

COMPARISON OF THE FIT ACCURACY OF HYBRID CERAMIC PROSTHESES GENERATED BY THREE CAD-CAM SYSTEMS

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ABSTRACT

BACKGROUND: Marginal and internal fit are believed to be very crucial guideline in the assessment of ceramic restorations and are a remarkable requirement for the long-term performance of fixed dental prostheses.

PURPOSE: Was to assess the effect of different CAD-CAM systems on the marginal and internal adaptation of hybrid ceramic restorations.

MATERIALS AND METHODS: Lower right six of a typodont resin cast with a 1.0 mm circumferential chamfer finish line, a 2.0 mm occlusal clearance, and an average of 10-12° convergence angle was prepared. This master die was duplicated to thirty acrylic resin dies milled from PMMA discs using CAD-CAM technique. Vita Enamic monolithic crowns were manufactured using three CAD-CAM systems Ceramill, Zirkonzahn and CEREC systems (n=10). Replica technique procedure was used to assess marginal and internal fit of the fabricated prostheses by placing light body impression material between the master die and the restoration and then measuring its thickness at seven points using digital microscope.

RESULTS: Measurements were collected for each group and appropriate statistical analysis was carried out.

CONCLUSION: CEREC system showed relatively lower marginal and internal discrepancy in a comparison with the other systems. Therefore, there is a significant difference among the three systems.

KEYWORDS: Marginal fit, Internal fit, CAD-CAM, VITA Enamic, Replica.

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INTRODUCTION

A dental prosthesis is a restoration that requires esthetic similarity to the configuration and the shade of the natural tooth, bio-stability, physiologic compatibility, adequate strength to withstand the occlusal forces and finally but of utmost importance, precise fit to the abutment (1,2) In the last three decades CAD/CAM technology has improved dramatically. This has had a huge positive impact on prosthesis manufacturing either chairside or in the dental laboratory (3, 4).

Holmes et al. described the perpendicular space between inner surface of the restoration and the axial surface of the prepared tooth as internal gap. However, this same distance when present at the margin is named marginal gap (5).

Since marginal defects may contribute to long-term failure of a prosthesis, marginal precision is crucial during manufacturing. Presence of a gap between restoration and abutment aids in the developing of bio-film formation. Consequently, inflammation of the gingivae occurs in addition to occurrence of secondary caries (6).

Marginal imprecision may yield several problems. A greater marginal gap has shown increased bacterial prevalence in the oral cavity, which will lead to periodontal deterioration. Furthermore, micro-leakage can lead to endodontic problems (7).

Another issue of marginal imprecision is cement dissolution and then decementation of the restoration (8). A research was done on zirconia restorations after five-year of cementation detected the existence of recurrent decay in almost 25% of cases (9). Literature agreed that the allowable space

between the restoration and the preparation must be under 120 μm (10).

Internal fit is obligatory to avoid crown failure and mechanical fracture. A 70 μm internal gap limit after which restoration failure occurs even under average biting load was the limit set by Tuntiprawon et al (11).

The computer aid design/computer aid manufacturing (CAD/CAM) techniques for dental restorations have been developed to optimize the quality of the restorations as well as the efficiency of the workflow (12). CAD/CAM systems can be divided into two types based on digital data sharing capacity: open and closed. Closed systems offer all CAD/CAM procedures, including data acquisition, virtual design, and restoration manufacturing. All the steps are integrated in the unique system. There is no interchangeability between different systems. Open systems allow the adoption of original digital data by other CAD software and CAM devices (13).

The CAD/CAM systems can also be classified into laboratory systems and chairside systems. The laboratory system is further classified into laboratory CAD/CAM in which the company has its own scanner and milling units while CAD (Computer Aided Design) systems in which the company has only the scanner and CAM (Computer Aided Manufacture) systems in which the company retains the milling machine unit (14).

The chairside CAD/CAM system is further classified into [1] chairside CAD/CAM system in which the company has its own scanner and milling units; and [2] image acquisition system in which the company has only a scanner without

designing capabilities. These in turn must be connected to an open laboratory scanner for designing of the restoration (14).

VITA ENAMIC® hybrid ceramic blocks were used in this study; it is a hybrid dental ceramic composed of dominant fine-structure ceramic network strengthened by an acrylate polymer network and both networks are fully integrated with one another.

Current literature presents several methods for assessing the marginal and internal gap, each with individual advantages and disadvantages. Sorensen stated that "there are four main methods for detecting the gap: direct view, cross-sectional view, impression technique, and use of explorer with visual examination (x-rays)" (15).

Replica technique (impression technique) is a popular method, which is frequently used to measure marginal and internal adaptation. Multiple researches have studied the precision of fixed restorations in lab testing and clinically. By using this technique, the coping and the abutment were preserved during assessment, as opposed to other techniques where they might be destroyed. This allows for repeating the assessment on the same specimens if needed (16, 17). Furthermore, this technique can assess the adaptation of the restoration in multiple different positions and provide a wider possibility for verifiable and precise results (18, 19).

Although micro-CT was considered during the planning phase of study, however it was later excluded due to some limitations. Firstly, materials have different radiation absorption coefficient, this lead to the difficulty in finding specific measuring points for marginal discrepancy and internal gap. Furthermore, radioactive rays tend to reflect on surfaces creating artificial defects (20).

Another technique for measuring the gap is cementation cross-sectioned technique which require cementation of the restoration to its corresponding die, in contrast with the replica technique where the restorations were not cemented to the die, thus it ensures precise primary adaptation of the restoration, which may not occur when crowns are cemented due to differences in cement kind, viscosity and cementation method (21).

There were different results reported in the previous studies that compared the marginal and internal fit of accustomed CAD-CAM systems (22, 23). Marginal design, space thickness of the die, cement type, and the cementation method are elements that influence the adaptation of CAD/CAM restorations (24). It was reported that acquisitioning, operating system, and manufacturing have an immediate impact on the fit accuracy of CAD/CAM restorations (25).

The goal of this research was to assess the marginal and internal fit of hybrid ceramic restorations (Vita Enamic®) fabricated by three different CAD/CAM systems (CEREC InLab, Ceramill, and Zirkonzhan). The null hypothesis of this present study was that changing the CAD-CAM system would have no effect on the adaptation of ceramic restorations.

MATERIAL AND METHODS

An ivory lower first molar tooth was seated in a typodont model and prepared to receive a full ceramic crown using tapered diamond bur. The preparation was designed with a 1.5-2mm occlusal reduction, 1-1.2mm Axial reduction, 10-12 degrees Axial taper and 1mm circumferential shoulder finish line. All margins from the axial to the occlusal surface were

Marginal adaptation difference between CAD/CAM systems. rounded, smooth and free from sharp angles or undercuts. The amount of reduction was evaluated using an external surface form (ESF) made of polyvinyl siloxane putty material. (Figure 1a, 1b)

According to the sample size, thirty acrylic resin master dies were fabricated as a copy from the prepared typodont tooth using PMMA CAD/CAM material. The prepared acrylic tooth was scanned by (Ceramill map 400) laboratory optical scanner. After making the proper software design for the die, a PMMA acrylic resin disc was loaded in the Ceramill Motion 2 milling engine to mill exact die replicas to produce thirty resin patterns for the master die. All the specimens were fabricated using Ceramill to ensure similarity of different dies, as the purpose of the study is to evaluate the marginal and internal adaptation of restorations fabricated by different CAD/CAM systems.

The thirty master dies were divided into three groups (10 for each group). Each group was used to manufacture ten monolithic crowns using Vita Enamic® material with one of the three different CAD/CAM systems.

Group I: Cerec-inLab MC-X5 (CL)

Group II: Ceramill motion 2 (5X) (CM)

Group III: Zirkonzahn milling unit M1 (Z)

Each system was used with its corresponding scanner and software to design and mill the restoration. The spacer thickness was 90µm in all designed crowns. Finally, the milled crowns were cut from the sprues attached to it by low speed diamond stone and smoothed carefully following the manufacturer's instructions.

Replica technique was the method of choice to measure the internal and marginal fit. First, each monolithic restoration was packed with light-body silicone and seated on its master die under constant force of 2 Kg (19.2 N) using static load device. (Figure 2)

After complete setting of the impression material, the restoration was detached from the master die and the thin silicone films representing the gap between the master die and its corresponding crown remained on the fitting surface of the restoration.

Regular-body silicone (medium wash consistency) with different color was used to stabilize the silicone film, which was used to fill the crown completely. (Figure 2). After complete polymerization under static load apparatus, the replica was then cut from the buccal to the lingual side in its center by using a number 10 surgical blade. The stereomicroscope connected with a HD camera (magnification of 90X) was used to photograph and measure the internal and marginal gap which was represented by the wash film thickness. A digital image analysis system was used to measure and qualitatively assess the gap width.

Silicone film thickness was evaluated at seven points for each replica. Five measurements were made internally to evaluate the internal gap. Three occlusal points; buccal cusp tip, lingual cusp tip and central fossa (d, f, e), and two measurements were made at points in the buccal and lingual internal axial surface (c, g). Two measurements were made at the buccal and lingual margin (a, b), this evaluates marginal discrepancies. (Figure 3,4).

Statistical analysis

Measurements of the specimens for each group were collected. Data was fed and analysed by software package IBM SPSS software package version 20.0. (Armonk, NY: IBM

Abdelrahman et al. Corp). Normal data distribution was verified using the Kolmogorov-Smirnov test. Data was described using mean and standard deviation. OneWay ANOVA test was used for data analysis. Significance of the obtained results was judged at the 5% level.

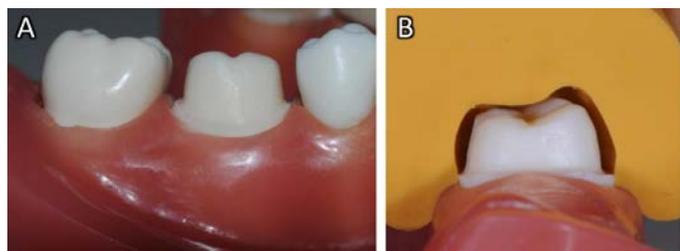


Figure 1: (A) prepared ivory tooth in a typodont model. (B) Evaluation of ivory tooth reduction by buccolingual sectioned ESF.

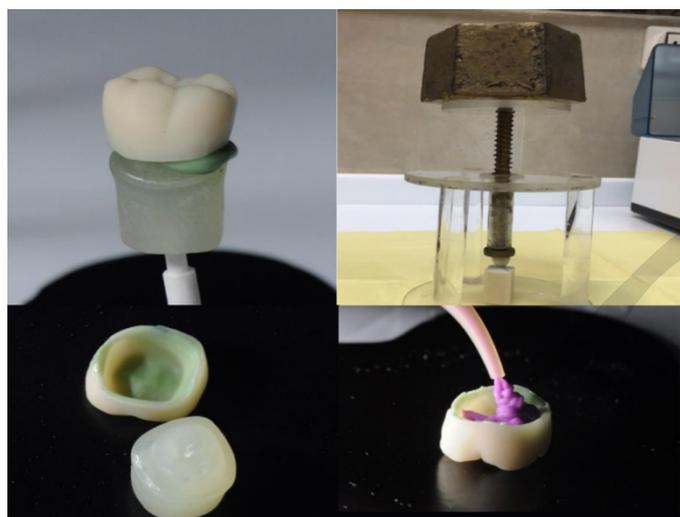


Figure 2: Steps of replica technique.

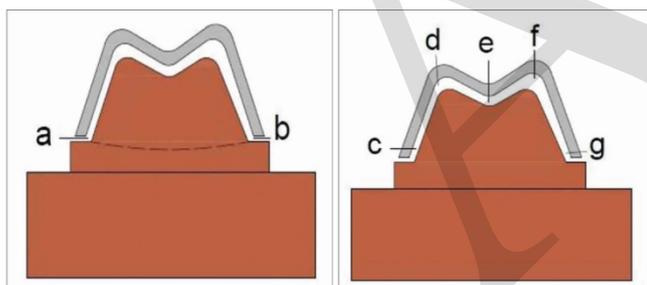


Figure 3: Marginal gap measurement points (a and b) and internal gap measurement points (c) axial, (d) buccal cusp, (e) fossa, (f) lingual cusp, (g) axial.



Marginal adaptation difference between CAD/CAM systems. **Figure 4:** Replica measurement for CEREC, CERAMILL & ZIRKONZHAN groups.

RESULTS

Statistical analysis showed that restorations produced with the CEREC system displayed the lowest mean marginal and internal gap (16.61 ± 1.59) and (32.19 ± 1.17) respectively, followed by Zirkozahn system, which displayed mean average marginal and internal gap (21.28 ± 1.03) and (35.03 ± 2.22) respectively. While the Cermill system had the largest marginal and internal gap among all groups (35.38 ± 36.9) and (38.83 ± 1.63). The difference in measurements between the groups were statistically significant ($P < 0.05$). (Table 1, 2).

Table (1): Comparison between the three studied groups according to the average marginal gap measurements.

| Average marginal gap | Ceramill (n = 10) | Cerec (n = 10) | Zirkonzahn (n = 10) | F | p |
|----------------------|---|--------------------|---------------------|----------|---------|
| Min. – Max. | 32.74 – 39.39 | 13.17 – 18.58 | 19.23 – 23.27 | | |
| Mean ± SD. | 35.32 ± 2.13 | 16.61 ± 1.59 | 21.28 ± 1.03 | 350.301* | <0.001* |
| Median (IQR) | 35.38(33.5 – 36.9) | 16.97(16.0 – 17.7) | 21.37(20.8 – 21.6) | | |
| Sig. bet. groups. | $p_1 < 0.001^*$, $p_2 < 0.001^*$, $p_3 < 0.001^*$ | | | | |

F: F for ANOVA test, Pairwise comparison bet. each 2 groups was done using Post Hoc Test (Tukey)

p: p value for comparing between the studied groups

p₁: p value between CERAMILL and CEREC

p₂: p value between CERAMILL and ZIRKONZAHN

p₃: p value between CEREC and ZIRKONZAHN

*: Statistically significant at $p \leq 0.05$

Table (2): Comparison between the three studied groups according to internal gap measurements.

| Average internal gap | Ceramill (n = 10) | Cerec (n = 10) | Zirkonzahn (n = 10) | F | p |
|----------------------|---|----------------|---------------------|---------|---------|
| Min. – Max. | 37.19 – 42.14 | 30.32 – 33.62 | 31.87 – 38.82 | | |
| Mean ± SD. | 38.83 ± 1.63 | 32.19 ± 1.17 | 35.03 ± 2.22 | 37.253* | <0.001* |
| Median | 38.52 | 32.17 | 35.01 | | |
| Sig. bet. groups. | $p_1 < 0.001^*$, $p_2 < 0.001^*$, $p_3 = 0.003^*$ | | | | |

F: F for ANOVA test, Pairwise comparison bet. each 2 groups was done using Post Hoc Test (Tukey)

p: p value for comparing between the studied groups

p₁: p value between CERAMILL and CEREC

p₂: p value between CERAMILL and ZIRKONZAHN

p₃: p value between CEREC and ZIRKONZAHN

DISCUSSION

The objective of this research was to assess the effect of the manufacturing systems on the marginal and internal fit of Vita Enamic monolithic crowns. Vita Enamic hybrid ceramic blocks were used to avoid the need for further crystallization firing after milling, based on previous research that showed using materials that do not require extra firing cycles reveal better marginal adaptation than those that require additional firing cycles post-milling (26).

Furthermore, another improvement of Vita Enamic material is the machinability of the material; it is a soft dual material of ceramic and composite. This feature allowed for faster milling with less wear to the cutting burs (26). Wear of the milling burs during successive manufacturing cycles could be affect their cutting efficiency and therefore cause inaccuracies in the marginal adaptation.

In the present study, static load apparatus was used to properly seat the restorations to the master dies to mimic the clinical condition and standardize the force applied (27).

Replica technique was the method used in this study to compare the marginal and internal fit of the three CAD-CAM systems; it is a common method to assess marginal and internal differences between crowns and its corresponding abutment. The replica technique can be used for both in-vitro and in vivo studies (28).

This technique has displayed its superiority in measuring the fit accuracy of a prosthesis and provide accurate insights about margin adaptation, which is critical for predicting prognosis (18, 29). Using this non-destructive method, the chance of damaging the specimen or the abutment is minimal. It also allows for measuring marginal gap at innumerable points on the same prosthesis.

Several studies in the literature evaluated the validity and reliability of the replica technique. Kokubo et al (30) reported that using low viscosity impression material as a substitute of luting cement to detect the relative margin gaps is an accurate and reliable technique with relatively less errors. McLean and von Fraunhofer published a similar conclusion and reported that it is an appropriate technique to assess the amount of luting cement three-dimensionally (10).

Regarding the influence of the CAD-CAM machine used on the measured marginal and internal gap mean values, the Cerec system revealed significantly superior results regarding the mean average marginal and internal gap (16.61 ± 1.59) and (32.19 ± 1.17) respectively, followed by Zirkonzahn system, which displayed mean average marginal and internal gap (21.28 ± 1.03) and (35.03 ± 2.22) respectively. While the Ceramill system, had the largest marginal and internal gap among all groups (35.38 ± 36.9) and (38.83 ± 1.63).

The results are in accordance with Rajan et al (31) who conducted a study comparing marginal discrepancy and internal adaptation in copings produced by Ceramill and Cerec InLab systems. The marginal and internal accuracy of Cerec system was found to be superior to Ceramill one ($P < 0.05$).

Abdel-Azim et al (32) evaluated the marginal and internal accuracy of single crowns generated from two extra-oral CAD/CAM systems (Cerec and Ceramill). They reported that Cerec system showed better marginal accuracy than Ceramill system which agreed with the results of this study, but

Marginal adaptation difference between CAD/CAM systems. regarding the internal accuracy their readings presented that Ceramill system had lower internal gap value which differ than this study. However, the author of that study used two different techniques to measure the marginal and internal gap. The former was measured by direct view technique using digital microscope while the latter was measured by using replica technique. Furthermore, the author also used different scanners with different milling machines not only comparing a complete closed system.

The findings of this research disagree with Jimenez SMJ et al. results in which they stated that CAD/CAM Zirkonzahn system displayed lower absolute marginal discrepancy when compared with CAD/CAM Cerec InLab system, but both were within the clinically accepted range (33).

Another study by Seok-Joon Ha et al. displayed that the marginal fit of Ceramill system had better marginal adaptation compared to Zirkonzahn, which fails to correspond to the present findings. However, concerning the internal gap their results concurs with this study in that Zirkonzahn system had superior internal adaptation (28).

For standardization the three CAD/CAM systems used in this study were all same sub-category five-axis milling units (dental laboratory type) not a chairside machines, depending on previous studies that have proven that Five-axis milling machines have been found to improve the productivity and precision when compared to three-axis or four-axis (chairside) milling systems.(33)

Giving the elements associated to the digitization of different systems, it is noted that there are statistically remarkable differences among all evaluated CAD-CAM groups. Scanning finite resolution is an obstacle to all systems. Reich et al, (34) reported that the presence of rounded angles or peaks during scanning procedure is the source of marginal inaccuracies. Different studies across the literature, (12, 35, 36) concluded that marginal adaptation is greatly affected by the CAD-CAM process (scanning and milling). Since the CAD-CAM technique is a sensitive process, the influence of the operator and practitioner is critical (12, 34).

Another explanation for the difference in marginal and internal results among the three systems could be a result of a phenomenon named point clouds during the scanning phase. This happens while scanning the fine areas and leads to imprecision in the restoration (37, 38).

An explanation of the lack of agreement may be variation in the methods used by various investigators studying marginal accuracy. Sulaiman et al (39) suggested that the cause could be the use of different measuring instruments. Sample size and the number of measurements per specimen may also have contributed to the variation. Furthermore, when milling the restorations, variables within the mill itself, such as diamond rotary cutting instrument wear and water quality, may affect the quality of the restoration.

Another point to be mentioned is that due to the contraction of the siloxane polyvinyl used in the replication technique, marginal discrepancy measures could indeed be lower than real measurements. (33) In later research projects, it is suggested to additionally conduct other marginal fit determination techniques such as cementation crosssectioned techniques.

CONCLUSION

The authors of this research can conclude that, changing the CAD-CAM machine has a notable effect on the marginal and internal fit. CEREC system displayed significantly superior results in comparison to Zirkozahn and Ceramill systems. The Zirkozahn system was second to Cerec system in both marginal and internal fit, but it was notably superior to the Ceramill group. The Ceramill system had the worse marginal and internal gap in comparison to the other two systems used in this study. In all groups, the marginal gap mean value measured in all the studied specimens were below 120 µm, therefore they were clinically accepted.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

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