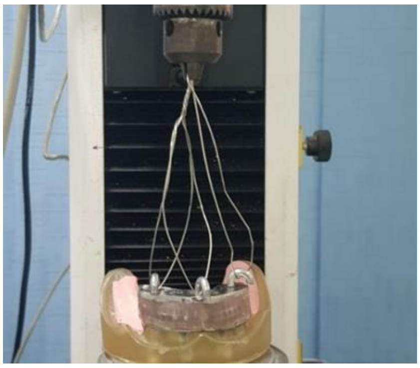

Figure (6) Metal pickup on epoxy model during measuring retention

Table 1 - Mean difference ± Standard deviation of retention changes in both groups at different intervals

	Retention				
	Cast cobalt chromium alloy		Milled cobalt chromium alloy		p-value
	MD	SD	MD	SD	
Baseline \ 12500 cycles	1.845	0.193	0.734	0.122	0.36
12500 cycles \ 37500 cycles	1.955	0.715	5.499	0.088	0.21
Baseline \ 37500 cycles	3.800	0.908	6.233	0.034	0.26
% of change	-29.58%		-40.078%		

*M; mean SD: standard deviation P; probability level (significant ≤ 0.05) *significant difference.*

Table 2 - Mean ± Standard deviation of retention of both groups at baseline, 12500 cycles & 37500 cycles

	Retention				
	Cast cobalt chromium alloy (C)		Milled cobalt chromium alloy (M)		P-value
	M	SD	M	SD	
Baseline	12.846	1.604	15.552	1.408	0.009*
12500 cycles	11.001	1.411	14.818	1.286	0.007*
37500 cycles	9.046	0.696	9.319	1.374	0.89 (ns)

*M; mean SD: standard deviation P; probability level (significant < 0.05) *significant difference.*

Results

Within both groups, there was a statistically significant decrease in retention from baseline, after 12500 cycles and after 37500 cycles with P<0.0001.

Comparison between group C & M

Group C showed a higher change in retention from baseline to 12500 cycles interval that was not significant. While Group M showed a higher change in retention from 12500 cycles to 37500 cycles and from baseline to 37500 cycles that were not significant.

The overall % change in retention was higher in the Group M than in the Group C. (Table 1).

Discussion

Group M showed a statistically significant higher retention value at baseline and after 12500 cycles when compared to Group C as P ≤ 0.05. While after 37500 cycles, Group M showed a non-significant higher retention value than Group C as P >0.05. (Table 2)

When the two sets of frameworks were being subjected to 12500 cycles (1 month) and 37500 cycles (3 months), there was a significant decrease in retention for both groups. The retention loss of the different telescopic retainers for implant overdentures was a common finding in several studies [12, 13, 14, 15].

Regarding the retention loss in cast and milled Co-Cr groups, the mechanical wear of the attachment occurring as a result of contact friction between retentive surfaces of attachments during insertion/removal cycles of the overdentures [16, 17]. Also, fatigue can cause overdenture attachments to gradually lose their retention [18].

Among the causes of the retention loss with cast Co-Cr frameworks attached to implant supported overdentures was the surface and dimensional changes of the attachments [19]. The fit of the cast Co-Cr frameworks would be compromised by errors in wax blocking out and duplication, variability in the expansion of the refractory material, and the techniques used for fitting and polishing the metal frameworks [20]. In addition to that, the surface roughness of the cast Co-Cr alloys would cause an increase in the release period which leads to decreased retention between primary and secondary copings [21]. Another reason maybe that the conventional processing (lost-wax technique) used for fabrication of cast Co-Cr alloys would result in fit deficiencies due to high casting temperatures and easy oxidation. The high modulus of elasticity decrease during conventional processing and the adjustment of the retention force becomes more difficult [22]. Cast Co-Cr alloys are subjected to high contraction cooling which would influence the accuracy and fit leading to decreased retention [23].

Group M showed a statistically significant higher retention value at baseline and after 12500 cycles when compared to Group C as P ≤ 0.05. While after 37500 cycles, Group M showed a higher retention value than Group C that was not significant as P >0.05. When comparing the change in retention values between the two groups from baseline throughout the different chewing cycles, Group C showed a higher decrease in retention from baseline to 12500 cycles that was not significant. While Group M showed a higher decrease in retention from 12500 to 37500 cycles and from baseline to 37500 cycles which were both not significant. These results coincided with previous studies which stated that the reason for the significant greater retention values initially in the milled Co-Cr frameworks over the cast Co-Cr frameworks may be explained by the elimination of the interdendritic micro porosity, errors in was blocking, and distortions that occur at the level of secondary frameworks surface during the casting procedures and subsequently increasing retention [24, 25, 26, 27]. Another explanation is that the milled Co-Cr framework produced by CAD/CAM technology would allow the framework to fit more intimately onto the coping and therefore needs a higher pull force to be separated [28, 29, 30]. The heat treatment process for fabrication of the cast Co-Cr alloy in telescopic crowns in overdentures leads to decrease in the overall strength of the alloy and slight elongation and dimensional variations of the alloy which will cause misfit of the overdenture leading to decrease in the retention [31, 32].

Despite that the milled Co-Cr frameworks showed a decrease in retentive forces over time. The decrease in retention values in the milled Co-Cr group when compared to the cast Co-Cr group would be due to the presence of the casting nodules on the surfaces of the secondary crowns in the cast Co-Cr alloy group that create wear tracks on the polished surface of the primary crowns, which would result in intricate meshing and wedging of the metal. Plastic deformation of these nodules results in an increase in adhesive friction along the path of insertion with increased retention values of the cast framework [33]. The smoother surface of the milled Co-Cr alloys would result in a faster loss of retention due to the continuous contact between the two smooth surfaces of the double crowns resulting in progressive force and wear [34]. In this study, both the milled and cast Co-Cr frameworks reported higher initial retention force value than the recommended range. Retention strengths between 5N to 8N are sufficient for stabilization of implant-retained overdentures during long term function [35, 36, 37].

Also, the slower decrease in the retention for the cast Co-Cr group may be due to that the cast Co-Cr alloy has a higher elastic modulus than the milled Co-Cr alloy meaning that more stress is required to deform the material. While the milled Co-Cr alloy has a lower yield strength and flexural strength than the cast Co-Cr alloy so plastic deformation occurs at lower stress levels, leading to greater decrease in retention values overtime [38, 39].

The results of this in vitro study demonstrated no statistically significant difference between the retentive mean values of the cast Co-Cr frameworks and the milled Co-Cr frameworks at 37500 cycles (3months). This could mainly be due to that the telescopic retainers in both groups depend mainly on the adhesive friction between the double crowns. When the two groups were subjected to different cycles, there was a progressive frictional wear between the primary and secondary copings resulted in loss of retention in both groups after 3 months, also, it has been reported that the contact surfaces (after saliva exposure), of both titanium implants and Co-Cr frameworks in implant-supported overdentures become rougher after saliva exposure, indicating a possible process of ongoing material degradation and wear leading to decreased retention. [12, 13, 14, 15].

Also, the decrease in retention of both groups overtime can be related to the use of a tapered design abutments in the double crown overdenture that would depend on the friction between the primary and secondary copings. Although this design provides sufficient retention at the beginning, there is a rapid loss of retention overtime due to the continuous contact of the double crown which results in progressive wear and excessive force on the supporting structures [34, 40, 41].

Conclusion

Within the limitations of this study, it can be concluded that the milled cobalt chromium frameworks showed a statistically significant higher initial retentive values than the cast cobalt chromium frameworks up to an equivalent period of 1 month, after which the retention of both frameworks became equivalent.

Conflict of Interest:
The authors declare no conflict of interest.

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