



Microleakage Evaluation of PMMA Provisional Crowns Made with CAD/CAM Technique

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ABSTRACT

Background and Objective: The provisional phase in crown and bridgework significantly influences the success or failure of the final restoration. They protect the prepared teeth, maintain occlusal stability, and meet aesthetic and functional needs during the period between tooth preparation and the final crown placement. Inadequate marginal sealing of temporary restorations may result in various complications; however, advancements in digital dentistry have recently enhanced the precision and marginal integrity of these restorations. This study aimed to evaluate the microleakage of poly methyl methacrylate (PMMA) provisional crowns made using the computer-aided design/computer-aided manufacturing (CAD/CAM) technique.

Materials and Methods: This in vitro experimental study was conducted using 12 identical resin dies milled from one extracted, standardized human mandibular first molar after preparation. Provisional crowns were designed and fabricated using CAD/CAM techniques from pre-polymerized PMMA blocks. All crowns were cemented with non-eugenol zinc oxide temporary cement (GC Free eugenol, Japan), subjected to static artificial aging in distilled water at 55 °C for 5 days, and loaded with a 5 kg vertical force to simulate clinical seating. The samples were then immersed in 2% methylene blue solution for 24 h, buccolingually sectioned using a low-speed diamond disc, and examined under a stereomicroscope (Cambridge, UK) at 30× magnification. A total of 12 specimens were evaluated, with four distinct areas examined in each specimen (Buccal A, Buccal B, Lingual A, Lingual B), and a total of 48 areas were assessed for microleakage. Dye penetration was scored from 0 to 4 (0 = no penetration; 4 = penetration up to the occlusal surface). Data were analyzed using IBM SPSS Statistics (version 27). The Wilcoxon signed-rank test was used to compare the buccal and lingual surfaces within the same sample. Friedman tests were used to assess the variations across all surfaces, and the chi-square test was used to evaluate the association between fabrication technique and leakage score categories. The significance level was set at $p < 0.05$.

Results: The CAD/CAM provisional crowns showed significantly low microleakage scores. Moreover, the buccal surfaces showed less microleakage than the lingual surfaces. Regarding occlusal surface microleakage, the CAD/CAM provisional crowns showed no occlusal leakage. However, the differences in microleakage on the lingual surfaces were not statistically significant. Furthermore, comparisons within the same group of surfaces were not significant.

Conclusion: According to the findings of the present study, CAD/CAM-fabricated temporary crowns demonstrated good marginal integrity and low scores of microleakage. The lower values on the buccal surfaces and the lack of occlusal microleakage indicate improved CAD/CAM restorative accuracy and adaptability.

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1. INTRODUCTION

Provisional crowns are temporary restorations used in fixed prosthodontic treatment. They are used as interim restorations that maintain function, aesthetics, and protection during the period between tooth preparation and the placement of definitive restorations [1–3]. These interim restorations are also used in diagnostic evaluation and treatment planning, particularly when assessing parameters related to occlusion and aesthetics [1].

Polymethyl methacrylate (PMMA) is a commonly used material for provisional crowns. It is favored for its cost-effectiveness, ease of manipulation, and acceptable aesthetics. However, PMMA has some disadvantages, such as polymerization shrinkage, heat generation during curing and potential pulpal irritation [1, 4]. In addition, The fabrication technique significantly influences crown fit and marginal adaptation. The direct (intraoral) fabrication method of provisional crowns is not favorable due to tissue trauma and less marginal adaptation compared with the indirect (extraoral) fabrication method [5, 6].

The marginal adaptation is a critical factor in minimizing complications such as bacterial penetration, secondary caries, and pulp inflammation. Poor marginal fit leads to the passage of fluids, bacteria, and debris between the restoration and the tooth structure. This process is called microleakage. [7]. Microleakage is influenced by polymerization characteristics, thermal changes, material properties, and cementation technique [8, 9].

Recent developments in digital dentistry, especially in computer-aided design/computer-aided manufacturing (CAD/CAM), have improved the precision of provisional restorations. CAD/CAM crowns fabricated using pre-polymerized PMMA blocks have been reported to have less polymerization shrinkage and better marginal fit [10, 11]. However, the accessibility of this method of fabrication is limited because of its high cost [12].

Several studies have evaluated the sealing ability of digitally fabricated restorations, including those made by milling and three-dimensional (3D) printing. Reyes et al, noted that 3D-printed provisional crowns showed lower microleakage compared to both CAD/CAM and conventionally fabricated crowns[13]. Conversely, Shabana et al. (2024) reported that CAD/CAM crowns provided a better marginal fit than 3D-printed crowns [14].

Al-Humood et al. (2023) and Kelvin Khng et al. (2016) studies showed that CAD/CAM crowns have less vertical marginal discrepancies and better marginal fit

than crowns fabricated by the conventional technique. These studies confirm that industrial-level precision contributes to a more effective biological seal [15, 16].

Another study by Sidhom et al. (2022) reported that CAD/CAM and 3D printed crowns can achieve clinically acceptable marginal fit. Nevertheless, CAD/CAM crowns exhibited lower microleakage. This result emphasizes that the fabrication technique influences the seal [17].

Although the use of digital methods is becoming more common, there is still no standard in vitro research evaluating the microleakage of long-term CAD/CAM PMMA provisional crowns. This study aimed to evaluate the microleakage of PMMA provisional crowns fabricated using the CAD/CAM method under controlled laboratory conditions.

2. MATERIAL AND METHODS

This in vitro study used a single extracted human mandibular first molar, free of caries and restorations, for standardization. The tooth was prepared with a 1.0 mm shoulder finish line, 1.5 mm occlusal reduction, and a convergence angle of 7–10°. A 3D scanner (UP3D-UP560, China) and Exocad CAD software were used to digitize the prepared teeth. 12 Resin master dies were milled from pre-polymerized PMMA blocks using a 5-axis milling machine (Amann Girrbach Ceramill Mikro 5X) to ensure uniformity and dimensional stability. 12 Provisional crowns were designed in Exocad, milled from Denxy PMMA A2 blocks, and polished using silicon carbide paper (600 and 1200 grit).

Provisional Crowns were cemented using zinc oxide non-eugenol temporary cement (GC Freegenol, Japan) under finger pressure for 10 s, followed by a static vertical load of 5 kg for 5 min. Excess cement was removed, and the specimens were stored in distilled water at 37 °C for 10 days. The specimens were then artificially aged in a water bath at 55 °C for 5 days, equivalent to approximately five months of clinical function [18–20].

Table 1. Descriptive Statistics of Microleakage Scores by Surface (CAD/CAM)

	Buccal A	Lingual A	Buccal B	Lingual B
N	12	12	12	12
Median	0.00	1.00	0.00	1.00
Mode	0	1	0	1
Minimum	0	0	0	0
Maximum	3	2	3	2

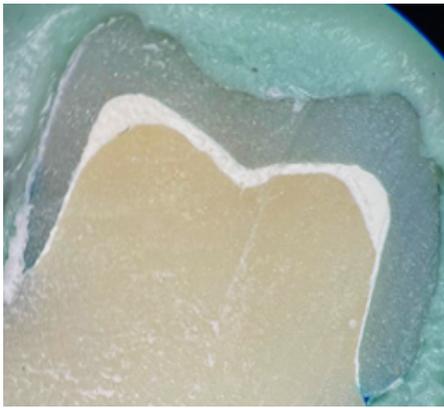


Figure 1. Cross-section of CAD/CAM crown luted with ZnO₂ non-eugenol cement (No microleakage of the dye can be seen)



Figure 2. Cross-section of CAD/CAM crown luted with ZnO₂ non-eugenol cement (No microleakage of the dye can be seen)

Each specimen was then coated with nail varnish, leaving a 1 mm window around the margin, and immersed in 2% methylene blue dye for 24 h. After rinsing, the specimens were buccolingually sectioned using a diamond disc and a guided metal template. Microleakage was evaluated on all four surfaces of each specimen (mesiobuccal (Buccal A), distobuccal (Buccal B), mesiolingual (Lingual A), and distolingual (Lingual B)) with three points assessed on each surface. Dye penetration was evaluated under a stereomicroscope (Cambridge Instruments, UK) at $\times 30$ magnification, which was enhanced to $\times 300$ using a digital camera. Scoring followed a five-point scale (0–4), as described by Punathil et al. (2019) [21].

Data were analyzed using IBM SPSS Statistics version 27.0 for Windows (IBM Corp., Armonk, NY, USA). Normality was assessed using the Shapiro–Wilk test. The Wilcoxon signed-rank and Friedman tests were used for within-group comparisons. A significance level of $p < 0.05$ was applied to all tests.

3. RESULTS

Overall, CAD/CAM provisional crowns demonstrated great resistance to microleakage, as shown in Table 1 that the CAD/CAM provisional crowns showed minimal microleakage, with median values of 0 for all three surfaces and a maximum score of 3.

Table 2 shows the frequencies and percentages of microleakage scores for the CAD/CAM groups. Provisional CAD/CAM crowns exhibited low microleakage scores. No microleakage. Figure 1 that score 0 was most frequently observed on the buccal surfaces, especially Buccal B (66.7%), whereas minimal leakage Figure 2, score 1, was more common on the lingual surfaces. Importantly, no cases of occlusal surface leakage (score 4) were observed in this group. These findings suggest that CAD/CAM-fabricated provisional crowns provide good marginal sealing and may reduce the risk of microleakage-related complications in the long term. The Wilcoxon signed-rank test was used to compare the buccal and lingual surfaces, as shown in Table 3.

The analysis found no significant difference in marginal sealing between the buccal and lingual surfaces of the CAD/CAM crowns, showing consistent performance across both areas. However, a slight trend toward higher microleakage on the lingual side was observed.

The Friedman test was performed to assess whether there were statistically significant differences in microleakage scores among the four surfaces (Buccal A, Buccal B, Lingual A, and Lingual B), as shown in Table 4.

The analysis showed only minor differences in mean ranks among the four surfaces, and the results were not statistically significant ($\chi^2(3) = 2.589, p = .459$). This suggests that microleakage in CAD/CAM-fabricated crowns was consistent across all surfaces, indicating a uniform marginal integrity.

4. DISCUSSION

One of the main and most important functions of a provisional restoration is to create an effective marginal seal against microbial and fluid penetration during the interim period before the final restoration placement. The provisional crown seal helps protect the pulp vitality and periodontal health. In this in vitro study, the marginal microleakage of PMMA provisional crowns fabricated using CAD/CAM techniques was evaluated using standardized preparation, cementation, and aging procedures. Microleakage was measured at four surfaces (Buccal A, Buccal B, Lingual A, and Lingual



B) using a dye penetration method and scored on a five-point ordinal scale. This study showed that the

Table 2. Microleakage Frequency Distribution for CAD/CAM provisional crowns

Score Description	Buccal A (N, %)	Lingual A (N, %)	Buccal B (N, %)	Lingual B (N, %)
0: No microleakage	(58.3%)	4 (33.3%)	8 (66.7%)	3 (25.0%)
1: Up to 1/3 of the axial wall	(25.0%)	6 (50.0%)	3 (25.0%)	7 (58.3%)
2: Up to 2/3 of the axial wall	(8.3%)	2 (16.7%)	-	2 (16.7%)
3: Along the full length of the axial wall	(8.3%)	0 (0%)	1 (8.3%)	0 (0%)
4: Microleakage over the occlusal surface	(0%)	0 (0%)	0 (0%)	0 (0%)

CAD/CAM process creates restorations with a precise marginal fit and sealing. The Wilcoxon test revealed no significant difference in microleakage between the buccal and lingual margins, indicating the consistent and reliable sealing of CAD/CAM crowns. A slightly

Table 3. Wilcoxon Signed-Rank Test Results

Comparison	p-value	Significance
Buccal_A vs Lingual_A (CAD/CAM)	0.527	No
Buccal_B vs Lingual_B (CAD/CAM)	0.096	No

non-significant likelihood of greater microleakage on the lingual side was noted, indicating that future studies with larger sample sizes should explore this finding further. Overall, the findings of this study show that CAD/CAM provisional crowns provide exceptional precision and marginal fit, which help minimize microleakage and

Table 4. Friedman Test: Within-Group Comparison of Microleakage Scores Among Surface.

Surface	Mean Rank	Chi-Square	df	p-value
Buccal A	2.42	2.589	3	0.459
Lingual A	2.63			
Buccal B	2.17			
Lingual B	2.79			

enhance the clinical reliability of temporary restoration. The low levels of microleakage observed can be attributed to the controlled manufacturing process of CAD/CAM systems, where restorations are milled from pre-polymerized PMMA blocks, reducing polymerization shrinkage and void formation. In contrast, manually fabricated restorations are more prone to human error, which can increase the microleakage levels. These results are consistent with those of Eid et al. (2024) and Kheir et al. (2023), who also reported that CAD/CAM restorations provide superior marginal sealing owing to their improved accuracy and fit[22, 23].

The present study showed no significant differences in microleakage on the lingual surfaces. This may be related to the complex anatomical morphology and reduced accessibility during the fabrication and seating of crowns, which could affect the accuracy of marginal adaptation. This observation is consistent with the findings of Balkenhol et al. (2008), who reported increased microleakage and fit issues at the lingual margins, even with advanced technologies[24]. Many studies have reported that CAD/CAM provisional crowns have less microleakage owing to better marginal fit. Abduo and Lyons (2013) reported that digital workflows have a favorable marginal fit. The findings of this study correspond to those of a previous study[25]. A comparative study using non-eugenol cements conducted by Robaian et al. (2021) agreed with the results of the present study [26]. Khsara et al. (2021) supported that better marginal sealing and adaptation are achieved when CAD/CAM is combined with non-eugenol temporary cements. These findings suggest that both material selection and cement type affect the presence of microleakage [27].

Finally, Arora et al. (2016) showed that non-eugenol temporary cements significantly reduced microleakage compared to eugenol-containing cements. Therefore, cement type plays a critical role in the marginal seal [7]. The strengths of this study include standardized tooth preparation and cementation, assessment of multiple crown surfaces, and the use of appropriate non-parametric statistical tests for ordinal data. However, this study has several limitations. As an in vitro study, it did not fully simulate oral conditions, such as thermal variations, pH changes, and occlusal forces. The lack of conventional provisional restorations to compare with CAD/CAM restorations. The small sample size (n = 12) and use of a single duplicated tooth limited the generalizability and anatomical variability of the results. Aging was limited to static water storage without thermocycling or mechanical loading, only one temporary cement was tested, and microleakage assessment relied solely on dye penetration under a stereomicroscope. Further in vivo studies with

larger, more diverse samples, and advanced evaluation methods are recommended.

5. CONCLUSION

The CAD/CAM-fabricated provisional crowns exhibited excellent marginal fit and very low microleakage on all surfaces. The consistent results across the buccal and lingual areas highlight the accuracy and reliability of the CAD/CAM process, suggesting that digital fabrication can improve the durability and clinical performance of provisional restorations.

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CONFLICT OF INTEREST

None to declare.

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