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Effect of Using Different Primary Crown Materials on the Retention of CAD/CAM Telescopic Partial Dentures

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Abstract

AIM: This study compared the effect of using different primary crown materials (zirconia and cobalt-chromium) on the retention of telescopic retained removable partial dentures.

MATERIALS AND METHODS: A maxillary Kennedy class I stone model was prepared and scanned. The virtual cast was adjusted to create four abutments at the positions of the canines and the first premolars. Primary crowns were designed and then milled. In Group I, seven primary crowns were milled out of zirconia, and in Group II, seven primary crowns were milled from cobalt-chromium blanks. Cobalt-chromium telescopic partial dentures were milled. The universal testing machine was utilized to apply vertically dislodging static forces. Initial retention values were recorded. Then, the chewing simulator (CS) was used to apply dynamic cyclic loading to each partial denture. And after, 50,000 cycles and 270 attempts of insertion and removal final retention values were recorded. The data were collected and statistically analyzed.

RESULTS: A significant decrease in retention in both groups after simulation of 3 months of partial denture function was recorded. It was found that after simulation of 3 months of function Group I (zirconia) recorded a statistically significant higher mean value; (1.935 ± 0.268 N) than Group II; (0.583 ± 0.018 N) as indicated by student t-test ($p \leq 0.0001 < 0.05$).

CONCLUSION: Zirconia primary crowns attain higher retention values than cobalt-chromium with cobalt-chromium telescopic partial dentures after simulation of 3 months of function.

Introduction

Kennedy class I is the most encountered partially edentulous class, where the main problem is the lack of posterior abutments. Thus, a challenging situation arises during the restoration of the missing teeth with a removable partial denture (RPD) that derives its support from the teeth and the residual ridge. Accordingly, the partial denture is subjected to movements as a result of functional loads as those developed from mastication [1].

RPDs are considered as a conservative and economical treatment approach to restore missing teeth in partially edentulous patients, enhancing their quality of life. However, the conventional construction technique is a complicated and time-consuming process. To improve the patient's satisfaction both esthetically and functionally, recent materials and techniques of dentures construction were developed [2], [3], [4], [5], [6].

Telescopic systems are employed to retain removable dentures that are usually indicated for patients with few remaining teeth [7], [8], [9]. It is considered an ideal treatment approach when a fixed treatment option cannot be utilized due to compromised or unfavorable general health conditions [10], [11]. Double crown retained partial dentures are proven to be an effective rehabilitation method for decreased residual dentition due to improved patients' satisfaction and long-term durability [12], [13], [14], [15].

Double crown systems are composed of an inner crown (primary crown) and an outer crown (secondary crown). The primary crown functions as a male part and is cemented to the abutment (tooth or implant), while the secondary crown functions as a female part for retaining the RPD [16].

Usually, the combination of materials in telescopic retained RPDs comprises a metal–metal, zirconia–metal, or metal–polymer contact that possess different surface wear patterns thus, varying resistance to repetitive removal–insertion cycles [17], [18].

The employment of zirconia as a primary crown has been proven to be reliable regarding retention and wear performance [19], [20]. In general, esthetic qualities, excellent physical properties, and the improved biocompatibility make zirconia an appealing material that meets many of the modern dentistry requirements [21].

Precise milling of the inner and outer crowns has been frequently applied with the introduction of computer-aided design and computer-aided manufacturing technologies. Accordingly, additional materials for primary and secondary crowns as zirconia (ZrO_2), titanium, or polyether ether ketone (PEEK) have been introduced [22], [23], [24]. Milling of the primary and secondary crowns from these materials decrease human labor and manufacturing costs [25].

Few data are available regarding the evaluation of the clinical performance of double crown attachments constructed of zirconia primary crowns combined with metal secondary crowns. Hence, this study was carried out to investigate, in which primary crown material has a better retention in telescopic retained metallic partial dentures. The null hypothesis was that there was no difference in the retention of telescopic retained metallic partial dentures fabricated with different primary crown materials.

Materials and Methods

A ready-made educational Kennedy class I stone model, with the first premolars as the last standing teeth, was mounted on the Nouvag drill press and surveyor machine (AF 30 milling and surveying machine, NOUVAG, Goldach, Switzerland). A rubber base index was made of addition silicone putty (Elite HD addition silicone 3M EPSE) and used as a reduction gauge to assess the amount of abutment reduction. Then, a clear vacuum formed stent was pressed on the cast. On the drill press machine, the canines and first premolars were prepared until a uniform amount of 2–3 mm reduction was achieved without any undercuts and the reduction was verified.

The prepared stone model was scanned using the 3D digital scanner D-850 from 3 Shape Shape (A/S, Holmens Kanal 7, 1060 Copenhagen K, Denmark). The virtual standard tessellation language (STL) model was introduced into Model Creator module from Exocad (Exocad Valetta 2.2, 2014–2020 Exocad GmbH) to produce a virtual cast with removable dies. Then, the files of the cast and dies were exported. The STL file of the cast was uploaded to the Meshmixer software (Autodesk software. 2017 Autodesk, Inc.), on which the saddle areas were outlined and depressed 1.5 mm.

Two models were fabricated by 3D printing. Then, the pre-fabricated clear stent was used as a matrix for the tissue simulating material (Multisil-Mask soft Assortment, bredent GmbH and Co.KG). The design order was given initially for the primary copings on the abutments using the Exocad software which automatically determines the finish lines and locks the crown buttons. A minimal thickness (0.7 mm) of the copings was created then the digital surveyor tool was used to determine a common path of insertion and to create a chamfer finish line of 0.5 mm thickness on each abutment along with 2–4° taper**.** The design of the primary copings was set to confirm to Marburg design, with a vertical parallel band height of 1.5–2 mm starting from the finish line and tapered occlusally.

Fourteen sets of primary copings were milled using COR I-TEC 350i Loader PRO$^+$ (imes-icore ® GmbH, 16 Leibolzgraben, 36132 Eiterfeld, Germany). Seven sets were made of a commercial Y-TZP substrate (Nacera Pearl 1, Doceram, GmbH, Dortmund, Germany) (Group I) and the other seven sets were milled from fully sintered cobalt-chromium disk (MESA DI SALA GIACOMO and C. S.N.C.,Via dell'Artigianato, 35/37/39–25039 Travagliato (BS) ITALY) (Group II). Cementation of the primary copings to the abutment teeth was done using the glass ionomer cement (Medicem (Promedica Dental Material GmbH) Figure 1.

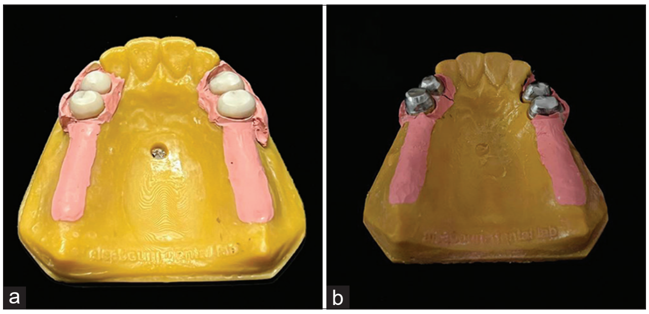

Figure 1: Cemented primary crowns. (a) Zirconia crowns. (b) Cobalt-chromium crowns

The design process of the RPD framework was initiated by designing the secondary copings. The path of insertion was determined, the undercuts were blocked out, and the anatomical tooth forms were selected and adapted to the finish lines. The crowns were splinted and the facial surface of each crown was cutback to provide a 1.2 mm space for the veneering material. The RPD was then designed following the conventional design principles.

RPD frameworks were milled out of fully sintered cobalt-chromium disks (MESA DI SALA GIACOMO and C. S.N.C.,Via dell'Artigianato, 35/37/39–25039 Travagliato (BS) ITALY).Then, the proper seating of the partial dentures was verified. The secondary copings were veneered and a rubber base index (Elite HD addition silicone 3M EPSE) was used to standardize the position of the teeth on the frameworks.

Evaluation of the retention values

The geometric center of each partial denture was determined by converting the STL file of the partial denture to the OBJ format which was imported to a 3D computer graphics software (Autodesk 3ds Max, Autodesk Media and Entertainment, USA). The 3D image was manipulated by the 3D MAX software until it became horizontal and the geometrical center was automatically detected [26]. A resin plate with a central hole coinciding with the predetermined center was designed to fit on the occlusal surface of the teeth.

The resin plate was printed then fixed to the RPD using a cold cured acrylic resin (PD PROCRYLA cold cure acrylic resin, President Dental, Germany) Figure 2.

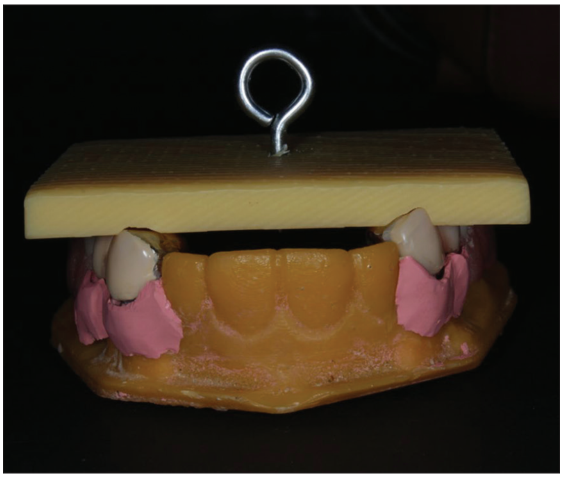

Figure 2: Resin plate attached to the occlusal surface of model

The model, the RPD, and the abutments were wetted with artificial saliva (Glandosane, No. 9235461109, cell pharm, Bad Vilbel, Germany) [27], [28], [29]. The occlusal plane of the RPD was adjusted to be parallel to the base of the Universal Testing Machine [30], [31], [32], [33] (INSTRON, 3365,USA Bluehill, ITW Inc., England).

The Universal Testing Machine was set to apply a preload of 50 Newton for 20 s at a constant crosshead speed of 50 mm/min [34], [35]. Then, vertically oriented tensile loads were applied on the resin plate until the RPD was separated from the abutments. The initial pull off test was carried out and maximum tensile loads required to dislodge the partial denture from the cast model were calculated in Newtons. Three measurements were executed for each set of abutments and the mean of these measurements was calculated as the initial retention values Figure 3.

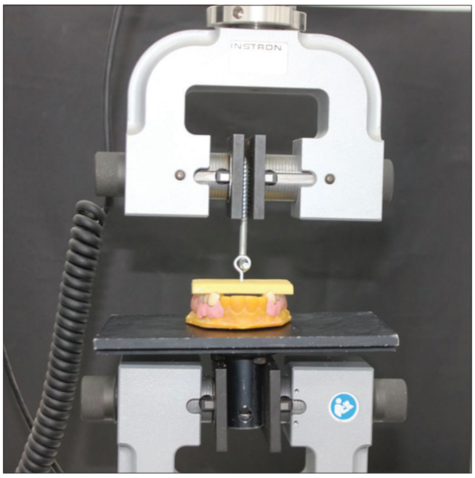

Figure 3: Initial pull-off test

The (CS-4.4; SD Mechatronic, Munich, Germany) was utilized to apply dynamic cyclic loading through a stylus falling at the center of the resin plate.

Each group was examined under the same conditions, that is, the specimen chamber was filled with artificial saliva load settings of 50 N [36] and the software parameters were set at 60 mm/s speed, 3 mm vertical path, 0.7 mm horizontal path, and 1.6 Hz frequency [37], [38]. Each RPD was subjected to bi-axial cyclic loading for a total of 50,000 cycles [39], [40], [41] Figure 4.

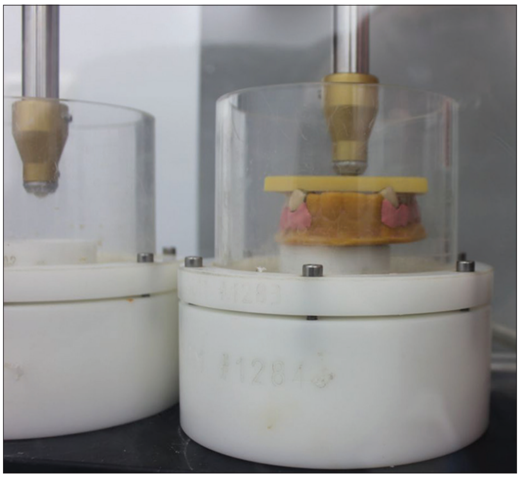

Figure 4: Model in the chewing simulator chamber

Each partial denture was inserted and removed manually 270 times, afterward, it was mounted again on the universal testing machine as described previously to measure the final retention values after simulation of 3 months of function [32], [33]. The results were recorded and statistically analyzed.

Data from the two groups were collected and presented as mean and standard deviation. Statistical analysis was performed using Graph-Pad Instat statistics software (version 3.06) for Windows. Student t-test and paired t-test were used to verify whether there was a statistical difference between both groups and between the measurement stages. Two-way ANOVA test was performed to detect influence of each variable ($p \leq 0.05$).

Results

The results of this paper showed that at baseline, Group I (zirconia) recorded statistically significant higher mean value; (4.746 ± 1.329 N) than Group II (cobalt-chromium); (1.999 ± 0.238 N) as determined by student (unpaired) t-test ($p = 0.0047 < 0.05$). It was also found that after 50,000 cycles, Group I (zirconia) recorded a statistically significant higher mean value; (1.935 ± 0.268 N) than Group II; (0.583 ± 0.018 N) as indicated by student t-test ($p \leq 0.0001 < 0.05$) Table 1.

After simulation of 3 months of partial denture use, the reduction of the retention values in the both groups was calculated in N. and %. Group I (zirconia)

Table 1: Comparison of retention results (mean ± SD) between both groups as function of measurement stage

Variable	Measurement stage								
	Baseline				50 k cycles				Paired t-test
	Mean	SD	95% CI		Mean	SD	95% CI		
			Low	High			Low	High	p-value
Experimental group									
Gp I (Zr)	4.746	1.329	3.761	5.731	1.935	0.268	1.736	2.133	0.0056*
Gp II (Co–Cr)	1.999	0.238	1.822	2.176	0.583	0.018	0.569	0.596	<0.0001*
Student t-test	p-value	0.0047*			p-value	<0.0001*			

baseline record was statistically significant with higher mean value; (4.746 ± 1.329 N) than the 50,000 cycles record; (1.935 ± 0.268 N) as indicated by paired t-test ($p = 0.0056 < 0.05$). It also showed that with cobalt-chromium (II), the baseline record was statistically significant with higher mean value; (1.999 ± 0.238 N) than the 50,000 cycles record; (0.583 ± 0.018 N) as indicated by paired t-test ($p \leq 0.0001 < 0.05$) Table 1.

Moreover, the results showed that irrespective of the measurement stage, the difference between both groups was statistically significant ($p \leq 0.0001 < 0.05$) as indicated by two-way ANOVA where zirconia group (I) recorded higher retention values than the cobalt-chromium group (II), the mean value and the standard deviation for the zirconia group (I) (3.340 ± 0.799N) was significantly higher than the cobalt-chromium group (1.291 ± 0.128 N) Table 2.

Table 2: Comparison of total retention results (mean ± SD) as function of experimental material groups

Variable	Mean	SD	95% CI	
			Low	High
Experimental group				
Gp I (Zr)	3.340	0.799	2.748	3.932
Gp II (Co–Cr)	1.291	0.128	1.195	1.386
Statistics			p-value	<0.0001*

Discussion

A strong friction fit of RPD can be achieved by utilizing telescopic attachments. However, long-term maintenance of fit over time is crucial for a successful treatment [25]. It is evident that various materials have different behaviors when being in function opposing one another [19]. Accordingly, this *in vitro* study was carried out to evaluate the retention values of zirconia and Co–Cr primary crowns with metallic telescopic partial dentures. The retention values were recorded at the time of framework insertion and after 3 months of function.

The CS device was utilized to simulate the lateral forces acting on the abutments during function and to simulate the chewing cycles. Since the universal testing machine allows only intermittent movements in one plane and produces static loads thus, it cannot be used to generate the complex chewing movements [42], [43].

The data of this study showed that under static loads, the retention values of zirconia primary crowns (Group I) were higher than that of cobalt-chromium primary crowns (Group II). Thus, the null hypothesis was rejected. These findings coincide with a previous study that stated that regarding different crown materials, zirconia primary crown systems showed higher retention forces than those with Co–Cr crowns, denoting that they are much feasible for the use of telescopic systems. The values of the forces recorded for the Co–Cr system were mainly within the range of 1–3 N which are considered low values that may cause potential problems during use. This was explained due to the utilization of a hard and wear resistant primary crown material (ZrO_2) opposing a less hard secondary crown material (Co–Cr), as in the metal-ceramic biomaterials coupling, that can be considered advantageous [44].

Moreover, the results were similar to Beuer *et al*. [20] who evaluated the effect of abutment height, the material of the inner crown, and taper on the retentive forces values of double crowns. They observed that the surface roughness of the primary crowns influenced the retention force. In their study, the Y-TZP primary crowns showed higher retention load values with smoother surfaces than crowns made from gold alloy.

The results were in contrast to Merk *et al*. [45] who reported no significant differences between groups with different primary crowns and the same secondary crown types (C/Z and Z/Z; C/G and Z/G). In association to these results, a study by Besimo *et al*. [46] reported that the retention force of telescopic crowns is not influenced significantly by the primary crowns material.

After 50,000 cycles of the CS representing 3 months of function of RPD, the results showed that the decrease in the retention values was higher in Group II (cobalt-chromium) compared to Group I (zirconia group). This may have resulted from the lower surface roughness of the Zirconia copings than CoCr copings; thus, zirconia copings have a wider contact area or dry friction (FD) [47].

This is consistent with the previous studies which reported that the amount of retention or friction between primary and secondary copings of telescopic over-dentures mostly results from FD, lubricated friction, and boundary friction. These three types of frictions can occur when the secondary internal surface coping moves into the loose direction of the primary polishing surface coping. Out of these frictions, FD has the strongest influence since wider contact area between copings will result in greater retention [47], [48].

It was found that irrespective of the measurement stage, the difference between both groups was statistically significant. This coincides with a study by Fischer *et al*. [44] who stated that the retention forces in the telescopic systems where the primary crowns were made of zirconia registered the highest values, compared to those with Co–Cr primary crowns. Moreover, the development of the retention forces and wear resistance during the 360 cycles (representing the equivalent of 1-year usage of the system) was favorable for the zirconia telescopic primary crowns [44].

The results also showed that regardless of the material, both groups showed a significant decrease in retentive forces after simulation of 3 months of partial denture use. It has been suggested that any attachment system is subjected to functional loads resulting from the friction between the telescopic copings which lead to lowering the retentive force values [49].

Conclusion

Within the limitations of the study, it can be concluded that zirconia primary crowns provide higher retention values than cobalt-chromium primary crowns after simulation of 3 months of partial denture use.

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