ORIGINAL RESEARCH

Assessment of Marginal and Internal Adaptation in Provisional Crowns Utilizing Three Distinct Materials

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Abstract

Aims: This study aimed to assess the marginal and internal adaptation of provisional crowns fabricated from polymethyl methacrylate (PMMA) blocks by the computer-aided design/computer-aided manufacturing (CAD/CAM) system, autopolymerizing PMMA, and acrylic base composite resin.

Materials and methods: In this *in vitro* experimental study, a brass die was obtained, and provisional crowns were fabricated in three groups using Teliocad PMMA blocks by the CAD/CAM system, Tempron GC auto-polymerizing PMMA, and Bisico acrylic base composite resin ($n = 7$ in each group). The provisional crowns were coded and randomly placed on the die. Their marginal adaptation was evaluated under a stereomicroscope at 40× magnification, while their internal adaptation was assessed by the replica technique. Data were analyzed by one-way analysis of variance (ANOVA) ($\alpha = 0.05$).

Results: The mean marginal gap was the highest in autopolymerizing PMMA and the lowest in the CAD/CAM PMMA group ($p < 0.05$). The mean marginal gap in the autopolymerizing PMMA group was significantly higher than that in the resin material ($p = 0.014$) and CAD/CAM PMMA ($p = 0.000$) groups. The difference between the resin material and CAD/CAM PMMA groups was not significant ($p = 0.13$). The mean internal gap was the highest in autopolymerizing PMMA group and the lowest in CAD/CAM PMMA group ($p < 0.05$). The mean internal gap in autopolymerizing PMMA group was significantly higher than that in composite resin ($p = 0.002$) and CAD/CAM PMMA ($p = 0.00$) groups. The difference between the resin material and CAD/CAM PMMA groups was not significant ($p = 0.322$).

Conclusion: Computer-aided design/Computer-aided manufacturing PMMA provisional crowns showed the highest marginal and internal adaptation followed by acrylic base resin material crowns.

Clinical significance: Computer-aided design/computer-aided manufacturing PMMA crowns demonstrate superior marginal and internal adaptation compared with autopolymerizing PMMA and acrylic base composite resin crowns, suggesting CAD/CAM technology's potential for enhancing clinical outcomes.

Keywords: Composite resins, Computer-aided design, Crowns, Dental marginal adaptation, Polymethyl methacrylate.

The Journal of Contemporary Dental Practice (2023): 10.5005/jp-journals-10024-3589

Introduction

Fabrication of provisional crowns is an important step in dental prosthetic treatment.[1] Provisional crowns are used to protect the prepared tooth until the delivery of final fixed prosthetic restoration. This period is often short, however, it may be prolonged in some cases.[2] Provisional crowns should be able to meet the important requirements of patients and dental clinicians. They should be able to preserve the health and natural structure of periodontal tissue. Also, they play an important role in treatment planning.[3] Provisional crowns are used to restore function, esthetics, and speech, protect the dentin and dental pulp, and stabilize the tooth position until the delivery of final restoration.[4,5] In order to achieve these goals, the materials used for the fabrication of provisional crowns should have specific properties such as low shrinkage, high strength and surface hardness, optimal fracture resistance and wear resistance, favorable polishability, minimal temperature rise during setting reactions and polymerization, and color stability. Optimal internal and marginal adaptation is another important requirement for provisional crowns.[6]

Provisional crowns remain in the biological oral environment for the required period of time only when the crown margin perfectly fits the finish line. Marginal adaptation of crowns affects periodontal health, and marginal misfit results in caries development below the crown and subsequent periodontal problems, which may lead to tooth loss.[7] These restorations, like their long-term counterparts, need to possess optimal marginal fit. This is essential for safeguarding the treated tooth against physical, chemical, bacterial, and thermal threats.[8] Dissolution of cement

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How to cite this article: Jalalian E, Younesi F, Golalipour S, *et al.* Assessment of Marginal and Internal Adaptation in Provisional Crowns Utilizing Three Distinct Materials. J Contemp Dent Pract 2023;24(11):853–858.

Source of support: Nil

Conflict of interest: None

over time creates an empty space between the tooth and crown, which serves as a suitable place for plaque accumulation and results in periodontal inflammation, caries, increased gingival crevicular fluid, alveolar bone loss, and eventual failure of provisional crown.[9] Therefore, assessment of the marginal adaptation of provisional crowns and minimizing their marginal gap are imperative to ensure their optimal clinical service.

Marginal adaptation of provisional crowns is influenced by a number of factors, and even the same material used for provisional crowns from different brands cannot provide similar marginal adaptation.[4] Factors affecting marginal and internal adaptation of crowns include beveling,[10] use of die spacer,[11] venting,[12] cement type, correct size and thickness of crown, cementation process,[13] type of impression material (dimensional stability of impression material affects marginal adaptation),[14] finish line design,[15] and type of prosthetic material and fabrication method of provisional crowns.[16]

Considering the significance of marginal adaptation in the success of provisional crowns and the gap of information regarding the marginal and internal adaptation of provisional crowns fabricated from different materials, this study aimed to assess the marginal and internal adaptation of provisional crowns fabricated from PMMA blocks by the system, autopolymerizing PMMA (a self-curing acrylic resin), and acrylic base composite resin (combination of acrylic resin and composite materials). Comparing the three types of provisional crowns enables an informed selection of materials based on their adaptation properties, contributing to enhanced patient comfort, safety, and treatment efficiency. Furthermore, this research contributes to the evolving body of dental knowledge, informing future studies and improvements in materials and techniques for temporary crown fabrication.

The first null hypothesis was that no significant difference would be found in marginal adaptation of the three types of provisional crowns. The second null hypothesis was that no significant difference would be found in internal adaptation of the three types of provisional crowns.

Materials and Methods

The study design employed in this research was an *in vitro* experimental approach that focused on the evaluation of three distinct types of provisional crowns, each crafted from different materials. The CAD/CAM PMMA group involves digitally designed crowns from PMMA blocks, the autopolymerizing PMMA group utilizes self-curing acrylic resin, and the acrylic base composite resin group employs a combination of composite material and acrylic shells. To ensure robust statistical analysis and meaningful results, the minimum sample size for each of the three groups was determined as 7 in each group. This determination was based on a precedent study by Abdullah et al.,[17] assuming $\alpha = 0.05$, $\beta = 0.2$, effect size = 0.76, and standard deviation of 4.5 using a one-way ANOVA feature of PASS 15.

The study was conducted on January 2021. The study did not involve human participants or collect sensitive data and, therefore, did not require Institutional Ethics Committee (IEC) approval. The research was conducted in compliance with relevant guidelines and regulations concerning material testing.

A brass die was first obtained, measuring 7 mm in length and 5 mm in diameter (thickest part). It received a classic chamfer finish line with 0.7 mm depth, and the walls were tapered by 8 degrees toward the occlusal surface (4 degrees for each wall). The die was then fixed on a metal stub (Figs 1 and 2).[18]

Flowchart 1 illustrates different methods for fabricating provisional crowns.

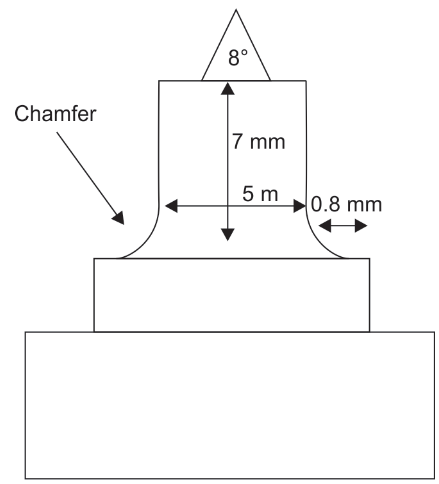

Fig. 1: Schematic view of brass die

Fig. 2: Actual view of brass die

Flowchart 1: Different methods for fabricating provisional crowns

CAD/CAM PMMA group	Autopolymerizing PMMA group	Acrylic base composite resin group
Brass die scanned by intraoral scanner • Crown design: uniform thickness (0.5 mm) • Die spacer (30 μm) at 1 mm from finish line • Crowns milled from PMMA blocks	Custom tray from acrylic resin • Vertical groove for indexing • Wax pattern fabricated using CAD/CAM • Silicone index made from wax pattern • Crowns fabricated using autopolymerizing PMMA	• Custom tray from acrylic resin • Vertical groove for indexing • Wax pattern fabricated using CAD/CAM • Silicone index made from wax pattern • Crowns fabricated using acrylic base resin

CAD/CAM Fabrication of Provisional Crowns from PMMA Blocks

The brass die was scanned by an intraoral scanner (Ceramill Map 400; Amann Girrbach, Austria), and the provisional crowns were designed such that the crown thickness was the same (0.5 mm) in all areas. A die spacer (30 µm) was considered at 1 mm distance from the finish line for the provisional crowns using Sure Fit TM software (Harvest Dental). Seven provisional crowns were milled out of PMMA blocks (TelioCad; Ivoclar Vidadent) by a milling machine (Ceramill Matik; Amann Girrbach, Austria). Homogeneous specimens without distortion were used for the study.[19]

Fabrication of Provisional Crowns Using Autopolymerizing PMMA and Acrylic Base Composite Resin

A silicone index was required for these two groups. Thus, a custom tray was fabricated from acrylic resin. To standardize the process of impression-making for all specimens, a vertical groove was created in the die stub to serve as an index. The same groove was created in the custom tray along the groove on the die stub. The wax pattern was fabricated by the CAD/CAM system using a wax block with 0.5 mm thickness and 30 µm die spacer. Thus, the custom tray only had one path of insertion and removal. Silicone index was made from the wax pattern on the die as instructed by the manufacturer (Speedex; Coltene). Seven provisional crowns were fabricated from autopolymerizing PMMA (Tempron) and seven from acrylic base resin material (Provi Temp K; Bisico). For this purpose, the composite resin was applied to the index by its auto-mix gun, and the index was placed over the metal die. The setting time of the composite was 3 minutes. Next, the powder and liquid of autopolymerizing PMMA (Tempron GC, GC Dental Product Co., Japan) were mixed for 20–30 seconds, as recommended by the manufacturer, and applied into the index. The index was then placed over the metal die and removed after 3 minutes.[17]

Assessment of Marginal Adaptation

To assess the marginal adaptation of specimens, they were randomly coded and placed on the die. They were inspected under a stereomicroscope (SMZ 1000; Nikon, Japan) at 40× magnification, and their marginal gap was measured at four points in the buccal, lingual, mesial, and distal for each specimen (same points in all specimens). The maximum distance between the die and provisional crown at the respective points was recorded as the marginal gap for the respective crown. To ensure the accuracy of the findings, the marginal gap at each point was measured in triplicate by the same examiner (Figs 3 and 4).[20]

Assessment of Internal Adaptation

The replica technique was used for assessment of internal adaptation of provisional crowns. For this purpose, light-body impression material (Speedex; Coltene, Switzerland) was applied into the provisional crowns, and it was placed on the die with 40 N force applied for 3 minutes in a universal testing machine (STM-20; Santam, Tehran, Iran). The provisional crown was then removed from the die with the light body inside it. Medium-body silicone impression material (HydroXtreme; Coltene, Switzerland) was mixed according to the manufacturer's instructions and applied into the crown. Next, medium-body and light-body silicone were removed from the crown and vertically cut in half. The thickness of light-body was measured under a stereomicroscope at 40× magnification at specific points (Figs 5 and 6).[21]

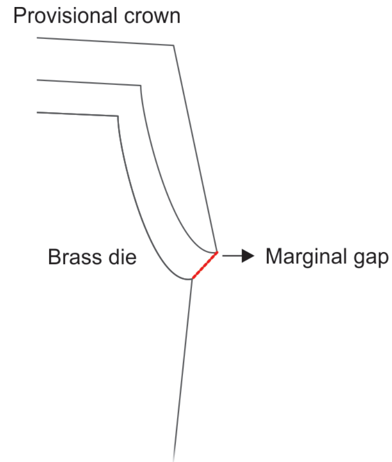

Fig. 3: Schematic view of measuring the marginal gap

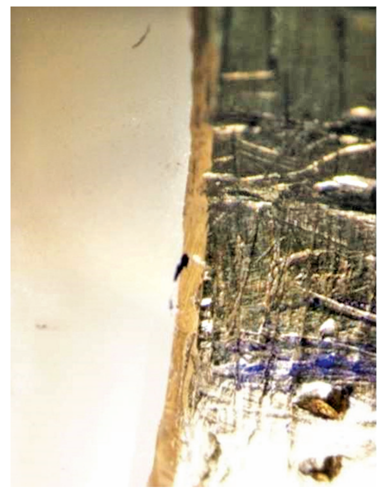

Fig. 4: Actual view of measuring the marginal gap

Fig. 5: Actual view of measuring the internal gap

Statistical Analysis

Prior to conducting the statistical analysis, the normal distribution of the collected data was verified using the Kolmogorov–Smirnov test ($p > 0.05$). This step ensured that the data met the assumption of normality. Subsequently, a one-way analysis of variance (ANOVA) was employed to compare the different groups based on their marginal and internal gap measurements. The pairwise comparisons among the groups were then performed using Tukey's test, which allowed for a comprehensive evaluation of differences between specific groups. To conduct these statistical analyses, the software utilized was IBM SPSS Statistics version 24. The significance level for all tests was set at 0.05, signifying a high level of statistical confidence in the results obtained.

Results

Table 1 presents the measures of central dispersion for the marginal gap and internal gap of provisional crowns in the three groups.

The mean marginal gap was the highest in the autopolymerizing PMMA group (100.8571 µm), followed by the acrylic base composite resin group (70.6190 µm), and lowest in the CAD/CAM PMMA group (51.0000 µm). The difference in marginal gap was significant among the three groups ($p < 0.05$). Pairwise comparisons showed that the mean marginal gap in autopolymerizing PMMA group was significantly higher than that in resin material ($p = 0.014$) and CAD/CAM PMMA ($p = 0.000$) groups. The difference between the autopolymerizing PMMA and CAD/CAM PMMA groups was not significant ($p = 0.13$).

The mean internal gap exhibited the highest value in the autopolymerizing PMMA group (91.8214 µm), followed by the acrylic base composite resin group (62.5714 µm), and the lowest value in the CAD/CAM PMMA group (51.6786 µm). The difference in internal gap was significant among the three groups ($p < 0.05$). Pairwise comparisons showed that the mean internal gap in autopolymerizing PMMA group was significantly higher than that in resin material ($p = 0.002$) and CAD/CAM PMMA ($p = 0.00$) groups. The difference between the autopolymerizing PMMA and CAD/CAM PMMA groups was not significant ($p = 0.322$).

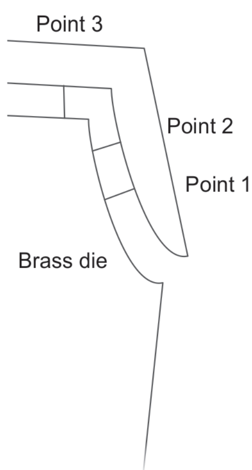

Fig. 6: Schematic view of measuring the internal gap

Discussion

This study assessed the marginal and internal adaptation of provisional crowns fabricated from PMMA blocks by the CAD/CAM technology, autopolymerizing PMMA, and acrylic base resin material. Ensuring proper marginal adaptation in temporary crowns is essential to maintain tooth health, prevent discomfort, reduce the risk of complications, provide an accurate template for the final restoration, and achieve optimal functional and aesthetic outcomes. Given the paucity of comprehensive comparative studies on different provisional crown materials, the aim of this investigation was to bridge this knowledge gap and provide valuable insights for dental practitioners and researchers.

The use of PMMA in provisional crowns has been widely adopted due to its reduced density, esthetic appeal, cost-effectiveness, ease of handling, and customizable physical and mechanical characteristics. Computer-aided design/computer-aided manufacturing technology ensures precision and convenience in crown fabrication. The utilization of autopolymerizing PMMA and acrylic base composite resin adds to the diversity of materials commonly employed in clinical practice.[17,22,23]

The chosen technique for outcome analysis involved rigorous statistical methods. We used one-way ANOVA to compare the marginal and internal gap measurements across different groups. The normal distribution of data was confirmed, validating the suitability of this approach. To identify specific group differences, pairwise comparisons were performed using Tukey's test. Similar

Table 1: Measures of central dispersion for the marginal gap and internal gap of provisional crowns in the three groups ($n = 7$)

				95% Confidence interval for mean			
	Mean	*Std. deviation*	*Std. error*	*Lower bound*	*Upper bound*	*Minimum*	*Maximum*
Internal gap							
CAD/CAM PMMA	51.6786	15.14356	5.72373	37.6731	65.6840	28.25	69.50
GC PMMA	91.8214	16.05571	6.06849	76.9724	106.6705	60.00	111.25
Bisico resin	62.5714	8.86909	3.35220	54.3689	70.7740	48.50	73.25
Total	68.6905	21.71159	4.73786	58.8075	78.5735	28.25	111.25
Marginal gap							
CAD/CAM PMMA	51.0000	16.08197	6.07841	36.1267	65.8733	37.00	83.00
GC PMMA	100.8571	21.53108	8.13798	80.9442	120.7701	62.67	125.00
Bisico resin	70.6190	15.56638	5.88354	56.2225	85.0155	55.00	102.33
Total	74.1587	27.03591	5.89972	61.8521	86.4653	37.00	125.00

techniques have been successfully applied in dental research, demonstrating their reliability and validity.[24]

The first null hypothesis was that no significant difference would be found in marginal adaptation of the three types of provisional crowns. The second null hypothesis was that no significant difference would be found in internal adaptation of the three types of provisional crowns. Comparison of resin material and PMMA was conducted to assess the effect of the type of material on marginal and internal adaptation of provisional crowns, while comparison of autopolymerizing PMMA and CAD/CAM PMMA was conducted to assess the effect of fabrication method (conventional or CAD/CAM) on marginal and internal adaptation of provisional crowns. The results showed that the mean marginal gap was the highest in auto-polymerizing PMMA and the lowest in CAD/CAM PMMA group ($p < 0.05$). The mean marginal gap in auto-polymerizing PMMA group was significantly higher than that in resin material ($p = 0.014$) and CAD/CAM PMMA ($p = 0.000$) groups. The difference between the resin material and CAD/CAM PMMA groups was not significant ($p = 0.13$). The mean internal gap was the highest in autopolymerizing PMMA group and the lowest in CAD/CAM PMMA group ($p < 0.05$). The mean internal gap in autopolymerizing PMMA group was significantly higher than that of resin material ($p = 0.002$) and CAD/CAM PMMA ($p = 0.00$) groups. The difference between the resin material and CAD/CAM PMMA groups was not significant ($p = 0.322$). Thus, the first and the second null hypotheses of the study were both rejected.

Regarding the marginal gap, most previous studies reported higher marginal adaptation of crowns fabricated by the CAD/CAM technology, compared with the manual technique, similar to this study.[17,18,25–29] However, this difference was not significant in a study by Elagra et al.[30] Variations in the reported results may be due to different preparation designs. It appears that higher marginal gap in the manual technique is due to the polymerization shrinkage of the material, while TelioCad PMMA blocks are prepolymerized, although slight polymerization shrinkage also occurs in the process of milling of these blocks.[27] Higher marginal adaptation of acrylic base resin material can be due to its lower shrinkage than PMMA. Burns et al.[31] reported the volumetric polymerization shrinkage of 6% for PMMA and 1–2% for resin materials.

Regarding the internal gap, the results of previous studies on this topic have been controversial. Most studies reported a significant difference between the manual and CAD/CAM techniques in internal adaptation,[17,25–27] however, this difference was not significant in some other studies.[32–34] Due to limitations in size and angle of sectioning tools in CAD/CAM technology, some limitations exist with respect to the preparation of the internal surface of restorations. Sampaio et al.[32] evaluated the internal adaptation of provisional crowns and reported different results. This difference may be due to the different measurement techniques. Wu et al.[34] investigated the internal fit and marginal discrepancy of provisional crowns constructed using various methods: manual fabrication, CAD/CAM technology, and 3D-printed technology. Although this study and the current study both examined the marginal and internal adaptation of provisional crowns using different fabrication methods, the materials and techniques used were different between the two studies. Moreover, the results differed, with the current study indicating that CAD/CAM PMMA crowns had the highest adaptation, while Wu et al.[34] found that manually fabricated crowns showed better internal fit and smaller marginal discrepancy. These could account for the difference in methodology since Wu et al.[34] use composite resin material to fabricate crowns by CAD/CAM technology, while in the current study PMMA blocks. Another study that aligns with current research is Aldahian et al.,[35] they reported that CAD/CAM PMMA provisional crowns exhibited superior marginal and internal adaptation compared with other fabrication techniques. In their systematic review, Al-Humood et al.[36] similarly concluded that milled interim fixed dental prostheses (FPDs) exhibited superior marginal fit, higher mechanical properties, and better aesthetic outcomes in terms of color stability when compared with both 3D-printed and conventionally fabricated interim FPDs.

In this study, the CAD/CAM fabrication method showed the best results regarding internal and marginal adaptation. Also, the results showed that a precise manual fabrication process by using acrylic base resin material also yielded optimal marginal and internal adaptation.

The *in vitro* nature of the study may not fully reflect the dynamic oral environment, warranting the need for future *in vivo* investigations. Additionally, the study solely evaluated the immediate adaptation of provisional crowns without considering the long-term effects or durability. Future research could encompass extended follow-up periods to explore the longevity and stability of the different crown materials and fabrication methods.

The present investigation demonstrated CAD/CAM fabrication and precise manual, optimal, marginal, and internal adaptation followed by acrylic base resin material crowns. These findings underscore the significance of employing these techniques to ensure superior provisional crown outcomes, ultimately contributing to enhanced patient satisfaction and overall treatment success.

Conclusion

In conclusion, this study addressed a critical gap in the literature by thoroughly assessing the marginal and internal adaptation of provisional crowns fabricated through different methods and materials. The study found that the highest mean internal gap was observed in the autopolymerizing PMMA group, indicating that this group exhibited the least-favorable internal adaptation among the three. Computer-aided design/Computer-aided manufacturing fabrication yielded the best results in terms of both internal and marginal adaptation.

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