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The Outcome of 3D printing and CAD-CAM Techniques on Marginal Accuracy of Provisional Crowns

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The Outcome of Three Dimensional Printing and Computer Aided Design-computer Aided Manufacturing Techniques on Marginal Accuracy of Provisional Crowns

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Abstract

Purpose: The current study aimed to evaluate the effect of fabrication techniques computed aided design-computer aided manufacturing three dimensional (CAD-CAM, 3D) Printing, and conventional techniques on the marginal accuracy of interim crowns. **Patients and methods:** Thirty interim crowns were constructed and distributed into three groups according to the technique of construction ($n = 10$): Auto polymerizing resin conventional group, poly methyl metha acrylate prefabricated blocks CAD-CAM group, and Light-cure biocompatible resin 3D printing group. A digital microscope tested the marginal accuracy of the constructed temporary crowns to detect micro gaps at selected points. **Result:** Before cementation, the highest mean value was recorded in the conventional group (13.17 ± 0.33) (μm), followed by the 3D printing group (12.83 ± 0.78) (μm), while the statistically lowest mean value (11.98 ± 1.66) (μm) was recorded in the CAD-CAM group. After cementation, the statistically highest mean value was recorded in the conventional group (35.65 ± 0.62) (μm), followed by the 3D printing group (20.10 ± 3.66) (μm), followed by the CAD-CAM (17.53 ± 2.47) (μm). **Conclusion:** The fabrication technique of provisional crowns affects their marginal accuracy. Superior margin accuracy was obtained with CAD CAM-constructed provisional crowns.

Keywords: Computer aided designs-computer aide manufacturing, Marginal accuracy, Provisional crowns

1. Introduction

Temporary crowns serve as a model for permanent restorations in addition to being useful from a cosmetic and functional standpoint. As a result, gingival health and margin precision have a role in the outcome of definitive restorations. Additionally, any slight misalignment and interruption in the crown's adaptation during interim restorations will have an impact on the placement and final restorative operations. Research reveals that specifically when using the direct approach with resin polymers, marginal accuracy in specially made interim crowns offers a higher outcome. Risks associated with these custom techniques include uneven margins, delayed setting, distortion of margins during early removal, polymerization exotherm, and shrinkage [1].

In some situations, such as implant cases, and orthodontic, and nonsurgical root canal treatments, the usage of temporary crowns is necessary for a prolonged period, which increases the demand for the best probable interim crown material strength and marginal accuracy whereas taking into the impact of a multifaceted oral media [2]. For the best aesthetics, strength, and function, it is therefore vital to understand the material's surface properties.

Surface roughness promotes microbial settlement, at the margin of restoration, which causes periodontal infection and soreness. It also improves plaque retention. These significant alterations contribute to tissue inflammation, gingival recession,

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and pulpal sensitivity [3,4]. Additionally, irritating soft tissues make restorative rehabilitation more difficult. Therefore, an ideal quality of the interim restoration is needed to maintain the periodontal health. The vertical gap distance and adjustment, which affect the quality of restoration and tooth structure conservation, are a critical characteristic of interim restorations made of resin. The durability and longevity of certain crowns depend heavily on the precision of restorative marginal fit [5,6].

These contemporary technologies effectively use the numerical picture of the abutment to create poly methyl metha acrylate (PMMA) temporary crowns. There is not enough information, though, to distinguish between the crucial traits of CAD-CAM and conventional procedures and 3D-printed interim repairs. The current study's objective was to evaluate the impact of fabrication methods (CAD-CAM, conventional, and 3D printing) on the margin accuracy of provisional restorations.

2. Patients and methods

2.1. Sample size calculation

To study the effect of conventional, CAD-CAM, and 3D printing techniques on the marginal integrity, based on the study done by Aldahian *et al.* [7], using the G power statistical power analysis program (version 3.1.9.4) for sample size determination, a total sample size ($n = 30$) subdivided into 10 in each group was sufficient to detect a large effect size (d) ranging from 0.61 to 0.63, with an actual power (1-β error) of 0.8 (80 %) and a significance level (α error) of 0.05 (5 %) for the two-sided hypothesis test.

Ethical approval was obtained from the Research Ethics Committee (REC) of the Faculty of Dental Medicine for Girls, Al-Azhar University, code REC-CR-23-01.

2.2. Teeth selection and preparation

One anonymous sound upper first premolar was selected. The selected premolar was scanned using an optical oral scanner. The scanned premolar was digitally prepared to receive a temporary crown, using Exocad software. Following the standard preparation guidelines for all-ceramic restoration. The guidelines of advanced ceramic restoration fabrication were 6-grade taper, 1 mm bevel finish line, and 1.5 mm occlusal preparation.

Thirty 3D dies were produced by using software for three groups (Fig. 1). Each die was immersed in an epoxy base mold (length 2 cm and diameter 1.5 cm).

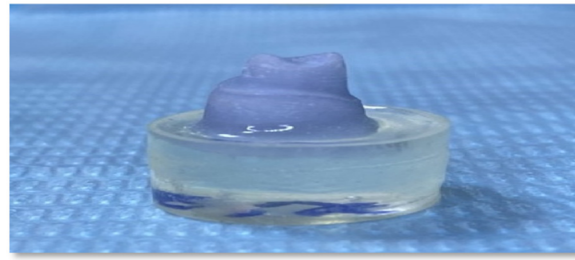

Fig. 1. Three dimensional printed master die.

Thirty crowns ($N = 30$) were constructed and distributed into three groups according to the technique of construction ($N = 10$):

Group 1: Charm Temp: interim restorations fabricated by the conventional method.
Group 2: Telio CAD disc interim restorations fabricated by CAD CAM milling method.
Group 3: Nextdent C and B: interim restorations fabricated by the 3D printing method.

2.3. Fabrication of provisional restorations

2.3.1. Group 1: Fabrication of conventional interim restorations

Charm temp (Dentkist, Korea) was used to construct interim crowns. Interim crowns were done by silicone imprint (Affinis, coltena, Germany) of previously fabricated CAD-CAM interim restorations that served as an index to fabricate interim crowns and were injected by Charm-Temp. The dies were painted with die spacer material. Five coats of die spacer were applied with a brush system on all axial and occlusal die surfaces, leaving 1 mm short of the finish line. Charm temp was mixed through the self-mixing gun and directly injected into the silicon index, which was then placed on the epoxy die and held in place until the mixed material was completely set. The crown was examined to detect any defects then finished and polished using rotary rubber cups (SofLex Disc 3 M ESPE, Germany) following the manufacturer's instructions.

2.3.2. Group 2: Fabrication of CAD CAM interim restorations

The DS Mizar 3D extraoral scanner scanned each epoxy die to get a 3D simulated model. The Exocad software (Dental CAD 3.0 Galway) was used to design a virtual model from scanned pictures, When the final virtual restoration was designed, the information was sent through a Standard triangle language to the milling machine, and then the final virtual restoration was designed, the complete milling provisional crowns were finished and polished.

2.3.3. Group 3: Fabrication of 3D-printed interim restorations

The Standard triangle language file used in the previous group was sent to 3D printer software (Chitubox Pro) to construct 3D-printed interim restorations, as well as for adopting the file for printing interim crowns, which were printed in a layer-by-layer pattern and cured by UV light until the completion of the full crowns by Epax 4 K (China), after which finishing and polishing were performed.

2.4. Cementing procedure

Each crown was seated onto the corresponding epoxy die and cemented with charm temp temporary cement (Dentkist, South Korea). The cementation procedure was carried out in a specially designed cementation device, under 3 kg of static load.

2.5. Marginal accuracy determination

The samples of the three groups were evaluated in terms of measuring the vertical marginal gap at specific circumferential points. The marginal accuracy of the samples was tested before and after cementation by a digital microscope camera connected to the personal computer. Gap width was evaluated by a numerical investigation system.

2.6. Statistical analysis

Comparisons among groups concerning normally distributed numeric variables were performed using the ANOVA test, followed by the Bonferroni post hoc test for pairwise comparisons. Comparisons between groups concerning nonparametric numeric variables (difference and percent change) were performed using the Kruskal–Wallis test. Comparison between different observations within the same group was performed using a paired *t*-test.

3. Results

3.1. Before cementation

The highest mean value was recorded in the conventional group (13.17 ± 0.33) (μm), followed by the 3D printing group (12.83 ± 0.78) (μm), followed by the CAD-CAM group (11.98 ± 1.66) (μm). The difference among the groups was statistically significant ($P = 0.045$), where the CAD CAM group recorded the lowest vertical marginal gap compared with the other groups Fig. 2 and Table 1.

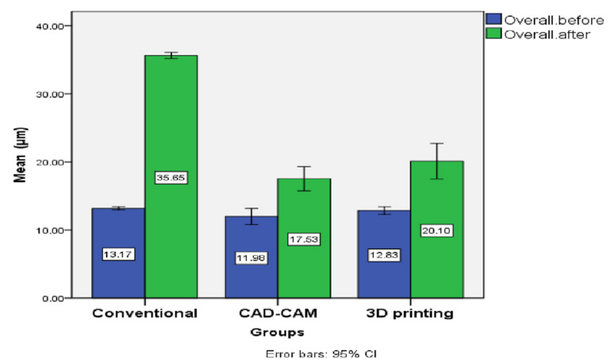

Fig. 2. A bar chart illustrating the mean marginal gap (μm) before and after cementation.

Table 1. Descriptive statistics and comparison between groups regarding overall marginal gap (μm) before and after (ANOVA test) and difference and percentage change from before to after (Kruskal–Wallis test).

Group	Before	After	Difference	Percent change	*P* value
Conventional					
Mean	13.17[a]	35.65[a]	22.48[a]	170.90[a]	0.000*
Median	13.08	35.70	22.38	173.39	
Std. Dev	0.33	0.62	0.73	8.52	
Min	12.60	34.65	21.05	154.78	
Max	13.60	36.58	23.40	180.05	
CAD CAM					
Mean	11.98[b]	17.53[b]	6.27[b]	55.34[b]	0.001*
Median	11.67	17.02	6.01	48.98	
Std. Dev	1.66	2.47	2.61	24.92	
Min	9.30	14.72	2.64	20.64	
Max	15.58	21.95	10.72	95.46	
3D print					
Mean	12.83[a]	20.10[b]	7.27 [b]	57.68[b]	0.000*
Median	12.85	19.43	6.14	47.71	
Std. Dev	0.78	3.66	3.95	33.99	
Min	11.68	14.86	2.08	16.28	
Max	13.89	26.55	14.86	127.12	
P value	0.045*	0.000*	0.000*	0.000*	

Significance level *P* less than or equal to 0.05, *significant Post hoc test: Within the same column, means sharing the same superscript letter is not significantly different.

3.2. After cementation

The highest mean value was recorded in the conventional group (35.65 ± 0.62) (μm), followed by the 3D printing group (20.10 ± 3.66) (μm), followed by the CAD-CAM (17.53 ± 2.47) (μm). The difference among the groups was statistically significant ($P = 0.000$), where the conventional group recorded the highest vertical marginal gap compared with the other groups Fig. 2 and Table 1.

4. Discussion

Intending to protect teeth from physical, biological, and mechanical harm before the final prosthesis can be placed, interim fixed dental prostheses are important. In cases where the cases need a longer course of treatment, such as oral rehabilitation cases, orthodontics, non-surgical root canal treatments, and oral surgical procedures, these restorations may be used temporarily (until the final prosthesis has been constructed [8].

Interim fixed dental prostheses should be made of materials with consistent color, appropriate dimensional accuracy, marginal accuracy, and good surface roughness [9]. Common chairside materials used in both direct and indirect restorative procedures include Poly-ethymethacrylate (PEMA) and PMMA. Polyethyl and polymethyl methacrylate are also known as PEMA and PMMAs. In addition to having qualities like those of traditional materials, bis-acryl, which depends on various methacrylic acid esters, may also be employed in the direct approach [10].

Although chairside manufacture of interim restorations is quick and simple, it has significant downsides since it may comprise voids during mixing and application that could affect the restoration's mechanical properties, surface texture, and marginal fit [11].

By minimizing chairside and laboratory time, numerical knowledge, and CAD/CAM have sped up the delivery of temporary restorations [12]. It is interesting to employ CAD/CAM to make interim crowns since it leverages optical impression technology and lessens patient discomfort. Additionally, CAD/CAM intermediate materials are prefabricated blocks that are industrially polymerized, which prevents shrinkage and the heat created by polymerization [13]. However, limitations of milling fabrication include material waste, the usage of microcracks, and the limited reproduction of surface features by milling tools [14].

Additionally, digitally planned temporary crowns can be done by 3D printing machines in addition to milling machines because of the growing accessibility of 3D printers. In comparison to milling, additive manufacturing generates less waste from raw materials, decreases manufacturing time, and enables mass production. The performance of the photocured material is poor: it is brittle, easily deformable, and has low biocompatibility. Therefore, it is utilized in the field of interim replacement materials [15].

In the current study, the marginal accuracy of interim crowns fabricated by CAD/CAM milling and 3D printing methods was compared with those fabricated by conventional manual methods.

Natural teeth are difficult to obtain uniform abutments because of their substantial variances in size, age, individual structures, and storage duration following extraction. In the current investigation, epoxy resin dies were utilized in place of natural teeth. Epoxy resin was utilized to create epoxy resin dies that substituted natural teeth to enable the manufacturing of reliable identical crowns, which is essential for a good comparison between various groups [16]. Epoxy resin was used in this study due to its higher dimensional accuracy and ability to reproduce surface features. Moreover, its elastic modulus is equal to dentin's (12.9 GPa) [17].

Charm temp is a special auto-mixed bis-acrylic composite resin that has strong wear resistance, and good color stability, and is enhanced with fillers to improve its mechanical properties [18]. It was used to construct samples using the conventional procedure (Group 1).

Using CAD/CAM technology, samples were built using the Telio CAD disc. A strongly cross-linked PMMA substance was used to create the disc [19].

The 3D-Printable dental material now available for temporary restorations is called Next Dent. It is a monomer based on methacrylic ester and a photocured liquid resin material utilized in 3D printing, as the printer only supports liquid resin [20].

In agreement with previous investigations, the thickness of the die spacer in the current study was standardized at 50 μm in all samples. It was reported that the die spacer's thickness worked well for the margin [21,22]. This was confirmed by a previous study, which reported that an internal space of 50 μm provides a high precision fit for restorations [23].

Using Charm Temp ZONE, a eugenol-free temporary cement, each provisional crown was attached to the corresponding epoxy die. Eugenol-free temporary cements exhibit less microleakage than those that include eugenol [24]. Each sample was fixed to a specifically built loading device with 3 kg of weight for static load application during cementation until the setting of temporary cement was complete to complete the conventional cementation technique and ensure even cementation [25].

One of the most critical parts for any restoration's longevity is good marginal accuracy because it influences how long the crown's cement system will last [21,26]. In the present study, the CAD/CAM group recorded the statistically significant lowest mean marginal gap distance (the best marginal adaptation) followed by 3D Printing and finally the conventional group. This could be explained by the occurrence of polymerization shrinkage, which results in dimensional alterations in provisional crowns made with charm temp conventional (manual) technique. When compared with the bis-acrylic resin charm temp, polymerization shrinkage has a relatively less but still detectable impact on PMMA resin accuracy [19], Polymerization shrinkage can adversely affect the marginal accuracy of provisional crowns.

Moreover, the success of the conventional manual technique depends to a great extent on the worker's qualifications, as it involves several processing stages. This fact may serve as a weakness in this technique, as it might lead to the incorporation of voids during mixing and application that could affect marginal accuracy [26].

The results of the present study agreed with two studies [19,21], which found that temporary restorations made using CAD/CAM and 3D printing methods had smaller marginal gaps than interim crowns made using the conventional method. Moreover, other studies [26,27] concluded that the CAD/CAM temporary crowns demonstrated superior marginal fit compared with traditional temporary crowns.

On the other hand, with the CAD-CAM technique, polymerization shrinkage is less of a problem because the higher-density CAD-CAM PMMA block was pre-polymerized under optimal manufacturing conditions, which enabled the production of interim restorations with ideal mechanical qualities during the industrial fabrication process [19]. Regarding the 3D printing group, the resin was printed layer by layer using cross-sectional polymerization under controlled 3D printer settings, resulting in less polymerization shrinkage in the restoration and increased marginal adaptation [19].

Two studies [28,29] were in contradiction with the results of the present study, they concluded that provisional restorations fabricated using 3D-Printing techniques exhibited a lower marginal gap (greater marginal fit) than restorations constructed using the CAD/CAM method. This could be due to the variations in 3D printing machines and various photocuring procedures, which affect the marginal accuracy of the restoration. Another study [30] used the SLA 3D printing photocuring technique, with good precision to print objects with complex structures and fine size by using a laser beam. In the current study, the light intensity of LCD 3D Printing is very weak because only 10 % of the light can penetrate from the LCD screen and 90 % of the light is absorbed by the LCD and this absorption of light explains the weakness of the LCD.

The limitation of this study includes the fact that in vitro studies cannot completely simulate the oral environment such as the presence of saliva. Another limitation was that all testing was performed on epoxy dies models, not on the natural teeth which might have lacked the stimulation of clinical situation. In addition, various printers were not used in the 3D printing technique.

4.1. Conclusion

The following may be valid within the limits of the current study:

The fabrication technique of provisional crowns affects their marginal accuracy. Superior margin accuracy is obtained with CAD CAM-constructed provisional crowns.

4.2. Recommendations

Both CAD CAM and 3D printing techniques for provisional restoration construction exhibit marginal accuracy within clinically accepted values and thus can be recommended for clinical application.

Ethics information

The ethics information mentioned in the first part of the material and method and the study approved under code RECCR-23-0.

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Biographical information

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Conflicts of interest

There is no conflict of interest.

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