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Original Article

EFFICACY OF BUILD DIRECTION OF 3D PRINTING FULL COVERAGE PROVISIONAL RESTORATION ON THE MARGINAL INTEGRITY (AN IN-VITRO STUDY)

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Abstract

The aim of this study was to evaluate efficacy of build direction of 3D printing full coverage provisional restoration on the marginal integrity. The prepared resin tooth was scanned and single crown was designed using computer-aided design (CAD) software. Provisional crowns were printed using a SLA-based 3D printer at 2 directions vertical (120°) and horizontal (180°) with 16 crowns in each direction. In total, Thirty two crowns were printed. To measure the marginal gap using USB Digital microscope, then morphometric measurements were done for each shot [3 equidistant landmarks along the cervical circumference for each surface of the specimen (Mesial, buccal, distal, and lingual), and a silicone replica was fabricated for measuring internal fit, the replicas were carefully sectioned into four equal segments.From the four sections obtained from each replica, two opposite sections were used to measure internal fit, with five regions measured on each section (finish line, axial wall and occlusal), yielding 10 internal measurements for each coping and the thickness of the silicone impression material was measured using a digital microscope. It was found that horizontal group recorded statistically significant higher marginal gap mean value (44.76 µm) than vertical group (34.37 µm) as indicated by t-test ($P=0.0002<0.05$), considering internal fit regardless to measurement site, totally there was non-significant difference between both groups vertical group (96.042 µm) and horizontal group (91.793 µm) as indicated by two-way ANOVA test ($p=0.6179 > 0.05$) where (vertical group > horizontal group)**.** With the limitation of this study the following conclusions could be drawn: Marginal fit of provisional restorations fabricated using a SLA based 3D printer revealed clinically accepted outcomes within the two build angles. Regarding the marginal gap, vertical orientation (120°) considered the optimal 3D printer building angle. The building angle of fabrication doesn't affect internal fit of the provisional restorations

Keywords:3D printer, fixed prosthesis, marginal gap, exocad, CAD/CAM.

I. INTRODUCTION:

The provisional restoration is a critical phase in fixed prosthetic treatment; it is used from the time of tooth preparation to the time of final cementation. A properly fabricated provisional restoration is important in achieving a successful final restoration.

A provisional crown is a temporary (short-term) crown used in dentistry. Like other interim restorations, it serves until a final (definitive) restoration can be inserted.The provi-sional restoration has a role in pulpal protection, stabilization of occlusal relationships and occlusal function. It's importance increases greatly for oral rehabilitation cases that needs long term provisionalization or when additional therapy is required before completion of the rehabilitation to protect the tooth, prevent teeth shifting, provide cosmetics, shape the gum tissue properly, and prevent sensitivity.

Many techniques are used to make temporary restorations. It began manually through direct, indirect and indirect-direct technique. However, the advances in materials and tech-nology contributed to the introduction of CAD/CAM technique (subtractive manufacturing) and 3D printing technique (additive manufacturing). The direct technique of fabricating temporary crowns using polymethyl methacrylate (PMMA) has been frequently used for convenience and low costs of production, but it has the drawbacks of polymerization shrinkage, marginal discrepancy, and heat production. Today, indirect fabrication is possi-ble using computer-aided design/ computer-aided manufacturing (CAD/CAM), which fa-cilitates remaking provisional crowns that were lost or fractured during long term use due to orthodontic treatment or altered vertical dimension.

The newly introduced technique 3D printing is spreading fast and various resins are used. It's an additive manufacturing (layer upon layer). It has the ability to manufacture precise prosthesis with minimal materials waste. It considers cheaper and faster than mill-ing technique. It is passive with no force application and can produce finer details (under-cuts & better anatomy). The 3D printing methods include Stereolithography (SLA), Digital light processing (DLP), Selective Laser Sintering (SLS) and Fused Deposition Modeling (FDM).

II. MATERIALS AND METHODS

This study was carried out to assess the marginal gap and internal fit of provisional crowns which were fabricated by horizontal 3D printing technique (intervention) compared to provisional crowns which were fabricated by vertical 3D printing technique (control).

According to the sample size calculation, a total of thirty-two crowns were constructed which were divided into two equal groups, sixteen samples for each group according to the technique of construction.

- Group (I): Sixteen crowns (n=16) fabricated by vertical 3D printing technique (control).
- Group (II): Sixteen crowns (n=16) fabricated by horizontal 3D printing technique (Intervention).

Dentoform model of maxillary 1st molar was prepared Figure (1) according to the following criteria: 2 mm occlusal reduction, 1.5 mm overall axial reductions. Figure (2). The prepared model was scanned using Medit T-300 scanner. Figure (3)

Duplication of master die into thirty two epoxy resin dies through using silicone duplicating material Figure (4) and then divided into two equal group (n=16). Figure (5)

Provisional crowns were designed using Exocad software. Figure (6). STL file was produced and sent to Formlabs printer. Thirty two crowns were placed on a platform in the 3D printer software and rotated at 2 directions (120°, 180°) as shown in Figure (7-8) using preform software then provisional crowns were printed using the formlabs form2 printer using Next dent C&B PMMA resin material . Each specimen was photographed using USB Digital microscope. A digital image analysis system was used to measure and qualitatively evaluate the gap width. Figure (9-10). Measurement at each point was repeated five times. Internal discrepancy was measured by a replica technique. Figure (11) Each tooth was filled with light-body silicone and inserted into under a constant load (750 g) for 10 min, by means of a modified parallelometer.

III. RESULTS

Vertical Marginal Gap

It was found that horizontal group recorded statistically significant higher marginal gap mean value (44.76 µm) than vertical group (34.37 µm) as indicated by student t-test ($P=0.0002<0.05$) Figure (12)

Effect of measurement surface

Internal discrepancy:

Regardless to measurement site, totally there was non-significant difference between both groups as indicated by two-way ANOVA test ($p=0.6179 > 0.05$) where (vertical group > horizontal group) Figure (13)

Figure (1): Prepared model

Figure (2): Silicone putty index

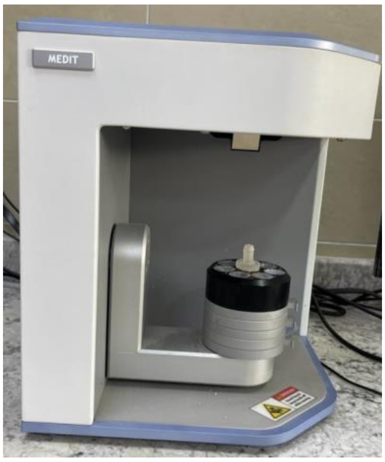


Figure (3): Scanning of the master die in Medit T-300 scanner

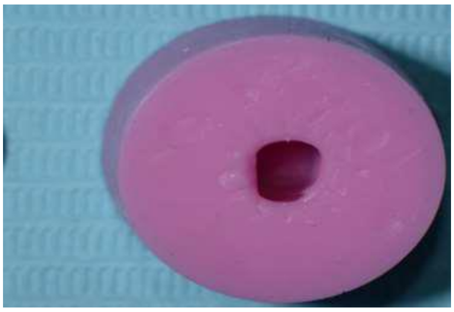
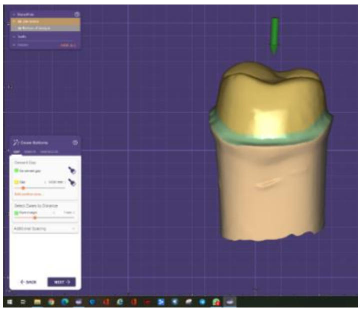


Figure (4): Silicon mold after setting

Figure (5): thirty two Epoxy resin divided into two equal group



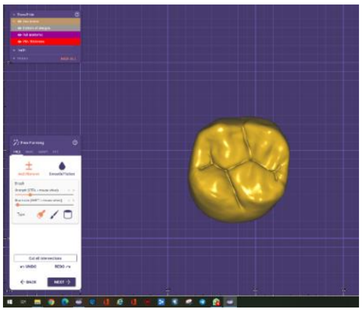


Figure (6): the final crown design ready to be saved

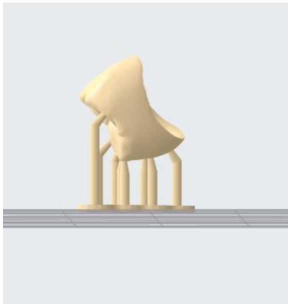


Figure (7): vertical orientation (120°)

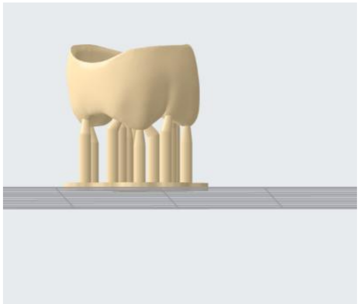


Figure (8): horizontal orientation (180°)

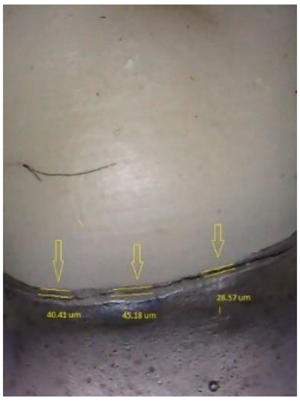


Figure (9) Representative microscopic image image showing VM gap values for 120o group

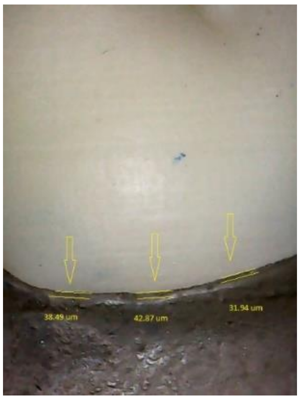


Figure (10) Representative microscopic showing VM gap values for 180o group

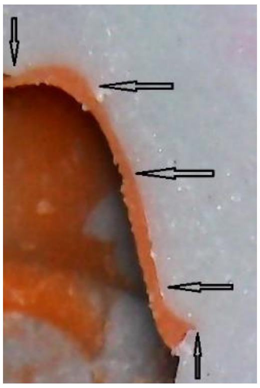


Figure (11) five regions measured in each section

IV. DISCUSSION: Recently 3D printing technology have been introduced in manufacturing of interim restorations and it has many advantages over milling subtractive technique: as it has the ability to print tiny and large objects not limited to the size of blocks as in subtractive milling technique.

This study was conducted to evaluate the effect of build directions on the marginal fit of the provisional crowns using SRT. As a result, there was a difference in the marginal fit according to build directions. Thus, the null hypothesis was rejected.

The artificial Dentoform upper right 1st molar in a model (A5AN-500,Nissin Dental Products Inc., Kyoto, Japan) was used for the aim of standardization.

In the present study, Stereolithography technique (SLA) was selected for additive manufacturing technology as it was fast with high resolution technique. The accuracy of SLA was superior to other 3D printing techniques, and it could print complex geometries with fine details.

The liquid resin used in present study was NextDent C&B biocompatible classII a material for fabrication of long term 3D printed interim restoration.

Direct view technique, through a high powerful microscope was the most commonly used method to detect marginal discrepancy. This study utilized the Digital microscope to observe marginal discrepancy, **which is a** high precision instrument that can accurately record the amount of discrepancy at various levels with remarkable precision.

Laurent et al found that if appropriate silicone is used, the cement space may be replicated and its thickness measured regardless of the location. Similarly, **Rahme et al** reported no significant difference between the silicone replica technique and sectioning technique in measuring the marginal gap of Procera crowns and advocated that using low-viscosity silicone for the replica technique can imitate the film thickness of a cemented crown applying glass-ionomer cement

Measurements were done under a fixed magnification of 40X

Then morphometric measurements were done for each shot [3 equidistant landmarks along the cervical circumference for each surface of the specimen (Mesial, buccal, distal, and lingual). Measurement at each point was repeated five times.

There were variations in the number of points measured to assess the marginal accuracy in the previous studies. While **Nawafleh, N.A. et al** recommended 50 measurements per specimen. Others suggested that 20 to 25 measurements per specimen could be used for measuring the marginal opening This study was conducted to evaluate the effect of build directions on the marginal and internal fit of the provisional crowns using Digital microscope(marginal gap) and SRT (internal fit).

As a result, there was a difference in the marginal and internal fit according to build directions. Thus, the null hypothesis was rejected.

In a previous study, **Abdullah et al.** evaluated a MG of provisional crowns made with 4 types of resin using low viscosity silicone impression material and reported a mean MG of 47 - 193µm.

Yao et al. reported a MG of 150 – 280µm, after fabricating provisional crowns using 4 resin types and attaching using glass ionomer cement.

Belser et al. asserted that the clinically permissible MG in the final prosthesis

was 120 µm, while **Beuer et al.** reported a range of 100 - 150 µm. In the present study, the MG was shown to be 28.18 – 65.81µm, which falls within the clinically permissible range.

Internal fit affects the retention and resistance of the crown, in which OG is often the largest measured gap than CG or AG. According to **Boitelle et al.,** the internal fit of CAD/CAM prostheses made with various materials was 45 - 219 µm in the OG. **Alharbi et al.** reported an incisal gap of 169 µm in the 3D-printed anterior provisional crown, which was 1.5 times greater than the assigned cement gap. **Kokubo et al.** reported an incisal gap of 170µm, which was 3 - 4 times greater than the cement gap.

In this study, the cement gap was set to be 30 µm and the measured OG was 58 - 130µm, which was 2.5 - 5 times greater.

The AG shows a different pattern. **Alharbi et al.** reported an AG of 41 µm, which is smaller than the defined cement gap of 60 µm.

Park et al. studied 3D-printed 3-unit fixed partial dentures using resin in 5 build angles (0°, 30°, 45°, 60°, 90°) and found a significant difference in the marginal and internal fit, in which the optimal build angles were 45° and 60°,corresponding to 135° and 120° (as in our study).

Alharbi et al. compared the three-dimensional accuracy of resin crowns 3D-printed at 9 different angles using superimposition software and concluded that the optimal build angle was 120°, considering the position of support and time needed for finishing and polishing.

In addition, **Osman et al.** compared the three-dimensional accuracy of DLP-printed resin crowns and reported 135° as the optimal angle.

In this study, MG were significantly larger in the 180° group than in 120° groups,. Therefore, considering the marginal gap, 120° are recommended as the optimal build angles.

Considering the internal fit Regardless to measurement site, totally it was found that ***Occlusal site*** recorded statistically significant highest gap mean value (115 µm) followed by ***axial site*** with an intermediate gap mean value (104.83 µm) while the lowest statistically significant gap mean value recorded with ***marginal site*** (61.926 µm) there was ***non-significant*** difference between both groups as indicated by two-way ANOVA test ($p=0.6179 > 0.05$) where (***vertical group*** > ***horizontal group***)

There are various reasons for the differences in the marginal and internal fit based on the build angle. First, the form of the layer created by the 3D printer differs according to the build angle. Since a SLA-based 3D printers contain a resin tank with a transparent base and non-stick surface, which serves as a substrate for the liquid resin to cure against, allowing for the gentle detachment of newly-formed layers.

The printing process starts as the build platform descends into a resin tank, leaving space equal to the layer height in between the build platform, or the last completed layer, and the bottom of the tank. A laser points at two mirror galvanometers, which direct the light to the correct coordinates on a series of mirrors, focusing the light upward through the bottom of the tank and curing a layer of resin.

The cured layer then gets separated from the bottom of the tank and the build platform moves up to let fresh resin flow beneath. The process repeats until the print is complete.

Any change in the layer form entails changes in the form and degree of polymerization shrinkage. For example, in the case of a hollow cylindrical object, there is a part that is consistently exposed to light, which affects the internal fit. Moreover, the position of support attachment changes with the build angle. Errors can arise from the unsupported section. If support is attached close to the crown margin, then unwanted damage can be incurred during the removal of the support.

Although supports were attached symmetrically in the 180° groups, OG was significantly larger in the 120° group whose support was located more lingually. The number of supports was 12 in the 180° group and 8 in the 120° group, which explains the error in the 120° group by its relatively fewer supports.

Ji-Eun Ryu et al fabricate provisional crowns at varying build directions at 6 directions (120°, 135°, 150°, 180°, 210°, 225°) using the digital light processing (DLP)-based 3D printing and evaluate the marginal and internal fit of the provisional crowns using the silicone replica technique (SRT). And reported that The marginal and internal fit of the 3D-printed provisional crowns can vary depending on the build angle and the best fit was achieved with build angles of 150° and 180°.

Osman et al. fabricated and scanned provisional crowns in 9 different angles using a DLP-based method and obtained a color map by superimposing with original data, which showed a positive change in the internal surfaces of the supported area and the opposite area when build angles of 90°, and 270° were used. This can be explained by the gravitational effects on the liquid medium as the platform moves up and down during printing. Furthermore, CG was smaller in the 180° group than in 120° groups, while OG and AG were larger, suggesting that fit was imperfect in the axial plane.

Attempts have been made in many studies to reduce the area of support by changing the build angle. Attaching support to the object increases the printing time and the amount of material used, while removing the support requires a considerable amount of manual work and time and can degrade surface quality. Here, the build angle is selected manually, semi-automatically or automatically.

In the manual mode, the user can directly set the build angle on the platform. In the semi-automatic mode, the angle is determined based on the feedback information on printing time and support area. In the automatic mode, it is determined by a specific algorithm that takes the printing time, as well as the amount and area of support into account.

Previous studies have proposed various algorithms to find the optimal build angle. The differences in fit after applying various algorithms must be further studied.

In this study, when the provisional crowns were printed at an build direction of 120° and 180° using a SLA 3D printer, the optimal build angles were 120°.

However, the limitation is that the cement thickness to which the crown was suitable at all angles was not set. As a result, the difference in the fit according to the position of the support was not comparable in all build angles. Also, further studies are needed to evaluate the influence of various parameters such as layer thickness, support type and location on the platform that should be considered during crown printing.

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