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MARGINAL INTEGRITY OF TEMPORARY BRIDGES CONSTRUCTED BY CAD/CAM, THREE DIMENSIONAL PRINTER AND CONVENTIONAL METHOD

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KEYWORDS

CAD/CAM, 3D printing, Marginal gap, Milling machine, Temporary bridges.

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ABSTRACT

Introduction: Temporary restorations are very important in fixed prosthodontic rehabilitation, especially when long-term treatment is needed. **Aim:** This study aimed to compare the vertical marginal gap of temporary bridges constructed by CAD/CAM, 3D printing and conventional method. **Material and methods:** The mandibular right second premolar and second molar of a dentoform acrylic resin cast was prepared to receive full coverage fixed partial denture. The model was scanned with Ceramill Map 400 optical scanner. A STL file was transferred to Ceramill motion 2 milling machine to mill twenty-one working models. One model was scanned by In Eos X5 scanner and twenty one standardized full contour temporary bridges were constructed by three different techniques. The bridges (n=21) were grouped into three groups (n=7); group A (CAD/CAM), group B (3D printing) and group C (Conventional). The retainers marginal gaps were measured using a digital stereomicroscope. Bridges were cemented using Temp Bond NE cement then their vertical marginal gaps were remeasured. Data were analyzed by one way ANOVA and Post Hoc Tests at p≤0.05. **Results:** The highest mean value was reported with the conventional samples (120.42±6.95 μm) and the lowest value was reported with the 3D printed samples (68.98±9.93 μm) before cementation, while after cementation the highest mean value was reported with the conventional samples (216.6±14.15 μm) and no statistically significant difference between the 3D printed samples and CAD/CAM samples. Data were analyzed by one way ANOVA and Post Hoc Tests at p ≤ 0.05. **Conclusion:** The method of fabrication of temporary bridges had an effect on the vertical marginal gap.

INTRODUCTION

The prosthetic treatment approach cannot succeed without temporary restorations. A precisely suited and a well temporary restoration serves various purposes, including pulp protection, abutment positional stability, and the restoration of function and aesthetics. Additionally, they have a crucial clinical function in cases of oral rehabilitation since they offer a forward-looking simulation of the final restoration. They offer a useful tool for reorganizing the occlusal scheme in situations that involve the loss of vertical dimension and challenging oral rehabilitation cases [1, 2].

Temporary restorations are crucial when performing a complete mouth reconstruction since many teeth must be prepared. Temporary restorations in these situations usually stay in the oral cavity for a long period, which is crucial to evaluate the patient's comfort and make any necessary adjustments [3].

To enable plaque removal and keep a healthy periodontium, marginal seal, a smooth surface finish, and correct contours are crucial. Invading marginal tissues and excessively long margins can cause the periodontium to inflame, hemorrhage making it more difficult to complete subsequent therapy processes like impression and cementation[4].

Different materials have been used for fabrication of temporary crowns such as acrylic resin. Several types of acrylic resin materials are available for temporary restorative treatment like polymethyl methacrylate resins, poly-R' methacrylates as polyethyl methacrylate, polyvinyl ethyl methacrylate, and poly butyl methacrylate [5].

There are several techniques of making temporary restorations that have improved over time and have a positive psychological influence on the patients.

Using the conventional direct technique, all intermediate laboratory steps are eliminated and the patient's prepared teeth and gingival tissues directly provide the tissue surface. When assistant training and the office laboratory space are insufficient for effectively creating an indirect restoration, this is convenient. The direct method, however, has a number of drawbacks, including a higher risk of tissue injury from the polymerizing resin and a marginal fit that is inherently poorer. Therefore, while indirect techniques are possible, it is not advised to regularly utilize the direct technique [6, 7].

In the conventional indirect approach, the temporary restoration is made outside the mouth. It has a number of benefits, including not exposing prepared teeth to the heat generated by the polymerizing resin, producing restorations with superior marginal fit, and saving the patient and dentist time compared to direct technique. Free monomer contact with the prepared teeth or gingiva could lead to tissue damage, allergic reaction, or sensitization. It also has drawbacks because making the temporary restoration requires producing an intermediate impression and a stone cast, which requires more time and materials [8, 9].

In the nearly 30 years that CAD/CAM systems have been in use in dentistry, numerous new equipment have been developed. These systems are always changing, resulting in restorations that are considerably more adapted [10].

The temporary restorations that are fabricated by CAD/CAM could provide better outcomes regarding marginal fit, increased mechanical strength, prevention of porosities within the restorations, and fabrication in a shorter time, So CAD/CAM systems have now achieved more acceptance in comparison to conventional techniques [11].

The process of building three-dimensional objects using numerous thin layers of a particular material is known as three-dimensional printing. The descriptive data required for printing should be obtained from a 3D STL file obtained using a 3D modeling software or by scanning an object that already exists. To enable the manufacturing of specific models for small restorations and removable prosthodontics, just a 3D scan of the mouth is required [12, 13].

The term "light curing technology" refers to a particular kind of 3D printing. Stereolithography, digital light processing, and photo jet are the three main types [14].

The marginal integrity of the provisional restorations is of major importance. Regardless of the technique used in fabrication, one of the key requirements of a temporary restoration is to provide a good marginal seal to prevent pulpal sensitivity, provisional cement washout, bacterial ingress, and secondary caries or pulpal necrosis, which may cause complications during the subsequent treatment steps of fixed prostheses [15].

The marginal gap has been measured using numerous methods, such as the direct-view technique, Scanning Electron Microscopy (SEM), Cross-sectioning method, Replica Technique, 3-D analysis of marginal fit, and microcomputed tomography (Micro CT) [16].

Due to the limited availability of studies investigating the long-term temporary bridges, the current study was conducted to assess marginal fit of temporary bridges constructed by CAD/CAM and the 3D printing and conventional methods.

It is hypothesized that there will be no difference regarding marginal integrity between CAD/CAM, 3D printed, and conventional temporary bridges.

MATERIALS AND METHODS

This study was waved from ethical revision from the research ethical committee of Faculty of Dentistry-Suez Canal University (number 179 /2019).

Model cast preparation:

A dentoform acrylic resin cast with a missing mandibular right first molar and blocking the socket space of the first molar with wax was used in this study. Using a dental milling device, the mandibular right second premolar and the mandibular right second molar were prepared prepared to receive full coverage fixed partial denture. The teeth were prepared using a tapered diamond stone with a flat end and 1 mm diameter head, occlusal reduction was carried out using a cylindrical diamond stone with a diameter of 2 mm to make 2mm occlusal reduction. The abutments were prepared with 1mm shoulder finish line. The prepared model was scanned with extra oral scanner (ceramill Map 400, Amann Girrbach, Austria). Three-dimensional images were displayed on the computer screen and saved as Standard Triangulation Language (STL) file. This STL file was transferred to milling machine (Ceramill Motion 2, Amann Girrbach, Austria) to mill twenty-one working models.

Grouping of the samples:

The samples (n=21) were grouped into three groups (n=7); group A: fabrication of temporary bridges by CAD/CAM system, group B: fabrication of temporary bridges by the 3D printer (phrozen, Taiwan), and group C: fabrication of temporary bridges by conventional method.

Construction of the CAD/CAM bridges (Group A):

Models were scanned with an extra oral scanner (inEos X5 scanner, Dentsply Sirona, USA). STL files were transferred to a computer software (Cerec software program in Lab 19.0 Dentsply Sirona, USA) to design the restoration on the virtual model. A five axis milling machine (Cerec MCX5, Dentsply Sirona, USA) was used to mill PMMA discs (Telio CAD, Ivoclar vivadent, Germany) (Figure 1).

Fig. (1) Finished restoration design.

Construction of the 3D printed bridges (Group B):

The same STL file that was used to fabricate the CAD/CAM bridges was transferred to the 3D printer (phrozen, Taiwan) to construct the 3D printed bridges from printing resin (Next Dent temp C&B, Vertex-Dental, Netherlands). Before the printing process, the bridges to be printed were positioned horizontally with the buccal surface of the bridge toward the printer platform. The printed bridges were put in a post-curing box (Bredent, Germany) with wavelengths 370 to 500 nm for about 30 minutes according to the manufacturer's instructions.

Construction of the conventional bridges (Group C):

One of the CAD/CAM bridges was placed in the correct position on the model. According to the manufacturer's instructions, a vinyl polysiloxane impression material base and catalyst (Kerr, USA) were mixed, dispensed in the special plastic tray, and positioned over the CAD/CAM bridge to function as a mold, Small holes were made in the mold to allow the escape of the excess temporary bridge material. Next thin layer of separating agent (Lascod, Italy) was applied to the model to allow easy removal of the bridge from the model. Acrylic resin powder and liquid (Next Dent, Vertex-Dental, Netherlands) were mixed according to the manufacturer's instructions and loaded into the mold when the resin was in its doughy stage from the bottom to top to prevent the incorporation of voids and to ensure adequate flow of temporary material on the model, then the two parts of the mold were secured firmly with rubber bands. All temporary bridges were finished and polished by one skilled operator according to manufacturer's instructions.

Vertical marginal gap before cementation:

The vertical marginal gap of each retainer was measured on its corresponding die before cementation. With the exclusion of the surfaces facing the pontic side, the temporary bridges underwent stereomicroscopy analysis (Olympus SZ 61, Japan) at 6 surfaces (3 in the molar abutment and 3 in the premolar abutment). All temporary bridges were photographed with a professional digital camera (Tucsen, China.) at a magnification of 40 X. To ensure the seating of the bridges over their corresponding die, a specially designed holding device with a spring rod was used to fix the bridges. A software module (IS Capture) was used to analyze the images and calculate the vertical marginal gap in micrometers (μm) (Figure 2).

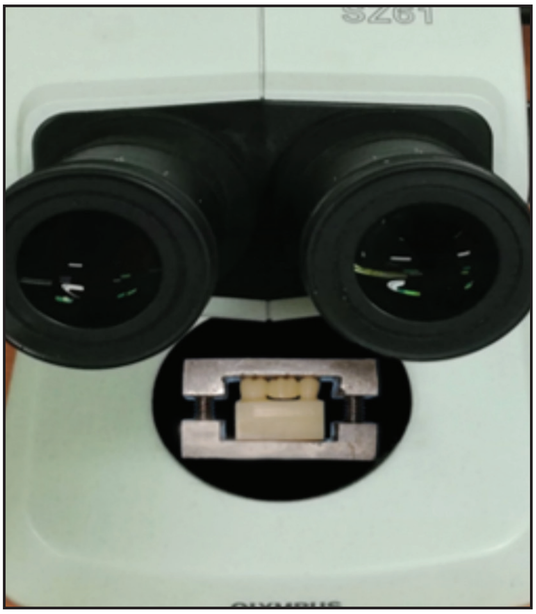

Fig. (2) The whole assembly of the model and the bridge was placed on the stage of the stereomicroscope.

Cementation of the bridges:

All the bridges were cemented on their corresponding models using Temp Bond NE (Kerr, Italy) following the manufacturer's instructions. A special device was used to standardize the load during the cementation procedure, which allowed static placement of 3Kg load on the occlusal surface of the bridges during the cementation procedures. Removal of any excess cement traces after initial setting using a sharp scaler (Nordent, USA).

Vertical marginal gap after cementation:

The vertical marginal gap after cementation was measured using the same technique used before cementation. An indentation made on the die was used as a reference point to standardize the measured points before and after bonding.

Statistical analysis

Statistical analysis using one-way ANOVA and the post-hoc test with a statistical significance of P-value ≤0.05.

RESULTS

Vertical marginal gap results : (Table 1)

Before cementation, there was a statistically significant difference between the three groups. Group C had a higher mean vertical marginal gap (120.42±6.95µm) than that of groups A (68.98±9.93 µm) and B (52.28±6.32 µm) (P<0.001).

After cementation, there was a statistically significant difference between groups C, and B (P<0.001), also between groups C and A (P<0.001). Group C showed a higher mean vertical marginal gap (216.6±14.15µm), but there was no statistically significant difference between groups A (117.75±5.57 µm), and B (120.25±7.34 µm).

Table (1) *Shows the mean and standard deviation (SD) values of vertical marginal gaps results for the tested groups*

	Group A CAD/CAM	Group B 3 D printing	Group C Conventional	Test of Significance
Marginal gap before cementation	68.98±9.93^{ab}	52.28±6.32^{ac}	120.42±6.95^{bc}	F= 607.88 P<0.001*
Marginal gap after cementation	117.75±5.57^{a}	120.25±7.34^{b}	216.6±14.15^{ab}	F= 1009.98 P<0.001*
Test of significance between before and after cementation	t =22.87 p<0.001*	t =45.83 p<0.001*	t =35.68 p<0.001*	

*F: One way ANOVA test t: Paired t test *statistically significant (if p ≤ 0.05).*

The similar superscripted letters in the same row denote significant differences between groups by the Post-hoc Tukey test.

DISCUSSION

For situations that require comprehensive occlusal reconstruction, where the restorations may be subjected to prolonged functional loading, long-term temporary restorations are required. The temporary materials must therefore have the best possible mechanical qualities, marginal integrity, and color stability. They may also act as a guidance for soft tissue healing (17). This in vitro study compared the vertical marginal gap of temporary bridges made using CAD/CAM, 3D printing, and conventional method.

Model fabrication by pouring an elastomeric mold with epoxy resin usually can lead to errors in the fabricated model as it depends on the technician's skills, the accuracy of the mold, and the mix of the epoxy resin, so it is not perfectly standard. In this study, The models were made using a CAD/CAM system, which produced 21 identical PMMA models (18). For samples of this study to be identical, one of the CAD/CAM models was scanned by the inEos X5 scanner, and all CAD/CAM temporary bridges were designed and milled by using the same software with Cerec in lab MCX5 to get seven identical temporary bridges. Through the use of the CAD software, the cement space of the bridges was standardized at 80 µm (19).

The same STL file that was used to create the CAD/CAM group was used to create the 3D printed temporary bridges in order to standardize their fabrication, giving them the same shape and size as the milled CAD/CAM bridges (20).

In order to standardize the conventional temporary bridges, they were manufactured from the mold on the CAD/CAM temporary bridge by using the additional silicone impression material which is used clinically for the fabrication of provisional restorations in order to get the conventional temporary bridges with the same dimensions of the CAD/CAM temporary bridges (17).

For evaluation of the marginal fit of the bridges, stereomicroscope was used in this study which had several advantages in comparison to other methods as it was accurate, not being invasive, and reduced the chance of errors (21, 22).

In this study, the vertical marginal gap of each one of the temporary bridges was analyzed at 6 surfaces (3 in the premolar abutment and 3 in the molar abutment) without measuring the distal surface of the premolar and mesial surface of the molar abutments because of the pontic was connected to the retainers at these surfaces (23).

In this study, eight measurements were taken on each surface of the retainers. This multiple and a predetermined number of readings allowed for obtaining comprehensive mean results (24). The marginal gap was measured before and after cementation. Measuring the marginal gap before cementation to avoid the influence of the temporary cement film thickness so that the inherent property of each material and accuracy of the fabrication method could be tested (25, 26).

Measuring the vertical marginal gap after cementation is of great importance to evaluate the effect of cement film thickness on the marginal fit of the bridges. The marginal gap was increased after cementation, where the temporary cement film thickness could be responsible for that (27, 28).

To ensure adequate maintenance of healthy periodontal and pulpal tissues, the size of the marginal gap for a temporary restoration should fall within the range of the final fixed restoration. As reported in the literatures, the marginal gap of a crown of less than 120 µm is considered clinically acceptable [22, 29]. In the present study, the hypothesis stating that no difference between CAD/CAM, 3D printed, and conventional temporary bridges regarding marginal integrity was rejected.

The 3D printed temporary bridges showed the lowest vertical marginal gap in comparison to the CAD/CAM and conventional temporary bridges before cementation. The conventional group showed the highest value of the vertical marginal gap before cementation. This could be attributed to the fact that they were manufactured from chemical cure PMMA material, which has volumetric shrinkage during the polymerization. It was bulk polymerized in the air resulting in higher discrepancies [29, 30]. Additionally, polymerization shrinkage happens in the center of the material, causing the material to contract away from the margins of the restoration [31]. The 3D printing group showed the lowest value of the vertical marginal gap before cementation. This could be attributed to the 3D Printed bridges manufactured by addition. The polymerization of the resin was carried out layer by layer, the layer thickness was minimal (50µm) and the shrinkage in the cured layer was repaired by the successive layers thus minimizing the shrinkage as reported by Chaturvedi *et al* [32] The CAD/CAM group displayed a greater vertical marginal gap than the printed group, although using the pre-polymerized PMMA blocks. This could be accounted for by the fact that the CAD/CAM system's milling of the CAD/CAM blocks may cause minor flaws, cracks, and chipping as mentioned by Atlas *et al*[33] The CAM can only mill to the smallest drill size employed, even if the CAD programme can define the finish line's precise location down to the micron level. As a result, imperfections smaller than the drill dimensions cannot be precisely replicated by the CAM as reported by Johnson *et al* [34]. The results of this study came in agreement with Chaturvedi *et al* [32].

Marginal gap after cementation, the vertical marginal gap between the three groups increased. The highest increase of the vertical marginal gap was noticed with the 3D printed group which was well above double that before cementation. While the increase of the vertical marginal gap with the CAD/CAM and conventional groups was much less than that produced by the 3D printed group. It's well reported in the literature by Reeponmaha *et al* [35] that the monomethacrylates could behave like a ductile material. While the 3D printed material had bisphenol acrylate-based acrylic in its structure which could make the material more rigid with a low elastic limit. Park *et al* [36] Based on these scientific data the difference in the vertical marginal gap can be attributed to the ductility of the conventional and CAD/CAM PMMA material, which could be responsible for allowing more cement to escape at the margins. Meanwhile, it could be said that the 3D printed material was rigid enough and subsequently might not allow the cement to easily escape at the margins. Furthermore, it is well reported in the literature by Shin et al. (2020) [37] that under the scanning electron microscope, the internal surface of the 3D printed restorations was smooth. While the CAD/CAM restorations showed a rough internal surface due to the traces of the milling burs. These scientific data can add to the explanation of the difference in the vertical marginal gap after cementation. In which the CAD/CAM restorations, the traces created by the milling burs in the fitting surface of the restoration might act as minor concavities and might be responsible for accommodating more cement than that with the smooth internal surface of the 3D printed group. This could justify the higher marginal gap produced with the 3D printed group compared to that produced with CAD/CAM group.

CONCLUSION

Within the limitations and conditions of this in vitro study, it was concluded that prior to cementation, the 3D printed group displayed the best marginal integrity. While there was no statistically significant difference between the CAD/CAM group and the 3D printed group after cementation.

Suggestions for further studies:

It would be beneficial to support these findings with clinical studies. More investigations are still required for different 3D printing materials, techniques and orientation angles.

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