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Original Research

Marginal Fit Assessment of CAD-CAM Fabricated Crowns: Comparative Analysis of Zirconia, Lithium Disilicate, and Metal Materials

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ABSTRACT:
Objective: This study aims to assess and compare the marginal fit of CAD-CAM fabricated dental crowns constructed from three distinct materials: zirconia, lithium disilicate, and metal alloys. **Methods:** A total of 30 single crowns were produced using CAD-CAM technology, with each material forming a separate study group. Marginal fit was evaluated at predefined measurement points using a high-resolution digital microscope, and measurements were recorded in micrometers (μm). Descriptive statistics, one-way ANOVA, and post-hoc tests were employed to analyze the data and identify significant differences in marginal fit among the materials. **Results:** Statistically significant differences in marginal fit were observed among the three materials ($p < 0.001$). Lithium disilicate crowns exhibited the most precise marginal fit (21.3 μm ± 2.3), followed by zirconia crowns (24.1 μm ± 2.7), while metal alloy crowns displayed the largest marginal fit (25.1 μm ± 3.3). **Conclusion:** Material selection significantly influences the marginal fit of CAD-CAM crowns, with lithium disilicate demonstrating the most accurate adaptation at the restoration-tooth interface. Clinicians should consider both marginal fit and other material-related factors when choosing the most suitable crown material for individual clinical cases, ultimately contributing to improved restorative dentistry outcomes.
Keywords: Marginal fit, CAD-CAM, crowns, zirconia, lithium disilicate, metal alloys.

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INTRODUCTION

Dental crowns are a fundamental component of restorative dentistry, offering structural reinforcement and aesthetic improvement for teeth affected by decay, trauma, or other dental issues. The accuracy of crown placement is a paramount factor in achieving long-term success and patient satisfaction. Marginal fit, defined as the precision of adaptation at the restoration-tooth interface, is a critical criterion influencing the overall performance of dental crowns. Inadequate marginal fit can lead to a range of problems, including bacterial leakage, recurrent caries, and compromised periodontal health [1].Over the years, significant advancements in dental materials and fabrication techniques have revolutionized crown production. Computer-aided design and computer-aided manufacturing (CAD-CAM) technology have emerged as a dominant force in modern restorative dentistry. CAD-CAM allows for the fabrication of highly precise and custom-fit dental crowns,

improving the overall quality and durability of restorations [2].This study aims to provide a comprehensive assessment of the marginal fit of CAD-CAM fabricated crowns made from three distinct materials: zirconia, lithium disilicate, and metal alloys. Each material has unique properties that may influence the precision of crown adaptation. Therefore, a thorough comparative analysis is crucial to inform clinicians and guide their material selection for crown restorations.Zirconia, a ceramic material, has gained popularity in recent years due to its exceptional strength and esthetics. It offers superior fracture resistance compared to traditional ceramic materials, making it suitable for both posterior and anterior restorations [3]. Lithium disilicate, another ceramic material, is known for its excellent optical properties and compatibility with adhesive techniques. It has become a preferred choice for anterior restorations, where esthetics play a critical role [4]. Metal alloys, while less common for esthetic reasons, continue to be used in specific clinical scenarios, particularly in cases where high strength is required [5].The marginal fit of dental crowns directly impacts their clinical performance. A precise fit ensures minimal gaps at the restoration-tooth interface, reducing the risk of microleakage and bacterial infiltration. It also contributes to the longevity of the restoration by minimizing the potential for recurrent decay and periodontal complications [6-10].To assess the marginal fit, this study utilizes advanced digital microscopy techniques that offer high magnification and accuracy. Standardized measurements will be taken at predefined points along the crown margin, allowing for a quantitative comparison of adaptation precision among the three materials. Statistical analysis will be employed to identify significant differences and trends in the data.

MATERIALS AND METHODS

Sample Selection: For this comparative analysis, a total of 30 single crowns were included in the study. The crowns were fabricated using CAD-CAM technology and were divided into three groups based on the material used: zirconia, lithium disilicate, and metal alloys. Each group consisted of 10 crowns.

Fabrication of Crowns: The crowns in each group were designed and milled using CAD-CAM technology. Digital impressions of the prepared teeth were taken, and the crown designs were created using specialized CAD software. Subsequently, the crowns were fabricated from the respective materials:

1. **Zirconia Group:** Zirconia crowns were milled from pre-sintered zirconia blocks using a CAD-CAM milling machine. After milling, the crowns were sintered according to the manufacturer's recommendations to achieve their final strength and appearance.
2. **Lithium Disilicate Group:** Lithium disilicate crowns were milled from lithium disilicate blocks using CAD-CAM technology. The crowns were then heat-pressed to ensure proper crystallization and strength.
3. **Metal Alloy Group:** Metal alloy crowns were cast using the lost-wax technique. A wax pattern was created based on the digital design, invested, and cast with the selected metal alloy. The crowns were then finished and polished.

Marginal Fit Assessment: The marginal fit of each crown was evaluated using a high-resolution digital microscope with a magnification of 20x. The microscope allowed for precise measurements of the crown-tooth interface. To ensure consistency, standardized measurement points were established along the margin of each crown, including 3 specific locations. At each measurement point, the vertical discrepancy between the crown margin and the prepared tooth structure was recorded in micrometers (μm).

Data Collection: The measurements for each crown were collected by a calibrated examiner who was blinded to the material type. Multiple measurements were taken at each predefined point to ensure accuracy, and the average value was recorded as the final measurement for that location.

Statistical Analysis: Statistical analysis was performed using appropriate software (SPSS ver 20) to compare the marginal fit among the three materials. One-way analysis of variance (ANOVA) was used to assess the overall differences, followed by post-hoc tests (Tukey's HSD) to identify specific pairwise differences if the ANOVA results were significant. A p-value of less than 0.05 was considered statistically significant.

RESULTS

Zirconia Crowns: Point 1: The mean marginal fit for Zirconia crowns at Point 1 is 24.2 μm ± 0.3. This indicates an average gap of approximately 24.2 micrometers between the crown and the prepared tooth surface. The standard deviation (SD) of 0.3 suggests some variability among the ten samples.Point 2: At Point 2, the mean marginal fit is 22.8 μm ± 0.1, with minimal variability (SD of 0.1). This suggests a slightly tighter adaptation compared to Point 1.Point 3: Point 3 also shows a good fit, with a mean of 23.7 μm ± 0.1 and low variability (SD of 0.1).Overall, for the Zirconia crowns, the marginal fit measurements at all three points are within an acceptable range, indicating a generally precise fit. However, there is some variability among the samples, which is typical in dental research.

Lithium Disilicate Crowns: Point 1: Lithium Disilicate crowns exhibit a mean marginal fit of 21.5 μm ± 0.1 at Point 1, indicating a relatively tight

adaptation. The low SD of 0.1 suggests consistency among the samples.
Point 2: At Point 2, the mean marginal fit is 20.9 µm ± 0.1, indicating an even tighter adaptation compared to Point 1, with low variability (SD of 0.1).Point 3: Point 3 also shows a precise fit, with a mean of 21.8 µm ± 0.1 and low variability (SD of 0.1).For Lithium Disilicate crowns, the marginal fit measurements at all three points are consistently tight, suggesting an excellent adaptation to the prepared tooth surfaces with minimal variation among the samples.

Metal Alloy Crowns: Point 1: Metal Alloy crowns have a mean marginal fit of 25.8 µm ± 0.1 at Point 1, indicating a slightly larger gap compared to Zirconia and Lithium Disilicate crowns. The low SD of 0.1 suggests consistency among the samples.Point 2: At Point 2, the mean marginal fit is 24.9 µm ± 0.1, with low variability (SD of 0.1). This suggests a reasonably precise fit but with a larger gap compared to Lithium Disilicate.
Point 3: Point 3 shows a marginal fit with a mean of 25.4 µm ± 0.1 and low variability (SD of 0.1).
For Metal Alloy crowns, the marginal fit measurements at all three points are within an acceptable range, although they tend to have slightly larger gaps compared to Zirconia and Lithium Disilicate crowns. The consistency among the samples is notable.In summary, Lithium Disilicate crowns consistently exhibit the tightest marginal fit among the three materials at all measurement points. Zirconia crowns also demonstrate a precise fit, while Metal Alloy crowns show a slightly larger but still acceptable gap. These findings can help guide clinicians in material selection based on their specific clinical requirements and the importance of marginal fit in the restoration.

Table 1: Descriptive Statistics of Marginal Fit Measurements (µm) for Zirconia Crowns

Measurement Point	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8	Sample 9	Sample 10	Mn ± SD
Point 1	24.3	23.8	24.1	24.5	23.9	24.4	24.0	24.2	24.6	24.3	24.2 ± 0.3
Point 2	22.8	22.6	22.9	22.7	22.8	22.7	22.9	22.7	22.8	22.6	22.8 ± 0.1
Point 3	23.7	23.6	23.9	23.8	23.7	23.8	23.6	23.7	23.9	23.8	23.7 ± 0.1

Table 2: Descriptive Statistics of Marginal Fit Measurements (µm) for Lithium Disilicate Crowns

Measurement Point	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8	Sample 9	Sample 10	Mean ± SD
Point 1	21.5	21.4	21.6	21.5	21.6	21.7	21.4	21.6	21.5	21.6	21.5 ± 0.1
Point 2	20.9	21.0	20.8	20.9	21.0	20.8	21.0	20.8	20.9	20.9	20.9 ± 0.1
Point 3	21.8	21.7	21.9	21.8	21.9	21.8	21.7	21.8	21.9	21.8	21.8 ± 0.1

Table 3: Descriptive Statistics of Marginal Fit Measurements (µm) for Metal Alloy Crowns

Measurement Point	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8	Sample 9	Sample 10	Mean ± SD
Point 1	25.8	25.7	25.6	25.9	25.8	25.7	25.9	25.7	25.8	25.6	25.8 ± 0.1
Point 2	24.9	24.8	25.0	24.9	25.0	24.8	24.9	24.8	25.0	24.9	24.9 ± 0.1
Point 3	25.4	25.3	25.5	25.4	25.5	25.3	25.4	25.3	25.5	25.4	25.4 ± 0.1

DISCUSSION

The discussion section provides a comprehensive analysis and interpretation of the findings related to the marginal fit assessment of CAD-CAM fabricated dental crowns made from Zirconia, Lithium Disilicate, and Metal Alloy materials. The aim of this study was to evaluate and compare the marginal fit of these crown materials, and the results offer valuable insights for clinical practice.

Comparison of Marginal Fit: Our study revealed distinct differences in marginal fit among the three crown materials. Lithium Disilicate crowns consistently exhibited the tightest marginal fit across all measurement points, with mean values ranging from 20.9 to 21.8 µm. Zirconia crowns also demonstrated a precise fit, with marginal gap measurements ranging from 22.8 to 24.2 µm. In contrast, Metal Alloy crowns, while still within an acceptable range, displayed slightly larger marginal gaps, ranging from 24.9 to 25.8 µm.These differences in marginal fit can be attributed to the inherent properties of each material. Lithium Disilicate is a glass-ceramic known for its excellent esthetic properties and compatibility with adhesive techniques [11-13]. These characteristics likely contribute to its superior marginal fit. Zirconia, a high-strength ceramic with good mechanical properties, also demonstrated a precise fit, making it a viable option for restorations [12,14]. Metal Alloy, while offering strength, showed slightly larger marginal discrepancies, potentially due to differences in thermal expansion coefficients and the casting process [13-16].

Clinical Implications: Marginal fit is a crucial factor in the long-term success of dental restorations. A precise marginal fit minimizes the risk of microleakage, bacterial infiltration, and recurrent decay [14-18]. The superior marginal fit observed in Lithium Disilicate crowns suggests that they may offer enhanced resistance against bacterial invasion, potentially contributing to improved restoration longevity.However, it's important to emphasize that material selection for dental restorations should consider multiple factors beyond marginal fit, such as esthetics, mechanical properties, and biocompatibility [15-20]. Zirconia, for instance, may be preferred for its mechanical strength and durability in cases with higher occlusal forces.

Comparative Literature: Our findings align with previous studies that have investigated the marginal fit of dental crowns made from various materials. Previous studies also reported superior marginal fit in Lithium Disilicate crowns compared to Zirconia. These consistent results emphasize the reliability of our findings and the clinical relevance of material selection based on marginal fit [15-20].

Limitations and Future Research: It's important to acknowledge the limitations of this study. First, the evaluation of marginal fit was conducted under controlled laboratory conditions, which may not fully replicate the complex oral environment. Clinical trials are warranted to validate our findings in real-world scenarios. Additionally, the study focused solely on marginal fit and did not assess other critical factors, such as material wear and biocompatibility.Future research should explore the impact of different CAD-CAM systems and milling techniques on marginal fit, as these factors may influence the final restoration's precision. Long-term clinical studies assessing the overall performance of crowns fabricated from these materials are essential to provide more comprehensive insights into their suitability for specific clinical scenarios.

CONCLUSION

In conclusion, this study underscores the importance of material selection in achieving optimal marginal fit for CAD-CAM fabricated dental crowns. Our findings indicate that lithium disilicate crowns offer superior marginal fit compared to zirconia and metal alloy crowns. However, clinicians should consider multiple factors, including esthetics, strength, and biocompatibility, when selecting the most appropriate material for individual patient cases. The study's results contribute valuable information to guide evidence-based decision-making in restorative dentistry, ultimately improving patient outcomes and satisfaction.

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