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Preliminary Study on the Assessment of the Marginal Fit of Three-Dimensional Methacrylate Oligomer Phosphine Oxide Provisional Fixed Dental Prostheses Made by Digital Light Processing

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Abstract: This article aimed to assess the marginal fit of methacrylate-oligomer-phosphine-oxide curable-resin provisional-fixed dental prostheses made by digital-light-processing (DLP) three-dimensional (3D) printing. A stainless-steel master model with two abutments was scanned, and five three-unit provisional bridges were designed and printed in VITA shade A3.5 curable resin in 50 µm-thick layers. The marginal fit of each abutment was measured at six points using a profile projector. A descriptive data analysis of the fit measurements was performed by descriptive and explorative processes with the SPSS software. The curable-resin provisional restorations made by DLP 3D printing reached values of 46.37 µm (SD: 29.58 µm), which were considered clinically acceptable, with values similar to polyethylene-methacrylate and polyether-ether-ketone provisional restorations.

Keywords: dental prosthesis; provisional restoration; CAD/CAM; marginal fit; 3D printing

1. Introduction

Background

Partially edentulous rehabilitation is currently a standard treatment option in daily clinical practice [1,2]. Although implant-supported restorations have grown in importance over the last 10 years due to patient and clinician demands, conventional tooth-borne restorations are still indicated [3]. These restorations have proven to be a reliable option over the years; however, their preparation in many cases requires several appointments to ensure their correct seating and performance [2–4].

Following dental preparation, provisional restorations ensure pulpal protection, periodontal health, interocclusal and intra-arch tooth relationships, occlusal function, and aesthetics during the confection of definitive fixed partial dentures (FPDs), aspects related to marginal fit [5].

One of the most important factors in relation to clinical behavior and survival in tooth-borne dental prostheses is marginal fit [6]. Marginal fit is related to the materials and manufacturing techniques of choice. Manufactured imperfections may result from a poor manufacturing process and the materials used for their confection. Lack of fit can create gaps leading to technical or biological complications [6,7].

With the establishment of computer-aided design/computer-aided manufacturing (CAD/CAM) technology in dental medicine, there has been an increase in the development of new materials, designs, and techniques in the manufacturing of dental prosthesis [8]. One of these recent methods has been the use of three-dimensional (3D) additive printers in dental laboratories and dental clinics [9]. Three-dimensional additive technology allows the obtaining of prostheses, radiological and/or surgical splints, digital models, etc. made with different materials at a competitive cost and without the loss of materials linked to the milling process [9,10]. In the case of resin polymers, these systems allow the 3D impression of provisional restorations as part of a chairside concept, within the same clinic and appointment [10]. Digital light processing (DLP) additive technology can use several monomers and resin systems, such as a UV-curable hybrid resin, cationic-initiated epoxy monomers, or photocuring multi-phase polymers [11].

One of these systems is digital light processing (DLP), a 3D printing system based on the use of a digital light projection source (high-power LED). The layers are illuminated using a light mask created by a digital micromirror device. Each mirror corresponds to a pixel of the projected image, polymerizing the entire resin layer at once [11,12].

Additive technology is relatively new in dental medicine, and there are few studies evaluating the preclinical behavior of systems and materials. Due to the increasing demand for CAD/CAM systems and the great offer of 3D printers by the industry, its evaluation is necessary.

This preliminary study aimed to assess the marginal fit of a curable resin as a material for provisional three-unit FPDs made from three-dimensional printing and to compare the fit values against those described in the literature, in order to determine whether these provisional restorations could be clinically acceptable.

2. Results

Five provisional three-unit FDPs were obtained for vertical-marginal-discrepancy assessment measured at six points, three in buccal and three in palatal/lingual areas.

A total of 60 measurements (30 per abutment) at 4× magnification were performed. The results of the analysis of marginal fit reported a maximal discrepancy of 152.52 µm, minimum of 7.5 µm, and mean of 46.37 µm. A descriptive analysis of the quantitative variables (DESCRIPTIVE and EXPLORE processes) was performed, as shown in Table 1.

Table 1. Frequency table of the marginal fit of provisional FDPs (µm).

Measurements	N	Mean	Median	SD	Minimum	Maximum
Distal–buccal	5	76.36	76.35	76.35	60.05	152.52
Distal–buccal	5	41.05	22.5	41.51	7.5	105.03
Distal–buccal	5	31.96	31.96	26.90	8.75	75.17
Distal–lingual	5	62.49	62.49	26.06	37.83	100.12
Distal–lingual	5	61.13	61.13	26.84	37.58	105.03
Distal–lingual	5	29.5	29.5	15.61	13.46	52.74
Mesial–Buccal	5	30.03	30.03	12.74	13.75	40.08
Mesial–Buccal	5	22.65	22.65	7.47	15.21	35.09
Mesial–Buccal	5	33.86	33.86	1.73	32.52	36.59
Mesial–lingual	5	43.47	43.47	18.29	18.2	60.21
Mesial–lingual	5	76.89	76.89	21.66	40.49	95.03
Mesial–lingual	5	47.05	52.74	21.21	16.68	70.04
Total	60	46.37	38.65	29.58	7.5	152.52

Data expressed in µm.

3. Discussion

This study evaluated the marginal fit of curable resin as a three-unit provisional FPD material made from 3D printing. The proposed null hypothesis was rejected since the marginal adjustment of these restorations was within the accepted margins in the literature.

To date, the literature has provided a range of marginal fit values for fixed prostheses between 10 and 110 µm, although what is considered clinically acceptable is 120 µm [13,14]. Despite the fact that several methods have been reported to assess the gap between a restoration and its margin, the present study was based on the use of a profile projector following the assessments performed by Holmes et al. and the reported marginal gap was measured for the marginal fit [15].

A study published by Park et al. in 2019 evaluated the internal and the marginal fit of resin interim FDPs that were 3D printed using DLP technology with two different thickness layers and five build orientations. In this study, in addition to an internal-fit evaluation, the authors assessed the marginal discrepancy according to the method described by Holmes et al. [14]. The results for the marginal discrepancy of the restorations confectioned at an orientation of 60° and made of 100 µm-thick layers provided the best mean discrepancy values (50.0 ± 14.7 µm). Nevertheless, it must be noted that most of the 3D printed groups showed worse results than the milled ones [16].

DLP technology is based on an ultraviolet (UV) light source that cures a photosensitive liquid polymer in layers following a CAD design [11]. A methodological limitation can be noted, considering that a direct comparison could not be obtained, as the thickness of the cement was different from that in the present study (0.24 mm) and the inner side of the prosthesis was not observed. However, considering the obtained fit ranges, the mean results can be considered clinically acceptable and are lower than those reported in the aforementioned study. A previous study of 3D provisional crowns made using the same methodology reported a mean marginal fit value of 122.89 µm in the marginal-fit discrepancy of the restorations made with polylactic acid (PLA) using a fused-deposition-modeling (FDM) 3D system. FDM uses a preformed polymer as a building material that uses the input of processing energy in the pre-deposition stage to obtain a polymer melt that can be applied using a fine print head or nozzle [11,17]. Although this study analyzed singe interim restorations by extrapolating the results, the FDPs of the present study obtained minor discrepancy results [16].

Comparing the misfit results of CAD/CAM 3D printing techniques with those of conventional manufacturing methods, Givens et al. assessed the marginal fit of provisional restorations made by direct manufacturing methods using polyethylene methacrylate (PEMA), self-polymerizing bisacrylic, and dual-curing bisacrylic, showing misfit results similar to those obtained in the present study, between 177 and 319 µm [5].

Alharbi et al. studied the marginal and internal fit of printed and milled restorations (additive and subtractive methods), in preparations with different finishing lines with a micro-CT; the mean discrepancy in 3D printing went from 28 to 41 µm, while in the milling group, it was between 32 and 56 µm [18].

Regarding CAD/CAM techniques, we found bigger discrepancies; Abdullah et al. also assessed the fit of direct-technique and CAD/CAM provisional materials. The average marginal discrepancy of the PEMA restorations was 193.07 µm, while the polyether ether ketone (PEEK) restorations manufactured by CAD/CAM ranged between 46.75 and 60.61 µm [19].

Since this study was designed as a descriptive preliminary study, its main limitation was the small sample size and the lack of a control group and direct comparisons against previously published studies. Nevertheless, this article intended to be the starting point for future clinical studies in order to assess the feasibility of this 3D printing system using the aforementioned material. Taking into account the sample size limitation and considering that the minimum values of 7.5 µm and maximum of 152.52 µm are very broad, alongside the fact that standard deviation (29.58) is more than 50% of the mean (46.37), these results should be carefully interpreted, as this SD shows that the data are less reliable.

Additive technology is relatively new for temporary restorations; material selection can influence marginal fit. Although there is no material for provisional restorations that can be considered as the "gold standard", the literature on methacrylate oligomer phosphine oxide is scarce. Although the results are within clinically acceptable limits, the ability of this material to be printed with 50 µm-thick layers can influence the marginal fit, since in milled or injected materials, the thickness can be influenced by the prosthetic design space [5].

4. Materials and Methods

A comparative preliminary in vitro study of the vertical marginal fit of provisional three-unit FPDs made of 3D-printed methacrylate oligomer phosphine oxide curable resin was carried out at the Department of Conservative Dentistry and Orofacial Prosthetics, Complutense University of Madrid.

A master model was designed from two abutment teeth for a tooth-supported three-unit resin dental prosthesis. A stainless-steel machined master model with two standardized abutments as a master die was confectioned to simulate a first premolar and first molar prepared for three-unit FPDs. The technical specifications of the abutments were a 5 mm height, an occlusal diameter of 5 mm, a 1 mm-wide chamfer finishing line, a 6° convergence angle of the axial walls, and rounded angles. The cast was scanned using the EVO Ceratomic Protechno scanner (PROTECHNO, Famadent S.L.U. Vilamalla, Girona, Spain); subsequently, five posterior three-unit FDPs were designed using the EXOCAD software (Exocad GmbH, Darmstadt, Germany) (Figure 1a,b).

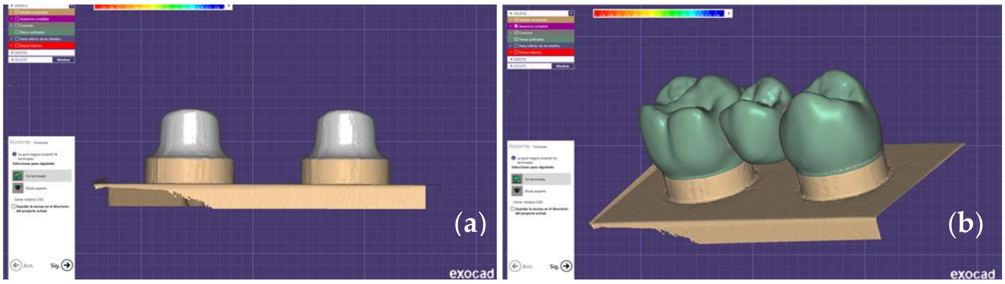

Figure 1. (**a**) Master die STL file. (**b**) Provisional fixed dental prostheses; STL file design.

The FPD abutments were designed with an insertion angle of 6°, using a cementation line of 0 mm at the cervical area and 0.08 mm at the rest of the prosthetic surface. The bridge connectors were 9 mm^2 in surface area. Once the restorations were designed, the STL file was obtained and transferred to the Rapidshape-SHERAprint 30 DLP system printer (SHERA Werkstoff-Technologie GmbH & Co. KG, Lemförde, Germany). As a preliminary study to test the feasibility of a possible clinical study, five three-unit tooth-supported provisional restorations were printed in curable resin (methacrylate oligomer phosphine oxide, SHERA Werkstoff-Technologie GmbH & Co. KG, Germany) with 50 µm-thick layers in the A3.5 VITA shade (VITA Zahnfabrik H, Bad Säckingen, Germany). The manufacturing process was carried out at the faculty dental laboratory in a room with controlled light that does not affect the 3D printer and with a constant controlled temperature between 25 and 30 °C (Table 2).

Table 2. Technical specifications of the curable resin (methacrylate oligomer phosphine oxide) provided by the manufacturer.

Characteristics	Value
Viscosity at 23 °C	0.9–1.4 Pa s
Bending strength	=85 MPa
Bending e-module	=2100 MPa
Shore hardness D	80–90
Absorption of water	<30 µg/mm^2
Water solubility	<5 µg/mm^2

The restorations were manufactured using the SHERAflash-light plus curing unit (SHERA Werkstoff-Technologie GmbH & Co. KG, Germany). After 3D printing, all the FPDs were examined both on the inside and on the finish line prior to measurement in order to identify printing imperfections and cleaned with 95% ethanol for 2 min, and subsequently, the bridges were trimmed at their base and polished. The vertical marginal fit of the restorations was assessed by measuring the external and marginal vertical gap. The measures were the vertical distance between the crown margin and the prepared cavosurface angle following previous studies at six points for each abutment, making three marks at the buccal and at the lingual surface of the die, using a profile projector with a 4× magnification (Toupview V.x643.7.6701, Photonics Co., Ltd., Suzhou, China) [20]. A total of sixty measurements were recorded for the FDPs (Figure 2a,b).

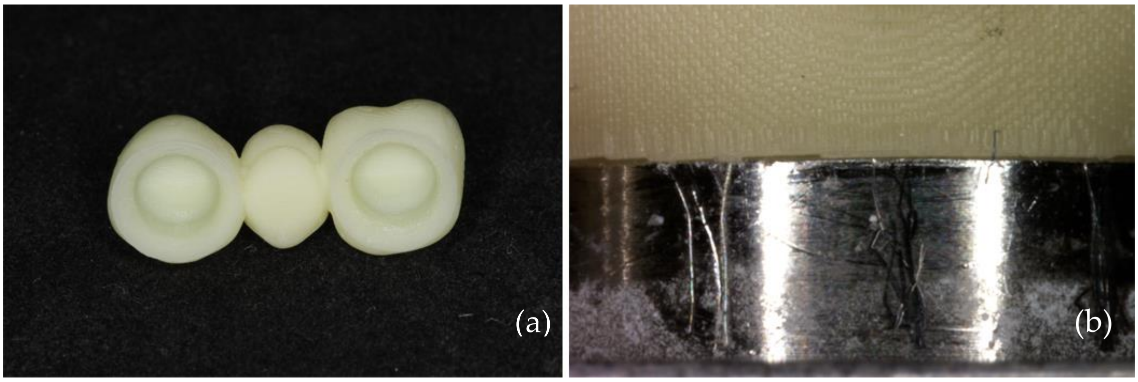

Figure 2. (**a**) Provisional fixed dental prostheses. (**b**) Vertical marginal fit profile projector (4x).

The statistical data analysis was performed by the descriptive analysis of the quantitative variables (DESCRIPTIVE and EXPLORE processes) using the SPSS software (SPSS 23.0, Chicago, IL, USA) and Microsoft Excel for Mac 2011 (Excel Version 14.4.6, Microsoft, WA, USA).

5. Conclusions

Within the limitations of this preliminary in vitro study, methacrylate oligomer phosphine oxide curable resin provisional restorations made by DLP 3D seems to provide marginal fit values within the clinically acceptable limits. Further well-designed comparative studies are needed to obtain more reliable conclusions.

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