FIT ACCURACY OF OPEN VERSUS CLOSED CAD/CAM SYSTEMS USING A SECTIONAL METHOD

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ABSTRACT

INTRODUCTION: Marginal fit is critical for the success of dental restorations. Zirconia full coverage restorations can be fabricated either chair-side or in a milling center.
OBJECTIVE: To evaluate the fit accuracy of all ceramic restorations fabricated by two different CAD/CAM systems using a sectional method.
MATERIAL AND METHODS: A lower first molar was prepared for a full coverage restoration, it was laser scanned (Ceramill map 400) and 24 replicas were milled using acrylic CAD/CAM block (Ceramill TEMP). Half of the dies were scanned using a closed system (CEREC inLab MC X5) while the other half used an open system (Ceramill motion 2). Zirconia restorations (Monolithic Katana zirconia) were milled from each system. Sectional method where each restoration was cut into thin sections (Buehler Isomet 4000 Linear Precision Saw) after cementation by self-adhesive resin cement (RelyX™ Unicem). A stereomicroscope was used for measurement. (n=24 α= 0.05).
RESULTS: There was a significant difference (t=2.387, P<0.030) as the open system was better than the closed system at the axial sites.
CONCLUSIONS: within the limitations of this study, better marginal qualities were achieved using an open CAD/CAM system.
KEYWORDS: CAD/CAM, Open system, closed system, Monolithic zirconia, Marginal adaptation.
RUNNING TITLE: Evaluation of fit accuracy using different CAD/CAM systems.

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INTRODUCTION

Indirect restorations such as ceramics and composite have increased the esthetic demands of patients over the years. Using of ceramics has increased because they are stable in color, have excellent esthetics, and are biocompatible. Zirconia restoration has excellent mechanical properties that can be used in high-stress areas alternative for metal restorations (1,2).
The weakest link in a fixed restoration is the tooth-restoration marginal interface which directly affects the longevity and success of the restoration. Poor fit may cause discoloration of the margins, sensitivity, dissolution of cement, and secondary caries. Studies by Sailer *et al.* stated that all-ceramic restorations failed by a ratio as high as 21.7% due to secondary caries. Producing a restoration with high fit accuracy necessitates precision in all fabrication steps. The clinical success of any cemented restoration requires a precise fit with the prepared tooth (3-5).
Usually, the internal fit evaluation can be done by measuring the gap between the fitting surface of the restoration and the prepared tooth. The thickness of the cement layer affects the gap size. There are many factors such as pressure during cementation, the roughness of the surface, design of the margin, duration of cementation, viscosity, and the cementation technique affecting the film thickness. In reality, achieving clinical perfection is very challenging. Previous researchers found that an acceptable gingival marginal gap reaches up to 120 μm without compromising clinical success (6-8).
With the introduction of CAD/CAM technology, human errors in fabrication techniques are eliminated and marginal gaps were much improved. Factors such as the type of system used for scanning (different digitization techniques), software design (CAD construction), and milling technique (wet versus dry and the number of milling axes) affect the marginal fit (9-11).
Comparison of marginal adaptation levels by using different CAD/CAM systems such as closed systems (CS), i.e., systems that use software and equipment belonging to one single manufacturer and using different open systems as well (OS) are carried out (12-14).

There are several methods used for evaluation of the marginal accuracy before clinical acceptance such as the silicone replica technique, cone beam computerized tomography (CBCT), and microscopic imaging of sectioned restorations. The sectioning technique is most commonly used (15-17).

Therefore, the purpose of this in vitro study was to evaluate the marginal integrity and internal fit accuracy of all-ceramic restorations fabricated using two different CAD/CAM systems, an open and a closed system using a sectional method. In this study, the null hypothesis was that neither the type of system used nor the assessment method will have an effect on marginal accuracy.

MATERIAL AND METHODS

Fabrication of master die

An ivory lower first molar tooth was prepared to receive a full coverage all-ceramic restoration using a tapered diamond bur (KOMET CE, ISO 806 314-881, USA). The preparation was done as recommended by accepted guidelines (18). The following parameters were verified, occlusal reduction (2 mm) was performed using depth orientation grooves, and axial reduction insuring 1.2 mm clearance with 12 degrees taper. 1.0 mm equi-gingival circumferential chamfer finish line. Roundation, smoothening of all transitions between axial and occlusal surfaces, and removal of any sharp angles or undercuts. A split silicone index was fabricated before preparation using polyvinyl siloxane impression material to check the amount of clearance during preparation (Fig. 1).

According to sample size calculations, 24 acrylic resin replicas were fabricated using Polymethyl methacrylate CAD/CAM monochromatic block (Ceramill TEMP) (22). A laboratory optical scanner was used to scan the prepared acrylic tooth. After fixation of the die to the scanning table, the master die was scanned (Ceramill map 400, Amann Girrbach AG, KOBLACH, Austria). The die was rotated 360º and tilted 100º to obtain all the details accurately. Milling of 24 replicas was done (Ceramill motion 2 (5x) Amann Girrbach AG, KOBLACH, Austria).

Fabrication of the restorations

For the closed system, dies were directly scanned using a simple flow motion in-lab scanner (Sirona in EosX5). After scanning, Cerec-inLab software (inLab CAM, Dentsply Sirona) was used for designing a monolithic restoration. Twelve monolithic restorations were milled from CAD/CAM blocks (Katana zirconia Multi-Layered, A2, Kuraray Noritake, Japan) by using (Cerec-in lab MC X5, Dentsply Sirona) milling machine.

For the open system, dies were scanned using an intraoral scanner (Carestream 3700, Kodak, France), and the STL files were imported to Ceramill mind CAD software (Amann Girrbach AG, KOBLACH, Austria) for designing a monolithic restoration. Twelve monolithic restorations were milled from CAD/CAM blocks (Katana zirconia Multi-Layered, A2, Kuraray Noritake, Japan) by using (Ceramill motion 2) milling machine (Fig. 2).

For both systems, the die spacer thickness was 80 µm, the same crown design was used and dry milling mode was selected.

All specimens were sintered (Dentsply Sirona Inlab profire furnace) at 1550 °C according to the manufacturer's instructions. Self-adhesive resin cement (RelyX™Unicem, 3M ESPE AG ESPE Platz 82229 Seefeld. Germany) was used for cementation of all specimens under a static load of 2 kg using a custom-made static loading device for 10 minutes (19, 20).

Fit evaluation

The evaluation of the internal and marginal adaptation was performed by measuring the cement film thickness after sectioning the restorations in mesiodistal and buccolingual directions. To avoid cracking, the coronal portion of each specimen was embedded in a transparent self-polymerizing acrylic resin. Precise cutting of the crowns into four quarters was done by using a precision cutting machine (Buehler Isomet 4000 Linear Precision Saw) under water-cooling. Polished sections were examined under stereo-microscope (SZ1145TR, Olympus, Japan) and image analysis software was used to measure fit accuracy in each section in each site of the restoration (Nine different point-locations present along crown die interface) (Fig. 3).

Figure (1): The prepared die.

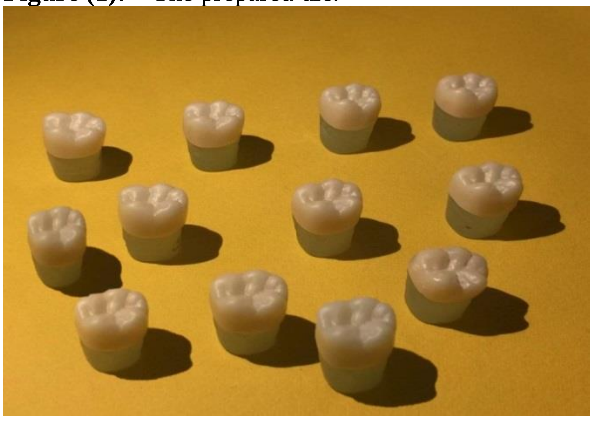

Figure (2): The milled crown restorations.

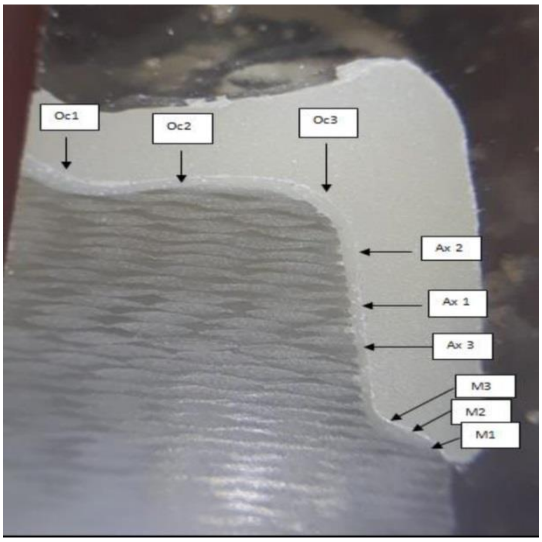

Figure (3): Stereomicroscopic image illustrating measurement points in sectional technique. Every three measurements were averaged for that location.

Statistical analysis

Data were fed to the computer and analyzed using (IBM SPSS software package version 20.0, IBM Corp**)**. The Shapiro-Wilk test was used to verify the normality of the distribution. Quantitative data were described using range (minimum and maximum), mean, standard deviation, median, and interquartile range (IQR). Student t-test and Paired t-test were used for pairwise comparison at 80% power with a target significance level of 5%.

RESULTS

Statistical analysis revealed that there was a significant difference between the two tested systems (t=2.387, *P*<0.030) as the open system showed better marginal and internal fit values compared to the closed system at the axial sites. Other sites (occlusal and marginal) were comparable (t=0.721, *P*<0.481, t=0.539, *P*<0.597 respectively). Detailed data are summarized in (Table 1).

Table (1): Fit accuracy measurements (um) at different sites.

Interval	Closed system	Open system	t	p
occlusal site Min. – Max. Mean ± SD.	110.31–277.84 205.77±57.37	143.87–346.02 184.27±68.59	0.721	0.481
Axial site Min. – Max. Mean ± SD.	58.61–115.36 98.09±16.41	55.02–102.01 78.16±18.93	2.387*	0.030*
Marginal site Min. – Max. Mean ± SD.	73.48–185.96 135.27±39.42	107.43–240.68 146.13±45.82	0.539	0.597

DISCUSSION

This study was designed to compare the fit accuracy of all-ceramic restorations fabricated using two different CAD/CAM systems, an open system (Ceramill motion 2) and a closed system (CEREC inLab MC X5). The sectional method was used to assess fitting accuracy, where each cemented restoration was cut into thin sections using a precision cutting machine. A stereomicroscope was used for measurement.

The close adaptation between the restoration and the prepared tooth is the main goal of a fixed restoration. The most important factors that determine successful clinical performance are an adequate internal fit and high marginal accuracy (21). Usually, small gaps remain, even after careful clinical and laboratory procedures. The closer adaptation between the margins of the restoration and the finish line of the prepared tooth, the smaller the marginal gap exposing the cement layer (22). The acceptable marginal gaps of dental prostheses have been described in numerous studies. Some authors have reported marginal gaps under 120 µm to be clinically acceptable (23). Others have reported marginal gaps of 160 - 172 µm, while others increased the bar to under 250 - 300 µm (24, 25).

The final fit of a restoration can be influenced by each step during fabrication such as the impression material, impression technique, and master cast production (4,26). CAD/CAM technology helps both dentists and clinicians to reduce human error (10). The advancements in CAD/CAM systems and digital intraoral scanners in the last few years can help in producing a complete digital workflow which is known to improve the fit accuracy of fixed restorations.

In this study, the milling of the specimens in two groups followed the manufacturers' recommendations. New burs at the start of each group were used in the milling unit. Also to standardize the applied force during the cementation of crowns, a static load device was used. This was more standardized than previous studies that used the finger pressure technique (19,20).

For standardization the two CAD/CAM systems used in this study were all five-axis milling units (dental laboratory type), not chairside machines, depending on previous studies, the Five-axis milling machines are more accurate and precise than three-axis or four-axis (chairside) milling systems (27). Although the five-axis milling machines take more time for the fabrication of a crown, it has superior cutting efficiency than three or four-axis milling machines that improve the milling process which improves the dimensional accuracy, surface texture, and surface finish of the milled products (28,29).

Several studies have compared closed CAD/CAM systems (30-33). but the comparison between a closed manufacturing system and an open system is scarce. Because the same configuration was used for crown construction and cementation in both groups. The research shows that systems that allow the choice of different software, scanners, and milling machines may present positive results. The literature, for example, shows that a simple version change of the CAD drawing software significantly interferes with the marginal adaptation of crowns and with the applicability of cement space (34). This study suggests that even using identical parameters in the studied groups, there may be intrinsic parameter differences between the drawing software used.

It would be, therefore, interesting for future studies to carry out comparative studies of different systems, software, and different types of materials, adding the internal adaptation analysis (micro-CT), which was a methodological limitation of our study, where we would analyze the passivity of the crown. In addition, the analysis of the marginal adaptation in all its extensions, (35) not only by points, would be interesting. Especially, comparing closed CAD/CAM systems with different types of open systems, to generate more knowledge about these systems, their compatibility, and prosthesis adaptation potential.

Kricheldorf et al. found higher fit accuracy for open systems compared to closed ones (14). Similarly, Beuer et al. identified significant differences when examining the marginal discrepancy of 3-unit zirconia frameworks (36). They found smaller gap values using an open milling center (29.1 μm) compared to frameworks produced by a closed system (CEREC in LAB) (56.6 μm).

On the contrary, other studies that compared the marginal fit of zirconia copings found that the CEREC in LAB system showed better marginal fit accuracy compared to other CAD-CAM systems (37-39).

Rajan et al. found significant differences between zirconia restorations produced by CEREC in LAB and CERAMILL systems, as CEREC in LAB copings were better than CERAMILL in marginal adaptation. The marginal fit of CERAMILL was 83 μm and the CEREC In LAB MC XL was 68 μm (39).

Saab et al. compared the marginal fit of zirconia restorations with four different CAD-CAM systems: CEREC in LAB, CERCON, CERAMILL, and LAVA milling units. CEREC in LAB showed significantly lower mean values, 37.68 μm (38).

The data of the current study indicated that the only significant difference in fit accuracy was observed at the axial wall mean while both CAD/CAM systems had comparable values at occlusal and marginal regions. The proposed hypothesis was thus rejected.

CONCLUSIONS

Within the limitations of this study, better marginal qualities were achieved using an open CAD/CAM system.

CONFLICT OF INTEREST

The authors declare that they have no financial or personal conflicts of interest.

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