EFFECT OF INTERNAL FIT OF BUILD DIRECTION OF 3D PRINTING FULL COVERAGE PROVISIONAL RESTORATION (AN IN-VITRO STUDY)

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ABSTRACT

Aim: This study aimed to assess the impact of build direction of 3D-printed provisional restorations on internal fit.

Materials and methods: The prepared resin tooth was scanned and single crown was designed using computer-aided design (CAD) software. Provisional crowns were printed using an 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 internal fit using morphometric, 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).

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

Results: horizontal Marginal Gap it was found that horizontal group recorded 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).

Conclusions: Within the limitation of this study the following conclusions could be drawn: internal fit of provisional restorations fabricated using a SLA based 3D printer revealed clinically accepted outcomes within the two build angles. The building angle of fabrication doesn't affect internal fit of the provisional restorations
Keywords:3D printer, fixed prosthesis, internal fit, exocad, CAD/CAM.

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.

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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 provisional 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 previsualization 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 technology 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 possible using computer-aided design/computer-aided manufacturing (CAD/CAM), which facilitates 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 milling technique. It is passive with no force application and can produce finer details (undercuts & better anatomy). The 3D printing methods include Stereolithography (SLA), Digital light processing (DLP), Selective Laser Sintering (SLS) and Fused Deposition Modeling (FDM).

Materials and methods:

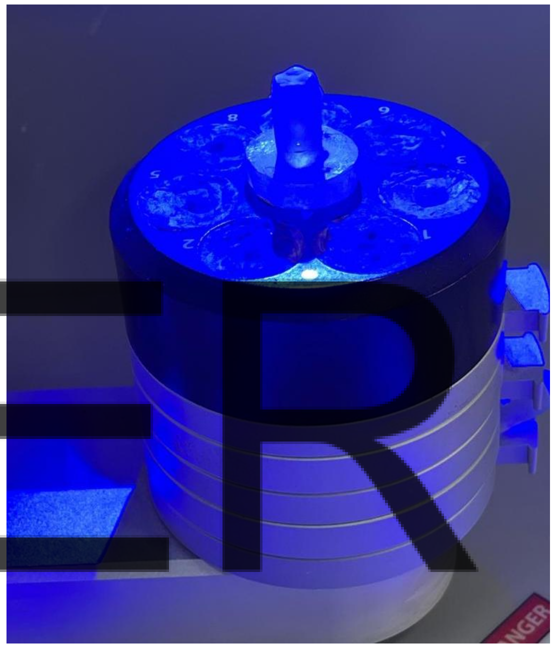
This study was carried out to assess the internal fit of provisional crowns which were fabricated by horizontal 3D printing technique (intervention) compared to provisional crowns which were fabricated by vertical 3D printing technique (control).

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.

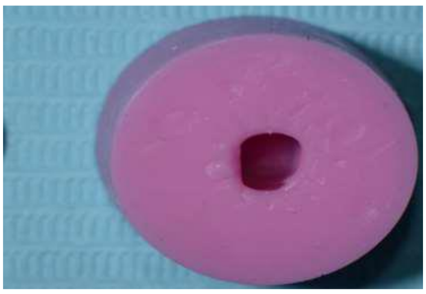
- Group (I): Sixteen crowns (n=16) fabricated by vertical 3D printing technique (control).
- Group (II): Sixteen crowns (n=16) fabricated by horizontal 3D printing technique (Intervention).

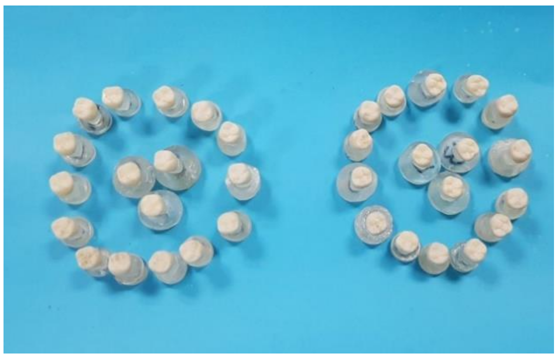
Dentoform model of maxillary 1st molar was prepared according to the following criteria: 2 mm occlusal reduction, 1.5 mm overall axial reductions.

The prepared model was scanned using Medit T-300 scanner.

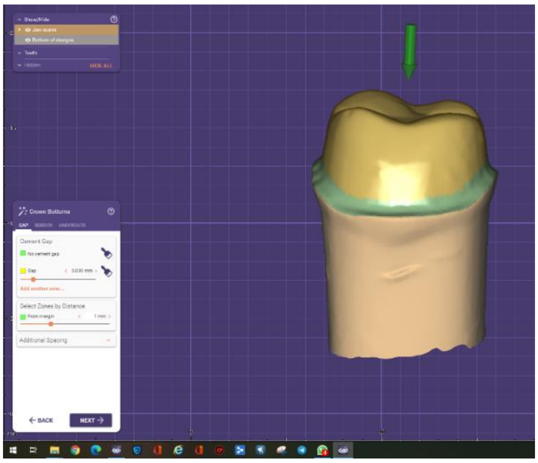


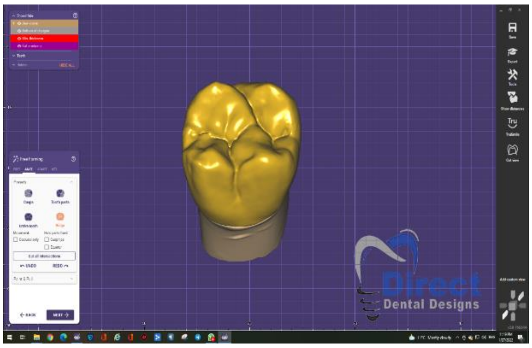
Duplication of master die into thirty-two epoxy resin dies through using silicone duplicating material and then divided into two equal group (n=16).



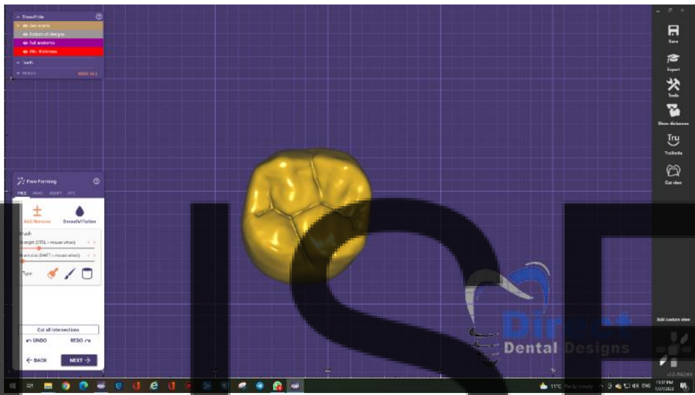


Provisional crowns were designed using Exocad software.

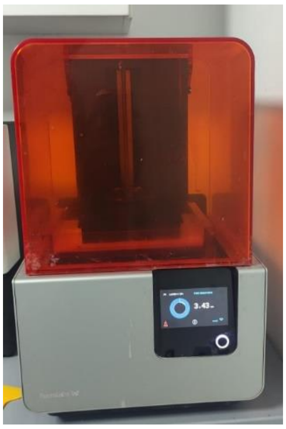


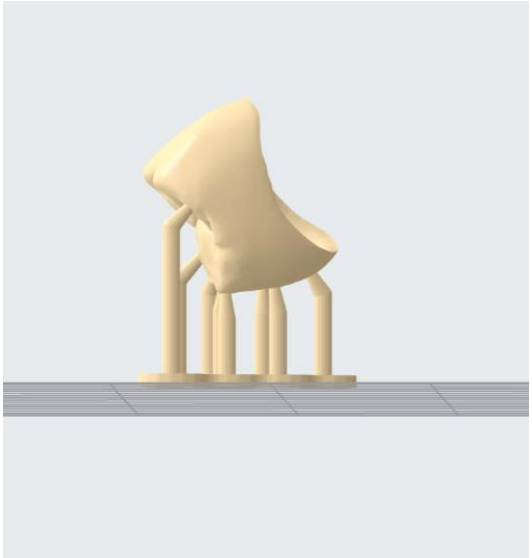


STL file was produced and sent to Formlabs printer.



The provisional crowns were printed using the formlabs form2 printer using Next dent C&B PMMA resin material.





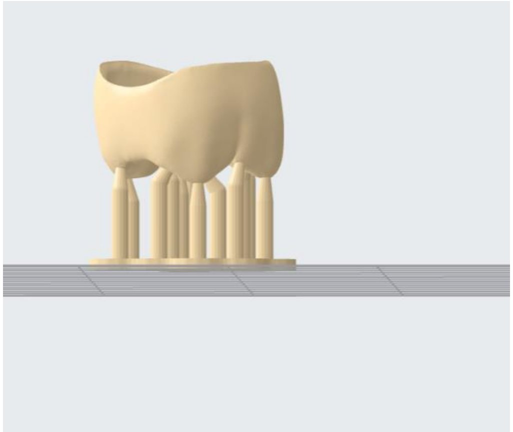


Figure 1120 horizontal

Figure 2180 virtical

Measurement at each point was repeated five times.

Results:

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**

Discussion

Provisional restorations are essential components of fixed prosthodontics treatment. Interim restorations must satisfy biologic, esthetic, and mechanical requirements such as resistance to functional loads, resistance to removal forces, and maintenance of abutment alignment.

CAD/CAM technology was recently used for fabrication of interim restorations and has demonstrated clinical success owing to advances in CAD/CAM systems and materials used, but it was reported to have some deficiencies as marginal discrepancies, wastage of large amount of material, and long fabrication time.

Also among the drawbacks of CAD/CAM technology is being expensive.

In addition, its accuracy is limited by complexity of the object, the size of tooling and the properties of the material.

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. It is called rapid prototyping as it is a faster manufacturing technique. In the 3D printing processes, the material was deposited layer by layer to produce the final 3D shape so less material was wasted, decreasing expenses and mechanical properties were improved as there is no cracks in addition to producing a cheaper interim restoration, high level of building resolution, smooth printing surfaces and high strength in z-axis (between layers) due to chemical bonding between layers.

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.

Since the standardization is not easily achieved with extracted natural molars due to the variation in mineralization, sizes, age of natural molars and its mechanical features. That’s why in the current study; 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.

The duplication of each master die was done by using REPLISIL 22 N as it has a low viscosity to record fine details, best mechanical characteristics with high ultimate tensile strength and offers an extremely high accuracy in dimensions and design of the duplicating form and has highest tear resistance, it is very flexible and easy to deflask and it has a 100% recovery after deflasking.

In the present study shrink free epoxy resin material was used to construct epoxy resin dies and the dies were used as a substitution to natural teeth to allow for fabrication of identical crowns, which is important for a reliable comparison of different groups.

Epoxy resin material was selected as it has elasticity similar to that of dentin(12.9GPa).

Also, the epoxy resin material was used in the present study because of it's superiority in dimensional accuracy, surface detail reproduction, strength and better abrasion resistance.

Digital caliper was used to verify the accuracy of reproduction & to ensure the standardized dimensions of all epoxy dies replicas, The replicas were measured occlusso- gingivally , facio-lingually and mesio-distally.

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.

In the impression replica technique, however, the crown is filled with low viscosity light-body silicone material and seated on the die simulating the cementation procedure. After setting of the silicone material, the crown is gently removed from the die, and heavy-body silicone is injected inside to stabilize the thin light-body film before removing it from inside the crown. The light-body silicone layer can then be sectioned and measured at different sites.

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

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 internal fit of the provisional crowns using SRT (internal fit).

As a result, there was a difference in the 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.

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 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.

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 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 internal fit of the provisional crowns using the silicone replica technique (SRT). And reported that The 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, 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.

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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