Official Dental Journal of Suez Canal University
DENTAL SCIENCE Updates
Print ISSN 2636-3836
Online ISSN 2636-3844
www.dsujournals.ekb.eg
DSU
DSU — Vol. 6, No. 2, September (2025) — PP. 379:386

EVALUATION OF INTERNAL RT OF THREE-DIMENSIONAL PROVISIONAL CROWNS PRINTED WITH DIFFERENT ORIENTATIONS AND DIFFERENT POST CURING TIME PROTOCOLS: AN IN-VITRO STUDY

Gehad Mohamed Ali [1], Tarek Abd El Hamid Abd El Hamid [2], Amr Abdelaziz Shebl Kassem[3], Mosaad Ali Elgabrouny [4]

DOI: 10.21608/dsu.2025.363461.1292
Manuscript ID: DSU-2502-1292

KEYWORDS

Provisional crowns, 3D printer, scanning

- E-mail address: PGS030007 @dent.suez.edu.eg

1. Demonstrator in Fixed Prosthodontics Department, Faculty of Dentistry, Suez Canal University, Ismailia, Egypt.
2. Professor of Fixed Prosthodontics Department, Suez Canal University, Ismailia, Egypt.
3. Assistant professor & Chairman of Fixed Prosthodontics Department, Faculty of Dentistry, Suez Canal University, Ismailia, Egypt.
4. Assistant professor of Fixed Prosthodontics Department, Faculty of Dentistry, Suez Canal University.

ABSTRACT

The effect of 3D printing parameters including different Orientations and post curing time protocols on the internal fit of 3D printed provisional crowns is not clear. **Aim:** This current study is to investigate the effect of three different printing orientations and two different post curing time protocols on the internal fit of provisional printed crowns. **Methods:** A ready-made model of an upper first premolar tooth was scanned. 30 dies were printed using. One of the printed dies was scanned. The design of crown was made. 30 crowns were printed. 18 Provisional crowns were divided into 3 groups (n= 6) according to the printing orientation used: group A (0˚), group B (90˚) and group C (30˚). 12 crowns were divided into 2 groups(n=6) according to the post curing time protocol used: group F (20 min), group G (40 min). Internal fit was measured using stereomicroscope. The effect of different printing orientations and post curing time protocols was statistically analyzed by using One-way ANOVA and independent T-test using IBM SPSS version 26.0. **Results:** There was a statistically significant difference in mean internal gap among the three groups ($p \leq 0.05$). The highest mean internal gap was reported by Group A. The lowest mean internal gap was reported by group C. There was no statically significant difference between group F and group G. **Conclusion:** Changing Printing orientations had an impact on internal fit of provisional restoration but changing post curing time protocols (20 min or 40 min) had no effect.

INTRODUCTION

Provisional restoration may be defined as a fixed or removable dental or maxillofacial prosthesis intended to restore function and aesthetics for a brief amount of time before being replaced by a final prosthesis. The provisional restorations are essential to protect the prepared teeth from thermal, chemical and physical irritations and restores esthetics, phonetics and chewing function in addition to fixing the teeth position until the final restorations are cemented [(1)].

One of the most ideal requirements of a proper provisional restoration is the marginal seal. The margin of the restoration should provide good protection for the prepared tooth in addition to its gingival tissues which is necessary for further cementation. Marginal discrepancies may lead to microleakage which is responsible for post operative sensitivity and recurrent caries [(2)].

There are different methods of fabrication of provisional restoration which involve direct(chairside), indirect (in the laboratory) and indirect- direct. Also, they can be classified according to the duration of its use into short term restoration (which can be used for several days to week), medium term restoration (which can be used for several weeks) and long-term restoration (which can be used for several months) [3].

Indirect fabrication methods involve subtractive manufacturing and additive manufacturing. Subtractive manufacturing using CAD-CAM technology. Additive manufacturing using 3D printing technology had rapidly developed in the recent years, because of its reliability and accuracy, making it highly attractive to the medical field like dentistry, medicine, engineered tissue models and orthopedics[4].

Different additive manufacturing techniques are available as stereolithography (SLA), digital light projection (DLP), powder bed fusion (PBF), fused deposition modeling (FDM), and laser powder forming[5]. These techniques mainly differ in the material used and the way the layers are built to produce the 3D object. SLA and DLP are the two main 3D printing technologies used in dental applications[4].

3D printing parameters including printing orientation and post curing time protocols might influence the property of provisional restoration [6].

After printing, the restoration should be cleaned from excess monomer in isopropyl alcohol then post cured with UV-light [7]. Post curing protocol with UV-light is needed to cross link unreacted monomers to complete the polymerization process of the printed object, which improves its mechanical properties [4]. The amount of polymerization is quantified as the degree of conversion. So, the mechanical properties are significantly improved with higher degree of conversion).Therefore, the time of post curing protocol has an important effect on the mechanical properties of the provisional restoration [8].

Various methods have been employed to measure internal gap, including the direct-view technique, scanning electron Microscopy (SEM), cross-sectioning method, replica technique, 3-D analysis of fit, and microcomputed tomography (Micro CT)[9,10].

Osman et al. [11] evaluated the influence of using nine build angles on the accuracy of 3D-printed dental restorations using digital light-processing technology. The result showed that 135° offered the highest dimensional accuracy and the most favorable deviation pattern followed by 150°. The build angle 270° showed no significant difference with 150°.

Bonada et al. [12] investigated the influence of exposure time on mechanical properties and photocuring conversion ratios for photosensitive materials used in additive manufacturing .

There is a lack of available studies on the effect of different printing orientations and different post curing time protocols on internal fit of 3d printed provisional resin crowns. Thus, this study will be carried out to evaluate the effect of different printing orientations and different post curing time protocols on the internal fit of 3d printed provisional resin crowns.

MATERIAL AND METHODS

Study design

This study was carried out after approval of Research Ethics Committee (REC), Faculty of Dentistry, Suez Canal University (approval number 577/2022).

To evaluate the effect of three different printing orientations and two different post curing time protocols on the internal fit of provisional resin crowns printed with DLP 3D printer.

One-way analysis of variance was proposed (ANOVA). The sample size was calculated according to G*Power software version 3.1.9.2.[5] Accordingly, a total sample size of 30 were found to be sufficient to detect the effect size of 0.85, a power (1-β) of 75% and at a significant level of 5% (p<0.05), with 6 samples for each group.

Samples preparation

A ready-made model of an upper first premolar tooth with an all-ceramic crown tooth preparation was scanned using an intraoral scanner (Omnicam,Dentsply Sirona, United States).

The 3D virtual model of the scanned tooth was sent in STL format (Standard Tesselation Language) to Accuware 3D printing software program of DLP 3D printer (AccuFab-D1s, Shinning 3D, China).

30 resin dies were printed. The 3D printing parameters were set up as follow: layer thickness 50 µm and horizontal printing orientation (0˚). Then, the dies were cleaned using an ultrasonic activated bath of 90% isopropyl alcohol for 5 minutes. Printed dies were post cured in the post curing unit (Fab Cure. Shinning 3D, China) with wavelengths 370 to 500 nm for about 20 minutes according to the manufacturer's instructions. Then, one of the printed dies was scanned using the intraoral scanner. CEREC InLab 16 software was used for crown designing. The cement space was set to 60 µm. The design was exported as a STL file to 3D printing software program (Accuware, Shinning 3D, China). A total of 30 provisional crowns were printed. The 3D printing parameters including (printing orientation, post curing time protocol) were established according to each printed group (n=6).

Samples Grouping:

Crowns were divided into three groups depending on printing orientation used as follow: Group A (n=6) 0◦ (horizontal orientation, occlusal surface facing the building platform). Group B(n=6) 90˚ (vertical orientation, buccal surface facing the building platform and making angle 90°with it). Group C (n=6) 30◦ (diagonal orientation, buccal surface facing the building platform and making angle 30°with it). The 3D printing parameters were set up as follow: layer thickness 50 µm and printing orientation according to each group printed. Then, cleaned using an ultrasonic activated bath of 90% isopropyl alcohol for 5 minutes. The crowns were post cured in the post curing unit (Fab Cure. Shinning 3D, China) with wavelengths 370 to 500nm for about 20 minutes according to the manufacturer's instructions.

All the crowns were cemented using Charm Temp NE cement on their corresponding dies. An epoxy resin was carefully poured onto the cemented crowns assembly within a pre-made mold. Internal gaps were recorded by sectioning half of the cemented crowns in a bucco-lingual direction and the other half in a mesio-distal direction using a low speed cutting saw (Micracut 125, Metkon). The internal gaps were recorded at 24 points: 8 points at the occlusal surface and 8 points at each axial wall of each crown fitting surface using the stereomicroscope at a magnification of 35 X.

Test involved internal fit were done for groups A, B and C.

Group C showed the most favorable results in comparison to groups A and B in the performed tests. Therefore, the diagonal printing orientation (30°) was used as the printing orientation for printing the remaining groups (F and G).

12 Provisional crowns were printed with the same printing orientation (printed in 30◦with diagonal orientation) and layer thickness (50 µm).

Then, cleaned using an ultrasonic activated bath of 90% isopropyl alcohol for 5 minutes. These crowns were divided into 2 groups according to the used post curing time protocol as follow:

Group F: 6 Provisional crowns were post cured for 20 min.

Group G: 6 Provisional crowns were post cured for 40 min.

Test involving internal gap were conducted as mentioned before.

Statistical analysis

All data were collected, calculated, tabulated, and statistically analyzed using the following statistical tests. A normality test (Shapiro-Wilk) was done to check the normal distribution of the samples. Descriptive statistics were calculated in the form of Mean ± Standard deviation (SD). To compare groups in each variable under study the tests as follow were used.

- One-way ANOVAs were performed. Bonferroni's post hoc test was used to determine statistical significance between groups.
- Dependent (paired) and Independent T- test was used to compare between times and the different two groups.
- P value ≤ 0.05 is considered statistically significant.
- All Statistical analysis was performed using the computer program SPSS software for windows version 26.0 (Statistical Package for Social Science, Armonk, NY: IBM Corp).

RESULTS

1. For groups printed with different orientations:

Internal gap results for groups (A, B, C) (**Fig. 1**) showed that: the mean internal gap of group C (60.76[± 6.96]) was significantly the lowest compared to group A (72.26µm [± 6.07]) and B (64.78 µm [± 6.11]). while there was no statistically significant difference between group B & group C (Table 1).

Table (1) *Mean and standard deviation (SD) va lues of the internal gap recorded in µm for the three groups printed with different printing orientations*

Groups	Mean	SD	P value
Group A	72.26[a]	6.07	
Group B	64.78[b]	6.11	<0.001**
Group C	60.76[b]	6.96	

** and different letters(a,b) mean significant difference using one way ANOVA test at P<0,.05

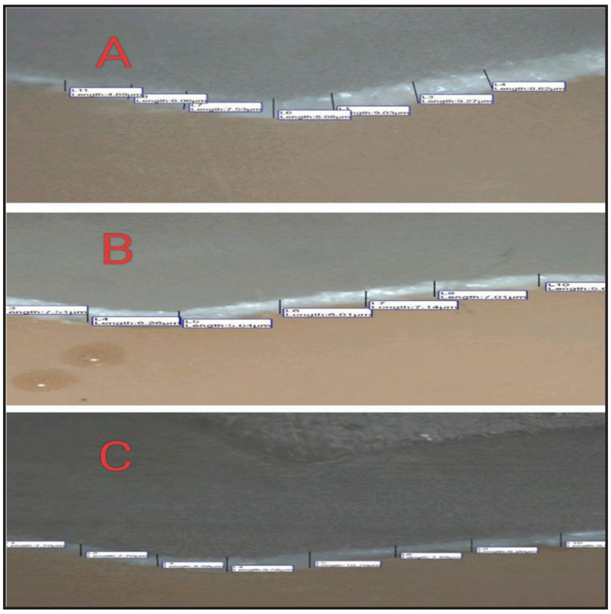

Fig. (1) The occlusal internal gap measurements of the buccolingual section for groups (A ,B,C) samples under a stereomicroscope.

2. **Groups post cured with different post curing time protocols:**

Internal gap results for groups F, G (**Fig. 2**) showed that: there was no statistically significant difference between the two groups: group F (61.66μm [±4.01])), group G (67.84μm [±3.70}) (Table 2).

Table (2) *Mean and standard deviation (SD) values of the internal gap recorded in µm for the two groups post cured with different post curing time protocols.*

Groups	Mean	(SD)	P value
Group F	61.66	4.01	0.06ns
Group G	67.84	3.70	

Ns means no significant difference using independent T test at P<0.05

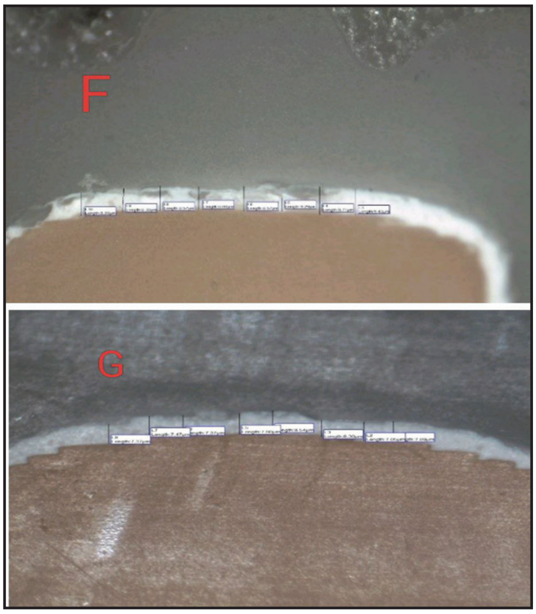

Fig. (2) Occlusal internal gap measurements of the mesiodistal section for groups (F,G) samples under stereomicroscope.

DISCUSSION

This study was performed to investigate the effect of 3D printing orientations and post curing time protocol of 3D printed provisional crowns on internal fit on the upper 1st premolar. Depending on the result, the internal fit impacted by different printing orientations and different post curing time protocols. The null hypothesis was rejected depending on the finding of the comparative of the internal fit for the different printing orientations and post curing time protocols.

For samples of these study to be identical, one of the printed dies was scanned using Cerec Omnicam intraoral scanner. A STL file was exported to the CEREC InLab 16 software to design the crowns [13]. 30 crowns were printed with the same design changing in 3D printing parameter according for each printed group.

The printed crowns were cleaned using an ultrasonic activated bath of 90% isopropyl alcohol for 5 minutes to remove the uncured resin [7]. Then, the crowns were placed in post curing unit to cross link unreacted monomers which were presented due to the oxygen in the air diffusing into the outer layers of resin while printing, preventing the printed object from fully curing. So, post curing was an essential step to complete the polymerization process of the printed crowns, thus improving their mechanical properties[4].

To standardize the cementation procedure, the provisional crowns were cemented on the dies by using a single temporary cement. Seating of the crowns on their corresponding dies was done by using a specially designed device, which allowed static placement of 3Kg load on the occlusal surface of the crowns during the cementation procedure to eliminate any potential discrepancies in pressure that may arise from manual manipulation. This load was recommended by **Abdel Hamid** [13] **and Emam & Aleem** [14] to prevent potential damage to the provisional crowns.

To evaluate the internal gap, an epoxy resin was carefully poured onto the cemented crowns assembly within a pre-made mold to ensure the stable positioning of the crowns over their corresponding dies during the cutting process. A low speed cutting saw was used to bisect half of the samples of each group in a mesio-distal direction, with the rest being bisected in a bucco-lingual direction. For measurement of the internal gap of the crowns, stereomicroscope with magnification 35 x was used due to its accuracy and non-invasiveness. [15 ,16]. 8 readings were recorded for each internal surface with a total of 24 readings for each half of the crown.

The effect of different printing orientations on the internal gap:

In order to standardize the production of provisional crowns, all crowns were printed using the identical STL file and layer thickness of 50 µm as mentioned by the manufacturer, with modification of printing orientation according to each group.

Group C printed with 30° orientation showed the lowest internal gap. This might be attributed to the fact that with this printing orientation, the buccal surface of the crown was positioned at an angle of 30° facing the printing platform. Polymerization shrinkage was directed towards the buccal surface. Also, this might be attributed to the fact that polymerization shrinkage occurred towards areas with higher resin content. Areas connected to supporting structures might show large amount of polymerization shrinkage as they contain high amount of resin volumes compared with other areas during printing [17]**.** As long as, the amount of resin increased, the polymerization shrinkage also increased as mentioned by [2]**.**

On the other hand, when the printing orientation was horizontal (0°) in group A, the 3D printed samples exhibited the highest average values of internal gap. This might be attributed to the fact that with this orientation, the occlusal surface of the crowns faced the 3D printer platform, where it was connected to the supporting structure with high resin volume in that area. This might lead to polymerization shrinkage directed towards this surface, resulting in larger internal gap. This came in agreement with **Park et al** [18] .

The vertical orientation at 90° did not show any significant difference in the internal gap compared to the diagonal printing orientation at 30°. By positioning the buccal surface of the crown at an angle 90° facing the printing platform, polymerization shrinkage was directed towards the buccal surface. This came in agreement with **Osman et al.** [11] **and Ryu et al.** [15]**.**

Osman et al. [11] investigated the dimensional accuracy of the provisional crowns in 9 different angles using a DLP 3D printer. They concluded that the build angle 150° which is corresponding to 30° build angle in the present study gave the lowest value of internal gap.

Also, **Ryu et al.** [15] investigated the marginal and internal fit of 3D printed provisional crowns using 6 building directions. They reported that build angle 150° which is corresponding to 30° build angle in the current study had the lowest internal gap.

The effect of different post curing time on internal gap:

To standardize the printing process for the provisional crowns, all crowns were printed using the same STL file and were oriented at a set angle of 30° and layer thickness 50 μm based on the achieved outcomes. The only variation between groups was in post curing time protocols, which were adjusted according to each specific group.

There was no statically significant difference in internal gap between group F (post cured for 20 min) and group G (post cured for 40 min). This might be explained by the fact that the resin shows the maximum degree of conversion into polymer after post curing for 20 min as mentioned by the manufacture. Therefore, no differences were observed when the post-curing time was extended to 40 minutes

The results of the current study came in agreement with the results of **Eić,** [19] **and Bonada et al.** [12] who reported that post-curing time did not affect the degree of conversion.

CONCLUSIONS

Within the limitations and conditions of this in vitro study, it was concluded that:

1. Provisional crowns printed with diagonal orientation of 30 ° showed the best internal fit compared to crowns printed with horizontal orientation of 0° and those printed with vertical orientation of 90 °.
2. Changing post curing time protocols (20 min or 40 min) had no impact on internal fit of 3D printed provisional crowns.

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