

The marginal and internal discrepancy of zirconia coping milled by two computer-aided design–computer-aided manufacturing systems

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Abstract

Aims: This study aimed to evaluate the marginal and internal discrepancy of the zirconia coping fabricated by two dental computer-aided design–computer-aided manufacturing (CAD-CAM) systems.

Settings and Design: *In vitro* comparative study.

Materials and Methods: Twenty zirconia crowns fabricated from inCoris ZI by Cerec InLab CAD-CAM system (Dentsply Sirona Inc, USA) and Ceramill ZI by Ceramill CAD-CAM system (Amann Girrbach, Austria) were measured the discrepancy at six locations using silicone replica technique. Absolute marginal discrepancy (AMD) and marginal gap (MG) represent the marginal discrepancy, and the other four locations at chamfer area, axial wall, cusp tip, and occlusal adaptation represent the internal discrepancy. The gap was measured using an optical light microscope at $\times 50$ magnification.

Statistical Analysis Used: The data were analyzed using two-way ANOVA and Game–Howell *post hoc* test.

Results: The statistical analysis showed that the accuracy of zirconia coping depends on CAD-CAM system and the location of measurement. Cerec InLab showed the marginal discrepancy of the coping $119.5 \pm 44.8 \mu\text{m}$ at MG position and $125.3 \pm 36.6 \mu\text{m}$ at AMD position, which was statistically larger than Ceramill system did at $53.0 \pm 12.1 \mu\text{m}$ and $67.2 \pm 19.1 \mu\text{m}$. On the other hand, the discrepancy in other positions showed no statistical difference between the two CAD-CAM systems.

Conclusions: The accuracy of zirconia coping was significant affected by CAD-CAM system and the location of measurement.

Keywords: Computer-aided design–computer-aided manufacturing system, internal discrepancy, marginal discrepancy

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Submitted: 22-Jan-2021 **Revised:** 03-Mar-2021 **Accepted:** 27-Mar-2021 **Published:** 28-Apr-2021

INTRODUCTION

Increasing popularity of esthetic dentistry leads to fabricate of all-ceramic restoration especially zirconia-based

restoration. The zirconia restoration has esthetics, biocompatibility, durability, and improved physical properties better than other all-ceramic restoration.^[1] However, zirconia needs computer-aided design–computer-aided

Access this article online	
Quick Response Code:	Website: www.j-ips.org
	DOI: 10.4103/jips.jips_30_21

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How to cite this article: Urapepon S. The marginal and internal discrepancy of zirconia coping milled by two computer-aided design–computer-aided manufacturing systems. *J Indian Prosthodont Soc* 2021;21:192-7.

manufacturing (CAD-CAM) technology for fabrication. There are a lot of CAD-CAM systems available in the market. Almost all of the CAD-CAM systems is a closed system with their own technology, materials used, milling axis, and milling fabrication techniques.^[2] Nowadays, CAD-CAM restorations are better fitting, stronger, and more esthetic than previously CAD-CAM restorations.^[3]

The key indicator for the success of dental restoration is the fabricated restoration to abutment discrepancy. The good adaptation of the restoration to tooth structure, especially at the margin, is the critical point of the success. The deficiency of marginal adaptation can lead to plaque accumulation, then develop a caries, poor periodontal status, and finally have a failure of the restoration.^[4] Therefore, the marginal and internal discrepancy is commonly used for comparing the accuracy of the restorations.^[4-7]

There is an abundance of CAD-CAM systems in the dental market, recently. Each system is a closed system with its own technology from the scanning to the final process of machining.^[2] Each system has its own benefit and disbenefit. Therefore, the accuracy of crown coping fabricated from different CAD-CAM systems is in question.

Therefore, the purpose of this study is to evaluate the internal and marginal discrepancy of zirconia coping fabricated by two CAD-CAM systems, Cerec inLab (Dentsply Sirona Inc, PA, USA) and Ceramill (Amann Girrbach, Koblach, Austria). The null hypothesis was that the CAD-CAM system had no influence on the internal and marginal gap (MG) of the restoration.

MATERIALS AND METHODS

The study was approved by institutional review board. Maxillary right second premolar plastic tooth model (Columbia Dentoform Corp, NY, USA) was used to prepare an abutment for zirconia crown. The preparation tooth was then duplicated and casted with cobalt–chromium alloy (Vitalium®, Dentsply Inc, PA, USA) and used as a master die.

The die was scanned and fabricated the crown coping by two CAD-CAM systems, Cerec InLab (Dentsply Sirona Inc, PA, USA) and Ceramill (Amann Girrbach, Koblach, Austria) to evaluate the accuracy of the crown coping. Cerec InLab composes of InEos Blue desktop scanner, InLab software, and InLab MC XL milling machine (Dentsply Sirona Inc, PA, USA) and Ceramill composes of Ceramill map300 scanner, Ceramill Mind software, and Ceramill Motion milling machine (Amann Girrbach, Koblach, Austria). The scanner and the milling unit of both

CAD-CAM systems were calibrated at the beginning and recalibrated each time along the study.

The master dies were fixed to a special model holder in the aligning tool provided by each CAD-CAM system and scanned to obtain abutment data. After scanning, the restoration on the abutment was designed by each CAD-CAM software. The full coverage 0.5-mm thick substructure for all-ceramic crown was designed. The cement space was set up at 10 μm . The restoration design was sent to each CAD-CAM milling machine to mill the zirconia block, inCoris ZI (Dentsply Sirona Inc, PA, USA) for Cerec InLab and Ceramill ZI (Amann Girrbach, Koblach, Austria) for Ceramill. All scanning and designing procedures were repeated 10 times to fabricate 10 coping in each group by completely random. The picture of the master die and their coping design is shown in Figure 1

The discrepancies of the crown are measured at six points on the definitions defined by Holmes *et al.*^[8] as following:

1. Occlusal adaptation (OA) is the internal adaptation of the surface of the crown to the abutment at that midpoint from the facial and proximal
2. Cusp tip (CT) is the internal adaptation of the surface of the crown to the abutment at the CT
3. Axial wall (AW) is the internal adaptation of the retainer walls at the midpoint of the AW (2 mm occlusal to the margin of the abutment)
4. Chamfer area (CA) is the internal adaptation of the substructure at the point of the biggest diameter of CA
5. MG is the perpendicular measurement from the internal surface of the substructure to the AW of the preparation at the margin

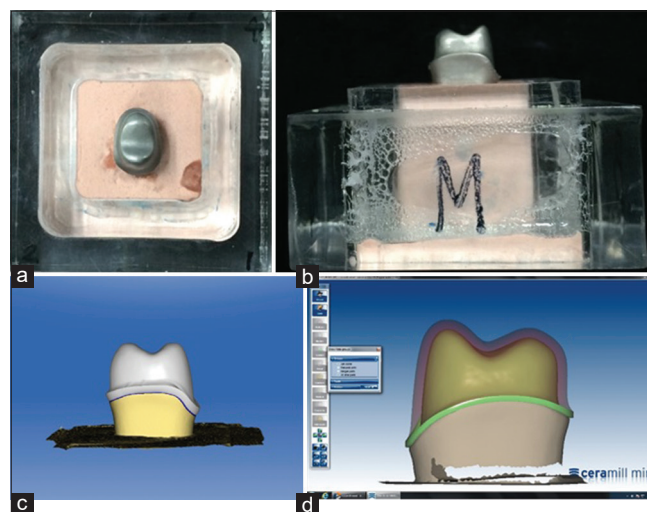


Figure 1: Picture of master die and their coping design. (a) Shows occlusal view of the master die, (b) shows lateral view of the master die. (c) Shows coping design on Cerec InLab system, (d) shows coping design on Ceramill system

- Absolute marginal discrepancy (AMD) is the distance from the margin of the substructure to the cavosurface angle of finish line preparation.

The schematic picture of the measuring point is shown in Figure 2. The AMD and MG were examined to represent the marginal discrepancy, while the CA, AW, CT, and OA were examined to represent the internal discrepancy.

The discrepancy of the crown was examined using cross-sectional combined with silicone replica technique under an optical measuring microscope (Nikon Eclipse E400, Tokyo, Japan) at $\times 50$ magnification at four-point measurement: mesial, distal, buccal, and lingual, then average to one datum for a crown.

The silicone replica technique was performed by filling light body silicone into the crown and placed onto the master abutment. Ten N load was applied on the occlusal surface for 10 s, then removed the load and waiting until silicone got complete set. The silicone films represented the discrepancy between the crown and abutment. The crown was stabilized by heavy body silicone in a customized plastic tray. After removal of the crown, the different color of heavy body silicone was filled into the crown to represent the abutment. A cutting machine was used to cut the silicone in buccolingual and mesiodistal direction along the slot of the tray to ensure the position

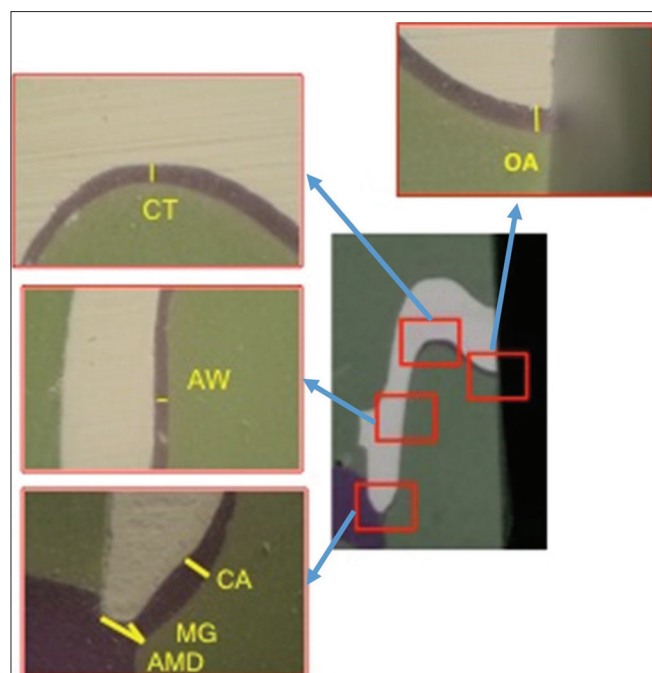


Figure 2: 2 Cross-sectional of the six-points discrepancy measurement. OA = Occlusal Adaptation, CT = Cusp tip, AW = Axial wall. CA = Chamfer area, MG = Marginal Gap, AMD = Absolute Marginal Discrepancy

of the measurement. The schematic picture of the silicone replica technique procedure is shown in Figure 3. Data were analyzed using two-way ANOVA and Games–Howell *post hoc* test.

RESULTS

The results of mean and standard deviation of the discrepancies of the crown fabricated from two CAD-CAM systems are shown in Table 1. The results of ANOVA in Table 2 showed that the discrepancy of the crown was influenced by both CAD-CAM system and location of measurement without their interaction.

Cerec InLab showed the marginal discrepancy of the coping at $119.5 \pm 44.8 \mu\text{m}$ for MG position and $125.3 \pm 36.6 \mu\text{m}$ for AMD position, which was statistically larger than Ceramill system did at $53.0 \pm 12.1 \mu\text{m}$ and $67.2 \pm 19.1 \mu\text{m}$ ($P < 0.05$), whereas the internal discrepancy of both systems was not a statistically significant difference in any location of measurement ($P > 0.05$). The internal discrepancy at AW showed the smallest gap among the other internal discrepancy measuring point.

DISCUSSION

The occurrence with an ill-fitting restoration is clearly shown the importance of well-fitting restoration. MG is a critical criterion for the success and quality of dental restorations. Higher marginal discrepancy could affect the dissolution of luting agent,^[9] microleakage, dental caries and pulpitis,^[10] periodontal inflammation,^[11] and marginal discoloration.^[11,12] From this implication, the smallest marginal discrepancy is needed. A clinical acceptable MG of fixed restorations is difficult to identify.^[13] In several studies, the MGs of 1–161 μm have been reported for various fabrication techniques for all-ceramic crowns.^[14,15] In contrast, MGs of CAD-CAM

Table 1: Mean and standard deviation of the discrepancies of the crown fabricated by two computer-aided design–computer aided manufacturing systems

Location	Discrepancy in μm (mean \pm SD)	
	Cerec InLab	Ceramill
Internal discrepancy		
OA	188.5 \pm 63.5 ^a	127.2 \pm 31.5 ^a
CT	175.6 \pm 69.9 ^a	114.4 \pm 31.4 ^a
AW	40.1 \pm 10.3 ^b	33.8 \pm 3.9 ^b
CA	152.5 \pm 57.8 ^a	115.5 \pm 32.5 ^a
Marginal discrepancy		
AMD	125.3 \pm 36.6 ^a	67.2 \pm 19.1 ^b
MG	119.5 \pm 44.8 ^a	53.0 \pm 12.1 ^b

The value with the same superscript letter in each row means no statistically significant difference. SD: Standard deviation, OA: Occlusal adaptation, CT: Cusp tip, AW: Axial wall, CA: Chamfer area, AMD: Absolute marginal discrepancy, MG: Marginal gap

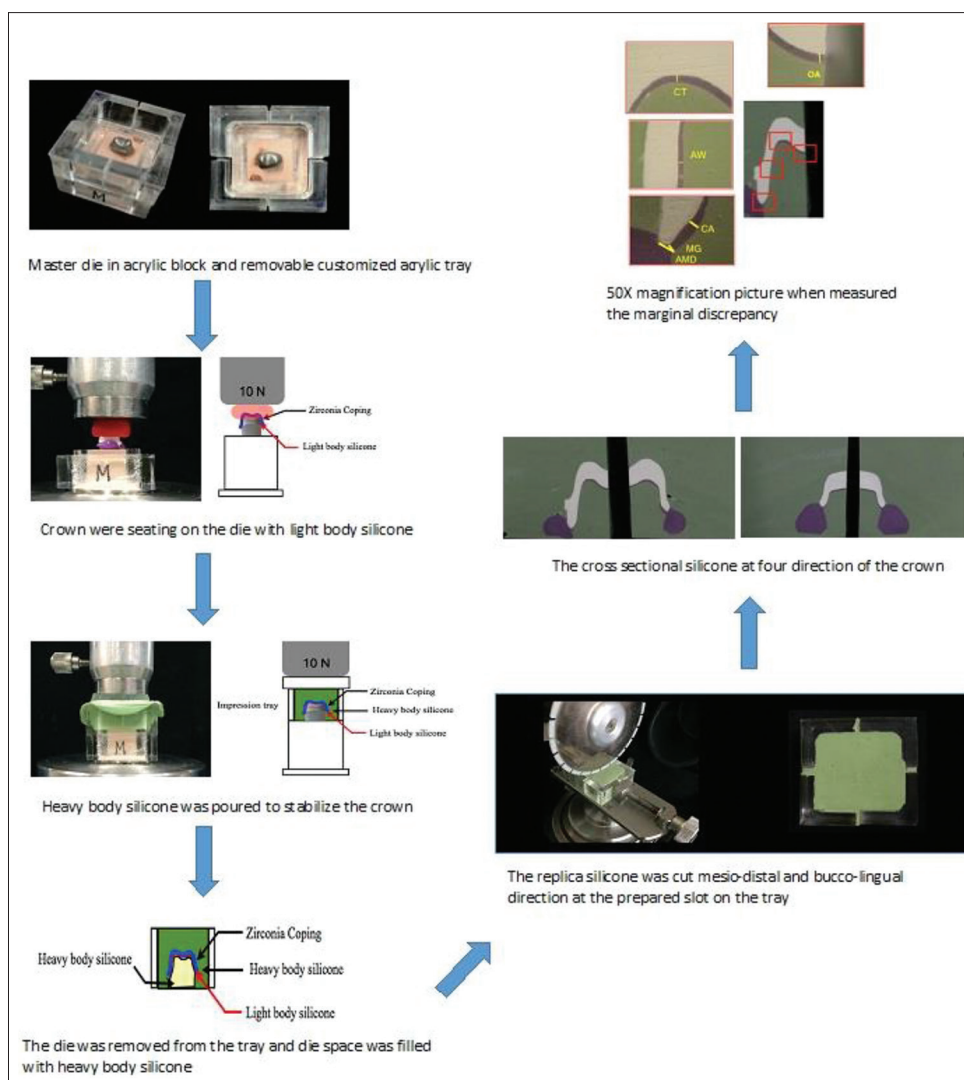


Figure 3: Schematic picture of the silicone replica procedure

Table 2: Results of ANOVA

Source	Sum of squares	df	Mean square	F	Significant
System	70,144.4	1	70,144.4	28.5	0.000
Location	203,496.6	5	40,699.3	16.5	0.000
System×location	13,305.1	5	2661.0	1.1	0.374
Error	265,402.9	108	2457.4		
Total	1,988,305.8	120			

DF: Degree of freedom

fabricated all-ceramic crowns have been reported a little bit smaller as 17–118 μm .^[14,16-18] A clinically acceptable MG width <120 μm defined by McLean and Von Fraunhofer is the famous criterion among researchers, using for evaluation the MG of restoration.^[19] Two locations which are AMD and MG were measured and represented the marginal discrepancy. The largest discrepancy at the margin would always be AMD and would reflect the total misfit because it is the angular combination of the MG both vertical and horizontal, either of overextension or

underextension that would reflect the true total misfit at the margin.

In this study, the Cerec InLab specimens showed significantly larger marginal discrepancy than those of the Ceramill specimens in both locations at AMD and MG. The mean of marginal discrepancy of crown copings milled by Ceramill reported at $67.2 \pm 19.1 \mu\text{m}$ for AMD and $53.0 \pm 12.1 \mu\text{m}$ for MG that was a clinically acceptable value. On the other hand, AMD ($125.3 \pm 36.6 \mu\text{m}$) and MG ($119.5 \pm 44.8 \mu\text{m}$) of crown copings milled by Cerec InLab were in the borderline of clinically acceptable values. This may be due to Ceramill motion that has a four-axis milling unit, while Cerec inLab MC XL machine has a three-axis milling unit. More axis devices can mill more complex geometry. This might be the reason of the difference in the marginal discrepancy between both CAD-CAM systems.

In addition to the marginal discrepancy, internal discrepancy also plays an important role in the longevity of the restoration as well. It influenced the retention and seating ability including increase fracture resistance of prosthesis. Too small internal gap would cause difficulty in seating the prosthesis due to back pressure of the cement, causing stress concentrations on the surface which led to initiate chipping damage of the veneering layer.^[20] Furthermore, too wide of the internal gap can increase cement thickness leading to higher amounts of water absorption^[21] resulting in degradation of resin cements, reducing the elastic modulus, reducing the retentive force,^[22] and changing of the mechanical properties.^[9,21,22]

Apart from the marginal discrepancy, the internal discrepancy was also investigated in this study. Several studies reported that the internal gap was within the range of 49–136 μm .^[20,23,24] However, most of the studies reported the overall internal gap, different from the detailed measurement of the internal gap at different locations, as in this study.^[17,23-26] In this study, four locations at CA, AW, CT, and OA were measured and represented the internal discrepancy.

The detailed measurement of internal discrepancy in this study can be done by the advantage of the cross-section of the silicone replica technique. In general, methods for marginal discrepancy measurement can be divided into two methods, one is direct-view method and the other is a cross-sectional method.^[27] The direct-view method including exploration by explorer, visual examination, and microscopy examination is used to measure discrepancy of the external surface of the restoration. This technique is a convenient, easy, rapid, and nondestructive method. The procedure is cheaper, less time consuming than other techniques, and can be used for continuous process or repeated measure research work,^[28] while the cross-sectional method can be measured both marginal and internal discrepancies. The advantages of this technique are the accuracy, precision, and repeatability of the measurements, and it allows the determination of horizontal marginal discrepancy.^[28] However, the obvious disadvantage of this method is the destruction of the specimens; therefore, the discrepancy measurement at various stages of prostheses fabrication is not possible.

In this study, the mean of internal discrepancy of crown copings in four different locations of both CAD-CAM systems were not statistically significant differences from each other. The internal discrepancy was in the same range with several studies.^[20,22,25,29] However, the mean discrepancy value of AW was found smallest among the

other location significantly ($P > 0.05$). The AW discrepancy seems to play an important role in the overall internal discrepancy.^[30] Milling process and the preparation design may also affect the internal adaptation.^[29] For the majority of CAD-CAM systems, an axial taper of 6° – 8° is recommended.^[31] However, the larger convergence angles such as 12° revealed the best marginal fit of CAD/CAM-generated restoration.^[30]

CONCLUSIONS

1. The discrepancy of zirconia coping depends on CAD-CAM system and the location of measurement
2. Marginal discrepancy (both AMD and MG) of zirconia coping showed a statistically significant difference between two CAD-CAM systems, while there is no difference for the internal discrepancy
3. Zirconia copings from Cerec InLab system showed higher marginal discrepancy than those from the Ceramill system.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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