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Comparative evaluation of marginal fit and fracture resistance in polymethyl methacrylate interim crowns fabricated by 3D printing, CAD-CAM milling, conventional method: An *in vitro* study

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Abstract:
Inadequate marginal adaptation and reduced fracture resistance of conventionally fabricated provisional crowns remain major clinical concerns in fixed prosthodontics. Therefore, it is of interest to evaluate the marginal fit and fracture resistance of 78 PMMA interim crowns fabricated using three different techniques: conventional fabrication, CAD/CAM milling and 3D printing. Provisional crowns should have optimal marginal fit and strength, during the interim period. The fit and fracture resistance of 78 samples of interim crowns made of PMMA using 3 different fabrication methods (conventional fabrication technique, CAD/CAM milling technique and 3D printing technique) were tested. Fit was determined by using scanning electron microscope, while fracture resistance was tested by using a Universal Testing Machine (UTM). The results of the investigation showed CAD/ CAM fabricated crowns demonstrated better marginal fit and greater fracture resistance than either of the other two methods. Thus, data shows that 3D printed interim crowns may be an acceptable method of construction, based on clinical need and have limitations.

Keywords: Polymethyl methacrylate (PMMA), provisional crowns, computer-aided design and computer-aided manufacturing (CAD/CAM), 3D printing, marginal fit, fracture resistance

Background:
Temporary restorations play a significant role in fixed prosthetic treatment as they provide protection and allow for maintenance of function during the interim period before placement of the final prosthesis on a prepared tooth. They also assist in maintaining the health of the gingiva and occlusion for the term of the treatment **[1]**. For many years, dentists have utilized PMMA for temporary crowns **[2]**. The ease of working with this material and its affordable price make it a common choice for clinical use. Although milling and 3D-printing methods both use the same CAD/CAM process, the slightly larger gap observed in the 3D-printing group of the present study can be attributed to polymerization shrinkage during curing and to dimensional changes during post-processing. Errors in slicing the STL file on the printer's software can also impact the fit of the restoration **[3]**. During the curing process of a temporary crown, the shrinkage of the polymer and the heat developed during this process can adversely impact how well the restoration will fit at the margins of the tooth preparation **[4]**. Poor-fitting restorations can be the result of either because of the growth of digital dentistry and the use of newer techniques to fabricate temporary restorations, such as CAD/CAM milling or 3D printing; these have been incorporated into clinical practice **[5]**. Using pre-polymerized PMMA blocks in the CAD/CAM process reduces the amount of shrinkage during polymerization and provides a means to create a more uniform restoration material, resulting in improved marginal accuracy **[6, 7]**. The current use of digitally fabricated IRs using computer aided design and computer aided manufacturing (CAD/CAM) technology overcame multiple drawbacks of chairside fabrication, allowing for reduced chair time, improved accuracy, and better quality of the resultant restorations **[8].** The use of 3D printing is also a viable alternative to traditional techniques due to its ability to build up the crown using successive layers of PMMA. The advantages of using 3D printing over conventional techniques are that there is less waste material and the turnaround time is less. However, the nature of the end product may be affected by layer thickness and orientation **[9]**. Marginal fit is an important aspect of a successful provisional restoration. When a provisional is poorly adapted at the margin, plaque may collect on the margin and cause irritation to surrounding tissues. Fracture resistance is also a critical factor, especially posteriorly where the load is greatest **[10]**. Therefore, it is of interest to assess the marginal fit and fracture resistance of PMMA provisional crowns fabricated by conventional methods, by CAD/CAM and 3D printing procedure.

Materials and Methods:
The present study was conducted with a sample size of 78 PMMA samples. Of these, 36 samples were utilized for marginal fit testing and 42 samples were utilized for fracture resistance analysis. The samples were divided into three groups based on

the method of fabrication (conventional, CAD/CAM, 3D printing). For the purpose of marginal fit testing, 12 crowns were included from each of the three groups. In total, 14 bar-shaped specimens were used from each of the three different groups for testing fracture resistance. The conventional group was fabricated from auto polymerizing acrylic resin, which was mixed as directed by the manufacturer and the resin was applied to a die using a template. The specimens were finished to remove the excess material following polymerization. Every effort was made to ensure consistent results, but there may be slight differences created during handling of materials. All master dies for both the CAD/CAM group and 3D printing group were scanned to produce digital files of the same size as each crown. CAD software was then used to design the crown and create a milling program that enabled crowns from pre-polymerized PMMA blocks to be milled using a 5-axis CNC milling machine. Because this method has some potential to cause variation in finishing, very little finishing was done so the margins would remain unchanged. The digital file of the crown was converted to STL format and sliced to prepare the digital file for printing using a DLP 3D printer, which uses a light-sensitive resin as a medium for printing. After printing, the crowns were cleaned in isopropyl alcohol and then post-cured under UV light according to the manufacturer's instructions. To evaluate the marginal fit, all crowns were seated on master dies and then measured at four predetermined locations using an optical microscope to obtain four marginal fit measurements. The means of these measurements was calculated and used for final analysis. To test fracture resistance, samples in the form of rectangular bars were subjected to a compressive load at an increasing rate until fracture occurred, using a universal testing machine. The maximum load was recorded as being reached when fracture occurred. The information collected was analyzed statistically by one-way analysis of variance, with post hoc comparisons being made as necessary for groups found to have statistically significant differences ($p<0.05$).

Results:

A significant difference was noted between all three experimental groups. In regard to marginal fit, the CAD / CAM group had the lowest marginal gap measurements of any of the groups, with the 3D printed group showing marginal gap measurements slightly above acceptable levels. The conventional group produced significantly greater mean marginal discrepancies than the other groups and there was a greater degree of variation seen within the conventional group samples than within any of the other groups **(Table 1)**. The marginal fit values from SEM readings for all test specimens varied as follows: Group 1 (conventional method): 41.43 µm to 68.42 µm, with a mean ± SD of 53.84 ± 8.85 µm. Group 2 (CAD/CAM method): 22.75 µm to 29.03 µm, with a mean ± SD of 25.71 ± 2.09 µm. Group 3 (3D printing method): 29.85 µm to 49.63 µm, with a mean ± SD of 39.30 ± 5.84 µm **(Table 1)**. The fracture resistance values for all test specimens varied as follows: Group A (conventional method): 305.32 N to 324.27 N, with a mean ± SD of 314.52 ± 6.22 N. Group B (CAD-CAM method): 345.90 N to 364.23 N, with a mean ± SD of 354.59 ± 5.77 N. Group C (3D printing method): 326.78 N to 339.90 N, with a mean ± SD of 332.99 ± 4.13 N **(Table 2)**.

Table 1: Marginal Fit of test samples for Group 1 (Conventional Crowns), Group 2 (CAD/CAM Crowns) and Group 3 (3D Printed Crowns) in µm

S no	Conventional (Group1)	CAD-CAM (Group 2)	3D printed (Group3)
1	62.7	28.18	40.56
2	41.43	24.8	37.83
3	65.56	25.7	39.88
4	49.95	26.01	29.85
5	48.28	22.87	47.9
6	46.03	25.32	40.88
7	46.08	23.44	41.64
8	58.59	26.77	36.21
9	68.42	25.41	49.63
10	54.87	29.03	31.75
11	45.73	22.75	41.01
12	58.48	28.26	34.46
Mean	53.84	25.71	39.30
SD	8.85	2.09	5.84

Table 2: Fracture Resistance (N) of test samples of Group1 (Conventional Sample), Group 2 (CAD/CAM Sample) and Group 3 (3D Printed Sample)

S no	Conventional (Group A)	CAD-CAM (Group B)	3Dprinted (Group C)
1	306.15	354.02	334.28
2	324.27	359.44	327.94
3	317.82	347.85	338.11
4	311.45	361.72	332.77
5	322.1	349.18	329.65
6	309.38	356.09	336.84
7	315.67	352.37	331.02
8	318.94	360.56	339.9
9	305.32	345.9	328.35
10	310.86	358.71	335.26
11	319.45	350.68	337.41
12	307.9	364.23	326.78
13	321.16	348.31	333.07
14	312.77	355.17	330.51
Mean	314.517	354.588	332.992
SD	6.223	5.769	4.132

Discussion:

The current study has showed that the method of fabrication does seem to be an important factor affecting final marginal fit and fracture resistance of PMMA interim restorations **[11]**. The CAD/CAM group also showed significantly better results than the other two groups for both marginal fit and fracture resistance. One possible explanation for this difference could be attributed to the fact that the pre-polymerized PMMA blocks used with the CAD/CAM systems were produced under strictly controlled conditions; as such, this material would be of a more consistent nature with fewer internal defects **[12]**. The results in the conventional group were much lower than the other two groups. This could be a result of the presence of polymerization shrinkage and handling methods during the fabrication process **[13, 14]**. There are many small variables that may vary with mixing and adaptation that could affect fit and this is frequently observed during day-to-day clinical work as well. The overall statistics for 3D printed samples were in the middle of the other two groups. Although they were not as high as CAD/CAM, the results obtained were still acceptable **[15, 16]**. The process of fabricating using layers may introduce small differences in their final fit, and this could be a contributing factor **[17]**. At the same time, materials and techniques for 3D printing may improve future results **[18]**. A practical benefit of utilizing 3D printing is that there will be a reduction in the amount of waste material and a reduction in the amount of time to produce the final product **[19]**. CAD/CAM techniques are better suited for situations requiring a highly precise fit, whereas 3D-printed crowns may provide greater mechanical strength for long-term use **[20]**. The interim restorations materialized by a milling technique showed a higher resistance to fracture compared to the provisional restorations obtained by 3D printing. The fabrication of interim restorations using a subtractive technique, or milling technique, could be considered a reliable and conservative method for the production of stronger provisional restorations **[21].** This may be beneficial in clinical situations where multiple provisional restorations may be required. It is important to keep in mind that this study was performed *in vitro* and did not take into consideration the effect of temperature variations, saliva, or long-term loading on the durability of the materials *in vivo*.

Conclusion:

CAD/CAM produced better marginal fit and higher fracture strength and 3D printing produced acceptable results and the conventional technique exhibited greater variability and relatively diminished values. From a clinical perspective, digital techniques seem to yield more reliable outcomes, although the selection of method may be contingent upon the particular circumstances.

Advancement to knowledge:

This study provides a direct comparative evaluation of marginal fit and fracture resistance among conventionally fabricated, CAD/CAM-milled and 3D-printed PMMA interim crowns under standardized laboratory conditions. The findings contribute contemporary evidence supporting the superiority of CAD/CAM-milled provisional restorations while also showing the clinical acceptability of 3D-printed interim crowns. The study additionally highlights the potential role of digital fabrication methods in improving accuracy, consistency and sustainability in provisional prosthodontics.

References:

[1] Burns DR *et al. J Prosthet Dent.* 2003 **90**:474. [PMID: 14586312]
[2] Givens EJ Jr *et al. J Prosthodont.* 2008 **17**:97. [PMID: 17971123]
[3] Elashkar M *et al. BMC Oral Health.* 2025 **25**:354. [PMID: 40055647]
[4] Felton DA *et al. J Prosthet Dent.* 1991 **65**:357. [PMID: 2056454]
[5] Alharbi N *et al. Int J Prosthodont.* 2017 **30**:474. [PMID: 28750105]
[6] Abdullah AO *et al. J Appl Oral Sci.* 2016 **24**:258. [PMID: 27383707]
[7] Abad-Coronel C *et al. Polymers.* 2023 **15**:1761. [PMID: 37050375]
[8] Meenakshi S *et al. Int J Prostho Restor Dent*. 2025 **15**:141. [DOI: 10.5005/jp-journals-10019-1508]
[9] Ryu JE *et al. J Adv Prosthodont.* 2020 **12**:225. [PMID: 32879713]
[10] Haselton DR *et al. J Prosthet Dent.* 2002 **87**:225. [PMID: 11854681]
[11] Sadighpour L *et al. Scientifica (Cairo).* 2025 **2025**:1608702. [PMID: 40458247]
[12] Torkamandi L *et al. Dent Res J (Isfahan).* 2021 **18**:36. [PMID: 34760075]
[13] Mohajeri M *et al. Front Dent.* 2021 **18**:31. [PMID: 35965729]
[14] Kanchan LB *et al. Int J Prosthodont Restor Dent.* 2021 **11**:112. [DOI: 10.5005/jp-journals-10019-1326]
[15] Falahchai M *et al. Clin Exp Dent Res.* 2022 **8**:1404. [PMID: 37422420]
[16] AlHelal A *et al. J Prosthet Dent.* 2016 **117**:233. [PMID: 27765399]
[17] Jain S *et al. Polymers.* 2022 **14**:2691. [PMID: 35808735]
[18] Sidhom M *et al. Polymers.* 2022 **14**:1285. [PMID: 35406159]
[19] Sadid-Zadeh R *et al. J Prosthodont.* 2021 **30**:720. [PMID: 33450099]
[20] Ravat HA *et al. J Med Dent Sci Res.* 2025 **15**:19. [DOI: 10.35629/076X-12051923]
[21] Abad-Coronel C *et al. Materials (Basel).* 2021 **14**:7791. [PMID: 34947384]