EVALUATION OF ACCURACY AND WEAR OF TWO DIFFERENT MATERIALS IN DIGITALLY-DESIGNED TELESCOPIC REMOVABLE PARTIAL DENTURES

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ABSTRACT

INTRODUCTION: Computer-assisted design and manufacturing (CAD/CAM) have been involved in fabrication of telescopic retained partial dentures to overcome deficiencies of conventional fabrication methods. Digitally-designed removable partial denture (RPDs) frameworks can be fabricated directly from metals and polymers or alternatively from milled or printed resin patterns by casting using conventional fabrication methods.

OBJECTIVES: This study was conducted to compare between Bio-HPP and Co-Cr, CAD/CAM telescopic RPDs regarding accuracy and wear of primary crowns.

MATERIAL AND METHODS: An educational model was scanned to create digital model after abutments reduction. Telescopic retained RPDs were milled from two different materials to fabricate twelve telescopic RPDs. In group 1, six Co-Cr telescopic retained RPDs were milled, and in group 2, six Bio-HPP telescopic retained RPDs were milled. Frameworks were scanned, and then the scans were superimposed onto the design to determine the accuracy. Chewing simulator was used for both groups. Primary copings were scanned and superimposed on original design to determine wear.

RESULTS: Group 1 showed higher accuracy, but the difference was not statistically significant. Furthermore, there was increased surface deviations of primary crowns in group 2 from original design denoting increased wear, and the difference was statistically significant.

CONCLUSIONS: Milling technology produces accurate Bio-HPP and Co-Cr telescopic retained RPDs. Increased wear of primary crowns occurs when Bio-HPP is used for fabrication of telescopic retained RPDs.

KEY WORDS: CAD/CAM, RPD, Bio-HPP, Co-Cr.

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INTRODUCTION

Rehabilitation of partially edentulous patients with removable partial dentures (RPDs) continues to be a valuable treatment option for many patients, especially in free end saddle cases. RPDs are also used in cases where dental implants are imprudent due to anatomical or medical conditions. Telescopic attachments enhance the esthetics, retention, and stability of RPDs. Moreover, the abutment teeth are splinted together and are protected from caries [1, 2].

RPD frameworks are often fabricated from cobalt-chromium (Co-Cr), which poses some limitations, including allergic reactions, galvanism, and plaque re-



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tention [3, 4]. High-performance polymer (Bio-HPP) may be used as an alternative treatment option in these situations. Mechanical properties and bio-compatibility of Bio-HPP rendered a material suitable for many applications. Abrasion resistance of Bio-HPP is comparable to metals; thus, it can be used for fabrication of telescopic retained RPDs [5].

Conventional fabrication methods of removable partial denture frameworks involve multiple steps requiring human intervention and manipulation of materials, which increases the possibility of errors during construction. Recently, computer-aided design and computer-aided manufacturing (CAD/CAM) have been involved in the fabrication of removable prosthesis. Digitally designed RPD frameworks can be fabricated directly from metals and polymers, or alternatively from milled or printed resin patterns by casting using conventional fabrication methods [6].

In comparison to the conventional fabrication methods, CAD/CAM has the advantages of omitting multiple error introducing steps, such as impressions, waxing, and casting. This is assumed to reduce the sources of errors and increase the precision of prosthesis. Furthermore, since modeling and production are automated procedures, there is an overall reduction of the fabrication time and cost [7].

OBJECTIVES

Few studies have investigated the qualities of CAD/ CAM-fabricated telescopic RPDs; thus this study was performed to compare Bio-HPP and Co-Cr CAD/ CAM-designed telescopic retained RPDs regarding accuracy of the frameworks and wear of the primary copings.

MATERIAL AND METHODS

Maxillary Kennedy class 1 educational model was applied in this study, where the first premolars were the last standing teeth. The canines and the first premolars were prepared using drill press machine (Nouvag Headquarters, 9403 Goldach, Switzerland). The amount of reduction of abutments was verified by using a rubber mold (Figure 1). A clear vacuum formed stent was constructed using the educational model. Then the model was scanned using 3D desktop scanner (3Shape D850) (3Shape A/S, Holmens Kanal 7, 1060 Copenhagen K Denmark).

The 3D virtual model was imported to model creator module of exocad (exocad GmbH; Darmstadt, Germany) and Meshmixer (Autodesk, Inc., USA). The virtual model was edited to convert the canines and premolars into removable dies with 0.2 mm PDL space, and 1.5 mm thickness was a cutback at edentulous areas.

The virtual model and twelve sets of dies were printed using Dent 2, 3D printer ([®]2019 Mogassam Co.) and model resin (NextDent B.V. Centurionbaan 190, 3769 AV Soesterberg, the Netherlands).

The vacuum formed stent was used for pressing soft-tissue simulation material (Multisil-Mask soft Assortment, Bredent GmbH & Co. KG) onto the cast guided by palate and remaining teeth (Figure 2). Two different materials were used to fabricate twelve telescopic RPDs. In group 1, six Co-Cr telescopic retained RPDs were fabricated, and in group 2, six Bio-HPP telescopic retained RPDs were created.

The design of primary copings was made to confirm to Marburg design, with a vertical parallel band height of 1.5-2 mm starting from the finish line and tapered occlusally (Figure 3). STL files of primary copings were exported to nesting software. In group 1, the primary copings were milled using COR I-TEC 350i Loader PRO (imes-icore[®] GmbH, 16 Leibolzgraben, 36132 Eiterfeld, Germany), from fully-sintered Co-Cr discs



FIGURE 1. Rubber mold to verify amount of reduction



FIGURE 2. Clear vacuum formed stent



FIGURE 3. Primary telescopic crown design



FIGURE 4. Digital removable partial denture design



FIGURE 5. Evaluation of accuracy of frameworks

(MESA DI SALA GIACOMO & C. S.N.C., Via dell'Artigianato, 35/37/39 – 25039 Travagliato (BS), Italy). While in group 2, the primary crowns were milled from Bio-HPP ([®]Bredent UK, 2020). After finishing, the primary copings were cemented to the abutment teeth using glass ionomer cement (Medicem; Promedica Dental Material GmbH, Germany), and then scanned.

Telescopic retained RPDs were then designed starting with secondary telescopes, which were splinted together covering primary copings on each side. Removable partial denture was designed following conventional design



FIGURE 6. Initial alignment of files

principles with a maxillary palatal plate major connector of 1.5 mm thick (Figure 4). Then, RPD frameworks were milled.

EVALUATION OF ACCURACY

The frameworks were scanned to create 3D STL files that were compared to original design files to detect surface deviations using Geomagic-X software ([®]2020 3D Systems, Inc.). The 3D compare tool in the software was



FIGURE 7. 3D comparison color map



FIGURE 8. Assessment of wear of primary copings

used after alignment of reference data (design files) with the scans of frameworks in 3 axes (Figures 5-7). Deviations from the original design were recorded and tabulated for statistical analysis.

EVALUATION OF THE WEAR OF PRIMARY COPINGS

Each partial denture was seated on the cast with a corresponding set of dies with primary copings, and introduced into chewing simulator (Robota, chewing simulator with thermocycle, Germany). A series of 50,000 chewing cycles were conducted to simulate the function of partial denture for 3 months. Forces were applied at the second premolar position (10 kg multiplied by gravitational acceleration (9.8 m/s²) equals 98N). 270 cycles of manual dislodgments were also performed [8, 9].

All primary copings in both the groups were scanned to obtain STL files and the outer surface of each coping was digitally compared to the original design of primary copings using Geomagic-X software ([©]2020 3D Systems, Inc.) to detect the amount of surface wear (Figure 8).

Collected data were tested for normality by checking data distribution and calculating mean values and normality curves. Numerical data were presented by mean, standard deviation (SD), and standard error of the mean. Student *t*-test was used for comparison between the groups. Significance level was set at $p \le 0.05$.

RESULTS

Regarding accuracy of the frameworks, group 1 showed higher accuracy with lower surface deviation (2.5070 \pm 0.05597 mm) in comparison with group 2 (2.5193 \pm 0.03747 mm). However, Student *t*-test showed that the difference was statistically insignificant (p = 0.663) (Table 1). On the other hand, there was increased surface deviation of the surface of primary copings from the original design in group 2 (0.6168 \pm 0.16047 mm) denoting increased wear in comparison with group 1 (0.3017

TABLE 1. Mean, standard deviation, standard error of mean, and *p*-value of Student *t*-test regarding the accuracy of frameworks

Groups	п	Mean	Standard deviation	Standard error of mean	<i>p</i> -value
Group 1: Co-Cr	6	2.5070	0.05597	0.02285	0.663
Group 2: Bio-HPP	6	2.5193	0.03747	0.01530	

TABLE 2. Mean, standard deviation, standard error of mean, and *p*-value of Student *t*-test regarding wear of the primary telescopes

Groups	n	Mean	Standard deviation	Standard error of mean	<i>p</i> -value
Group 1: Co-Cr	6	0.3017	0.14575	0.05950	0.005
Group 2: Bio-HPP	6	0.6168	0.16047	0.06551	

 \pm 0.14575 mm). Student *t*-test showed that the difference was statistically significant denoting higher wear resistance of group 1 (*p* = 0.005) (Table 2).

DISCUSSION

An in vitro study was conducted as the laboratory studies can be easily controlled and yield more accurate results, especially when the experiments concern comparative values. Abutment teeth were prepared to allow circumferential clearance of 2 mm for the telescopic crowns, as the minimum thickness required for designing of the Bio-HPP copings is 0.7 mm [10]. The cast was constructed with removable dies with 0.2 mm clearance accounting for periodontal ligament thickness around the normal teeth. 1.5 mm reduction of the saddle areas was done to create space for mucosa simulating material. These spaces were filled with tissue simulating material to resemble conditions of the oral cavity, and ensure a natural stress distribution pattern during loading as well as normal movements during application of chewing simulation [11, 12].

Up to date, few investigations have focused on the accuracy of milled restorations. Previous studies have mostly been restricted to analyze the fit of restorations. Digital 3D analysis provides comprehensive results over the complete surface, without data loss that usually occurs in 2D analysis methods. In 3D analysis, manufactured specimen is scanned and superimposed on the original design using a software. The enhanced quality of analysis can be used to detect up to 20 μ m deviations [13].

Both the groups showed accurate RPDs, and this finding was attributed to the software program, which provides small path differences of the milling machine. Small path differences offer a smooth inner surface area and thus, increase the accuracy of prosthesis [11]. These potentials for design control, such as multiple milling axis manufacturing coupled with the application of advanced materials, provided significant advances in RPDs with enhanced accuracy in comparison to conventional approaches [14].

The chewing simulator was used to simulate function in the oral cavity and the applied forces acted on the partial denture [8, 9]. Surfaces alterations of the primary copings were detected by 3D comparison using the Geomagic control X software [15]. Wear of the primary copings in group 2 (Bio-HPP) was significantly higher than those of group 1. This could be attributed to several factors, including the heterogenous composition of Bio-HPP (the ceramic filler phase and the matrix phase) and the bond between the two phases, which makes it more conductive to wear [16]. Higher surface roughness of Bio-HPP is another factor that increases the surface wear during masticatory function. On the other hand, in group 1, the copings were composed

CONCLUSIONS

Within the limitations of this study, it could be concluded that: 1) accurate Bio-HPP and Co-Cr telescopic retained RPDs could be fabricated using the milling technique; 2) a remarkable amount of wear of the primary copings occurs when Bio-HPP is used for the fabrication of telescopic retained RPDs.

CONFLICT OF INTEREST

The authors declare no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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