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Marginal fit of interim restoration constructed by 3D printing versus conventional chair-side method: An *in vitro* study

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Abstract
Purpose: The aim of the present study was to assess the marginal fit of interim restorations fabricated by 3D printing technique compared to conventional technique.
Methods: Typodont model of maxillary 1st molar was prepared for full coverage crowns. The prepared model was digitally scanned by 3D scanner. Duplication of master die into 20-epoxy resin dies. Interim crowns were constructed by two techniques: conventional chair side technology using a bis-acrylic based self-cure temporary material (structure-2- Voco, Germany) and 3D printing technology using (Next-dent C&B resin, Netherlands) material. The specimens were divided into 2 equal groups (n=10). Marginal adaptation was evaluated using stereomicroscope.
Results: The mean marginal gap value of 3D printing interim crowns (38.76±27.21 μm) was significantly lower than that of conventional chair-side crowns (120.43±32.63 μm).
Conclusion: Interim crowns fabricated by 3D printing showed superior marginal accuracy than conventionally constructed crowns.

Keywords: Interim crown, 3D printing, rapid prototyping, conventional chair-side, marginal fit

Introduction

Temporary restorations are an important part of fixed prosthodontics treatment since they are employed as a short or long-term protection of prepared teeth. They are utilized directly after tooth preparation until the fabrication and placement of the final indirect restoration [1].

The material used to fabricate the interim prosthesis should have low polymerization shrinkage, antibacterial properties, and good marginal adaptation and should meet biologic, aesthetic, and mechanical requirements, such as functional load resistance [1].

The interim restoration contributes to pulpal protection, occlusal relationship stabilization, and occlusal function. For cases of oral rehabilitation requiring long-term pro-visualization, its significance rises significantly [2].

Temporary repairs can be made using a variety of methods. These restorations are traditionally created manually using direct, indirect, and indirect-direct methods. Nowadays, the advances in materials and CAD/CAM technology allowed the production of temporary restorations by milling (subtractive manufacturing) & 3D printing technique (additive manufacturing) [3].

The freshly developed method in which different materials are used in 3D printing is growing quickly. Additive production (layer upon layer) is capable of producing exact prostheses with little material waste. It is thought to be more affordable and quicker than milling method [4].

Marginal accuracy of provisional restorations highly depends on their fabrication technique [5]. The integrity of fit between the crowns and prepared tooth structure is important to the success of restorations. To prevent irritation or inflammation of the periodontal pulpal tissues and to achieve an acceptable outcome, the marginal adaptation of an interim restoration should be as accurate as the final restoration [6]. A null hypothesis was that there would be no difference in marginal fit of 3D printed and conventional interim restoration.

Materials & Methods

Typodont model of a maxillary first molar (NISSIN, Kyoto, JAPAN) was prepared to receive an all-ceramic crown preparation with 2 mm occlusal reduction, 1.5 mm axial reduction, 1mm deep chamfer finish line and 6 degree convergence. The preparation was carried out by an experienced prosthodontist using a silicone index of an unprepared tooth to accomplish the tooth reduction.

Fig 1: Prepared tooth in model

Duplication of master die into epoxy resin die

Silicon mold of the master typodont die was made using duplicating addition silicon material (Replisil N 22, Dent-e-Cone.k., Lonsee, Germany). The silicon mixture was placed in a cylindrical teflon container.

The mixture of epoxy resin material (Kemapoxy, CMB, Egypt) was then added to the silicon copies, which were then put on the lab vibrator to remove voids and air pockets. To ensure full setting, epoxy resin dies were left in place for 24 hours. A total of 20 dies were fabricated.

Conventional crown fabrication

A putty-type vinyl polysiloxane (Elite HD+, Zhermack) was used to produce an index. This index served as the matrix for making the interim crown restorations. Then a thin layer of petroleum jelly (Vaseline, Unilever PLC, LONDON, UK) was applied on the typodont.

Interim crown material (Structure-2-Sc, Voco, Germany) was then manipulated according to the manufacturer’s instructions and applied into the putty index. The resin-filled index was then adapted on the lubricated typodont.

After complete polymerization, excess flash was trimmed from the margins of interim restorations and polishing was done by using Kenda dental polishers[1] (Kenda AG dental manufacturing, Liechtenstein).

3D printed crown fabrication

Optical Impression; (Scanning the preparation)

The master cast was placed on the lower separate compartment part to be fixed to the scanner and the area to be scanned was sprayed with powder in preparation for scanning of the area. A dental laboratory 3D scanner (ACTIVITY 885 3D SCANNER, Germany) was used for scanning of the master cast.

The 3D virtual cast was obtained from scanning the master cast and the 3D virtual die was obtained from scanning of the die separately. Summing up the data collected was done with a CAD software (Exocad Dental CAD, Germany) to get final virtual 3D master cast with fine details. Figure (2).

Restoration designing

The finish line could be identified using the virtual model created from the scanned images, and the margin was detected automatically. Fig (3)

The next step involved choosing the dental morphology and adjusting the placement of the restorations. Software was used to build up the cement area at 0.03 mm [7]. In order to standardize all samples, the occlusal thickness was then measured from the central fossa and corrected to 1.5 mm; the information was saved as STL file to be sent to the printer unit (Phrozen Tech Co., Ltd, Taiwan). Fig (4).

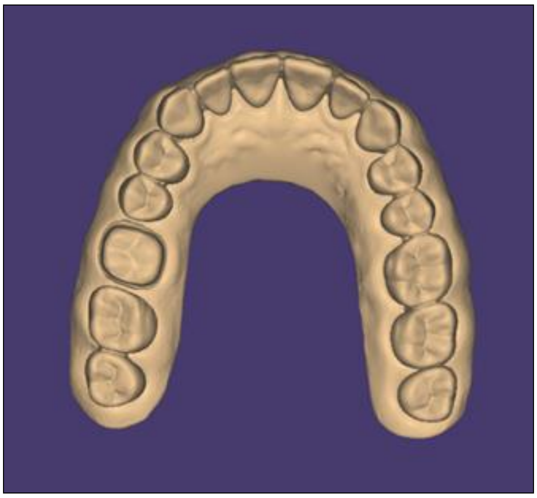

Fig 2: Final 3D virtual cast

Fig 3: Tracing the finish line, occlusal view

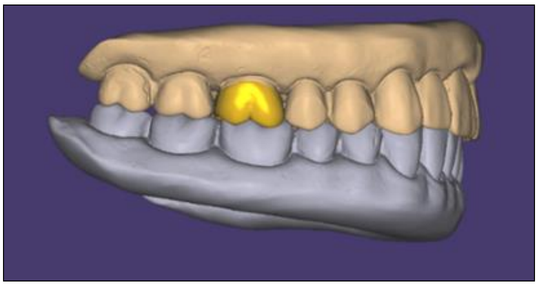

Fig 4: Checking finished crown design, lateral view

Processing of 3D Printing Crowns

A computer software (Flash Print 4.6.4, 3D Technology) was used to modify the STL file in preparation for printing as well as to transfer information about the printer and the substance. The 3D model is adjusted and placed on the virtual platform at the correct angle and position. A building support system

was added and modified. The STL file was sent to the 3D printer after selecting the appropriate construction style and calibrating the DLP (digital light processing) device. The printing parameters were adjusted so that the building process can begin**.** Next dent C&B resin (Next-Dent, Soesterberg, Netherland) was used and poured in a container specially fabricated to be accurately fit in the printer. The resin liquid was mixed gently with special brush to avoid unequal distribution of components and to avoid any precipitation that may adverse the setting and polymerization of resin. The printer cover was closed then the printing process was started. The platform was lowered to coat it with a thin coat of resin and then elevated to be exposed to the UV light to cure the previous layer after the objects were constructed layer by layer. The process continued until the completion of the full object. Then, the object was removed from the bath. With supporting buildings, there were 307 layers with a layer thickness of about 50 m. Each provisional crown's printing cycle required about 45 minutes to partially cure. After the completion of printing process, the 3D printed crowns were attached to the upper compartment by supporting structure.
After fabrication of the interim crowns by 3D printing technique. All the supporting structures at the 3D printed crown were removed, finished and polished with Jota Arkansas stone 6498. The finished interim crown was put in ethanol to wash away uncured resin then the object was removed from the bath.

Post processing and curing
It is an important step where the final object was carried out to complete the polymerization process. Each printer has post-processing recommendations provided by the manufacturer. The LC-3D Print Box is an ultraviolet light box appropriate for post-curing resin components for 3D printing. The presence of 12 ultraviolet light bulbs inside the box to ensure that a product is illuminated from all sides. This results in a quick and uniform curing cycle to ensure that resin materials obtain full polymer conversion, through this the residual monomer is reduced to a minimum and the highest mechanical properties are obtained. The post curing cycle took 30 minutes. After post processing curing of all crowns, they were seated on their corresponding epoxy resin die

Vertical Marginal Gap Measurement
Ten samples in each group, with a total of 20 crowns were checked for marginal adaptation using a stereomicroscope (Leica DFC290 stereomicroscope, Germany) at ×40 magnification. Each specimen was placed under the microscope and fixed in position.
The specimens were then captured by a microscope-attached device. The vertical marginal gap was then measured at preset 20 reference locations for each crown marked on the epoxy die of each sample using image analysis software after the images had been transferred. Figure (5).

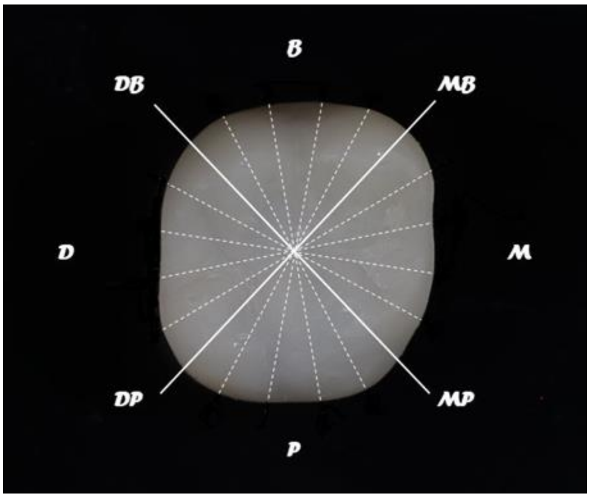

Fig (5): A diagram showing occlusal view of twenty assigned points of interim crown buccal (B), distal (D), palatal (P), mesial (M), buccal and distal surfaces line angle (DB), buccal and mesial surfaces line angle (MB) palatal and distal surfaces line angle (DP) and palatal and mesial surfaces line angle (MP)

Each epoxy die was marked using a Fine-tip Art pen at each line angle and then each die surface was further marked by 4 equidistant points at which the measurements were made.
Measurements of marginal gap at each marked point were recorded in microns. Figure (6, 7) Then the data obtained were collected, tabulated and then subjected to statistical analysis.

Fig 6: Measurement of marginal gap at two points marked on the epoxy die in conventional group

Fig 7: Measurement of marginal gap at two points marked on the epoxy die in 3D printing group

Statistical analysis

All Data of marginal gap were collected, tabulated, and subjected to statistical analysis. The Mean and Standard Deviation were used to characterize quantitative variables (SD). Frequencies and percentages were used to characterize the qualitative categorical variables. All quantitative factors were put to the test for normality using the Kolmogorov-Smirnov and Shapiro-Wilk tests before the proper parametric and non-parametric tests were selected. All the variables were found to be normally distributed allowing the use of parametric tests. Two Tailed tests are assumed throughout the analysis for all statistical tests.

Results

The mean of marginal gap values of the group in crowns group constructed by 3D Printing was (38.76±27.21 µm) lower than those values of the group constructed by Conventional technique (120.43±32.63 µm). There was a highly significant statistical difference in the means of marginal gap values between the samples of the two groups ($p<0.001$). As shown in Table (1) and Figure (8).

Table 1: Descriptive statistics of marginal gap values in both study groups

Group	Minimum	Maximum	Mean	SD	95% CI for Mean	Mean difference	*p*-value
3D Printing	11.76	114.25	38.76	27.21	(34.97, 42.56)	81.67	<0.001 HS
Conventional	51.48	209.46	120.43	32.63	(115.88, 124.98)		

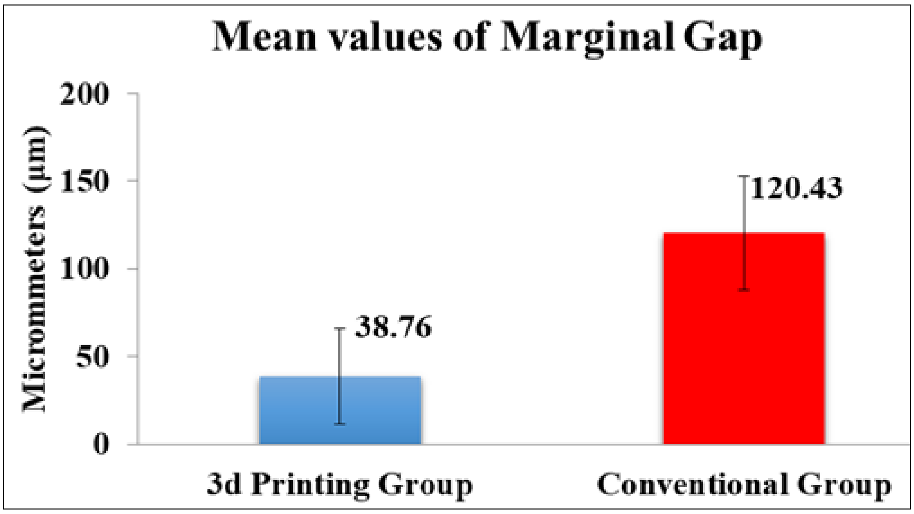

Fig 8: Bar Chart showing mean values of marginal gap in both study groups

Discussion

In prosthodontics, temporary restorations are of utmost significance. Premiss protection, mastication, aesthetics, and positional security are all provided by temporary crown and bridge restorations. After dental preparation, the protection of the preexisting tooth structure is the most important function of a provisional restoration; as a result, temporary materials must be robust with high fracture resistance. They should also keep positional stability and be aesthetically pleasing. Temporary materials now perform much better materials in terms of biocompatibility, aesthetics, and strength [8].

Recently, 3D printing technology has been used to manufacture temporary restorations and was proved to have many benefits 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 a faster manufacturing technique and since; the material is deposited layer by layer to produce the final 3D shape so less material is wasted; thus decreasing expenses with better mechanical properties [9].

So, The current *in vitro* study's objective was to assess the vertical marginal fit of interim crown materials made using 3D printing technology compared to those made using more traditional methods.

In the current study, a crown preparation was done on a typodont that was duplicated to epoxy dies instead of using natural teeth for standardization [10].

The duplication of each master die was done by using (REPLISIL22N, Dent-e-cone.k, Lonsee, Germany) as it has low viscosity to record fine details and has the best mechanical characteristics with high ultimate tensile strength.

Also, it offers an extremely high accuracy in dimensions and design of the duplicating form [11].

Epoxy resin material was chosen for construction of duplicate dies as it has an elasticity similar to that of dentin (12.9 GPa). In addition, it was proved to be superior in dimensional accuracy, surface detail reproduction, strength and abrasion resistance [12].

The earliest category of polymer-based direct temporary materials is acrylic MMA/PMMA resins. The composite resin type has many benefits when compared to methacrylates, such as better aesthetics; allowing them to be used in anterior zones where aesthetics are important and in circumstances where long-span FPDs are required [13], Accordingly, this type of resin was chosen in our study for constructing provisional restorations by conventional chair side technique**.**

In the present study; for production of 3D printed crowns. The scanning of die was done using the extra-oral scanner (Activity 885 3D scanner) and For standardization, the cement space was set at 0.030 mm as suggested by Kale and coworker.[7]Additionally, the same software was used to standardize the occlusal thickness of all crowns, which was fixed to 1.5mm from the central fossa [14].

Measurement of marginal gap was done without cementation of the crowns on to epoxy dies, in order to exclude the effect of cementation technique variations on marginal gap values as reported by different authors [15, 16].

Assessment of marginal gap values was done using a stereomicroscope, as it was reported to be an accurate technique of evaluation by different studies [10, 17, 18]. The null hypothesis was rejected and the results showed that 3D printed interim crowns had higher marginal fit than conventional crowns.

Results of the present study revealed that the marginal gap mean value recorded for the conventional chair-side group was (120.43±32.63 μm), while that of the 3D printed group mean value was (38.76±27.21 μm)

3D printed provisional crowns showed a statistically significant higher marginal adaptation and less marginal discrepancy compared to conventionally constructed ones, this might be attributed to the high accuracy results of (digital light processing) technique selected for additive manufacturing technology [19]. While the higher marginal gap reported with crowns constructed using the conventional technique might be attributed to the volumetric polymerization shrinkage of acrylic resin, which is around 6%; leading to a decrease in retention and deformation of restorations, as reported in the literature [8, 20]. Yet, it should be noted that the dimensional accuracy of all restorations in our study in both groups was within the clinically acceptable range, between 20 to 150 μm, as reported by *Hazeveld* and colleagues [21].

However, contradicting results were reported by *Doh* and coworkers who evaluated the dimensional accuracy of intra-coronal restorations made using traditional and digital techniques and demonstrated that 3D printing was not as precise as the traditional resin pattern technique [22].

3D printing technology revealed its success in our study in producing single-unit interim restorations of high quality with regard to their marginal accuracy. This opens the field for future research on both laboratory and clinical levels.

Conclusions

1. Provisional (interim) crowns fabricated by 3D printing showed superior marginal accuracy than conventionally constructed crowns.
2. 3D printing technique can be used successfully used to construct long term interim restorations.

Recommendations

1. Based on the results of the current study further investigation with regard to other mechanical and physical properties of the interim restorations produced by both tested techniques should be conducted.
2. *In vivo* studies must be carried out under oral conditions to assess the behavior of long-term provisional restorations constructed using both techniques.
3. Future work utilizing different 3D printing systems that allow for optimization of printing parameters should be performed to improve the mechanical properties of 3D printed restorations.

Conflict of Interest

Not available

Financial Support

Not available

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