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RESEARCH AND EDUCATION

Comparison of marginal fit between CAD-CAM and hot-press lithium disilicate crowns

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ABSTRACT

Statement of problem. Hot-pressing and computer-aided design and computer-aided manufacturing (CAD-CAM) are major techniques for the fabrication of lithium disilicate crowns. They exhibit different accuracies regarding marginal fit, an important factor in restoration survival. However, studies comparing the marginal fit of different fabrication methods are lacking.

Purpose. The purpose of this in vitro study was to compare the marginal discrepancy (MD) and absolute marginal discrepancy (AMD) of lithium disilicate crowns produced by the hot-press and CAD-CAM techniques.

Material and methods. Thirty typodont teeth were divided into 2 groups. Fifteen teeth were scanned with the CEREC Omnicam intraoral scanner, and crowns were fabricated with the CEREC MC XL chairside CAD-CAM milling unit from IPS e.max CAD blocks. Fifteen typodont teeth were sent to a dental laboratory, and lithium disilicate crowns were fabricated from IPS e.max press ingots using the hot-press technique. The 30 crowns were cemented and then sectioned with a precision saw. The MD and AMD were measured for each crown with a light microscope. One-way ANOVA was conducted to analyze significant differences in crown marginal fit between the fabrication systems (α=.05).

Results. For the CAD-CAM technique, the mean values of the AMD measurements were 115 µm, and for the hot-press technique, 130 µm. The MD measurements were 87 µm for the CAD-CAM technique and 90 µm for the hot-press technique. One-way ANOVA revealed no significant differences between the fabrication methods regarding marginal fit (P>.05).

Conclusions. No significant differences were found between the fabrication methods tested. Both the CAD-CAM and hot-press techniques for producing monolithic lithium disilicate crowns produced MD values of less than 120 µm, within the clinically acceptable range. (J Prosthet Dent 2019;121:124-8)

Increasing demand for esthetic dental restorations has led to the popularity of ceramic restoration systems.[1] One such system is a lithium disilicate–reinforced ceramic (IPS e.max; Ivoclar Vivadent AG), which can be processed using either a hot-press technique (IPS e.max Press) or a computer-aided-design and computer-aided-manufacturing (CAD-CAM) approach (IPS e.max CAD).[2,3] The flexural strength is 360 MPa for IPS e.max CAD and 400 MPa for IPS e.max Press. They both have 70% of crystal content and differ only in crystal size. Consequently, their mechanical characteristics, such as the module of elasticity, thermal expansion coefficient, and chemical solubility, are identical, and only their flexural strength is different (Ivoclar Vivadent AG. IPS e.max lithium disilicate: The future of all-ceramic dentistry material science, practical applications, keys to success. Amherst: Ivoclar Vivadent; 2009. p. 1-15).

Marginal fit is an important predictor of the clinical success and longevity of dental restorations. A restoration with poor marginal fit can damage the tooth, periodontal tissue, and even the restoration. A large marginal discrepancy (MD) can lead to cement dissolution, microleakage, and plaque accumulation, which results in gingival inflammation, caries, and pulpal lesions.[4,5] A consensus regarding a clinically

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Clinical Implications

Marginal fit is an important factor in the clinical success and longevity of a restoration. Both the CAD-CAM and hot-press techniques produced a clinically acceptable marginal fit for monolithic lithium disilicate crowns.

acceptable MD is lacking; however, different studies have suggested that a 50 μm to 120 μm gap is clinically acceptable, whereas other studies have suggested gaps of less than 100 μm.[6-8] In an in vivo study of more than 1000 crowns, McLean and von Fraunhofer[9] observed that restorations with a MD of less than 120 μm were more likely to be successful. For CAD-CAM-fabricated crowns, the reported MD ranges between 50 and 100 μm.[10-12]

Holmes et al[13] defined the MD as the perpendicular measurement from the cervical margin of the casting to the preparation margin and the absolute marginal discrepancy (AMD) as the angular combination of the MD and the extension error (overextension or underextension). The AMD is measured from the cavosurface of the preparation to the cervical margin of the cast. The MD is the surface of the cement that is exposed to the oral environment and can be dissolved, resulting in microleakage. The AMD is indicative of the extension of the crown margins relative to the margins of the preparation and is important because it increases plaque accumulation (Fig. 1).[13]

Studies have compared the marginal fit of lithium disilicate crowns fabricated by the hot-press technique with the fit of those fabricated by the CAD-CAM technique and found that CAD-CAM ceramic restorations produce an inferior marginal fit compared with pressed restorations.[8,14,15] However, more recent studies have reported the opposite results with the CAD-CAM ceramic restorations having better fit.[16,17] Advancements in CAD-CAM milling technology have been suggested for the better fitting restorations.[18] These recently introduced systems include the CEREC MC XL (Dentsply Sirona), a chairside CAD-CAM milling device. However, a comparison of the marginal fit between crowns fabricated with the hot-press technique and the chairside CEREC MC XL is lacking.

Therefore, the purpose of this in vitro study was to compare the marginal fit of these 2 fabrication methods. The null hypothesis was no difference would be found in the marginal fit between the fabrication methods. Different methods have been used to evaluate the marginal fit.[4,7,19-21] In this study, the sectioning method[19,20] was used to examine the AMD and MD as the 2 parameters of the marginal fit.

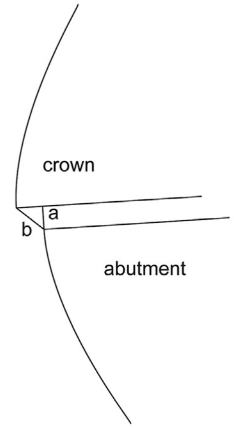

Figure 1. Types of marginal misfit. Marginal discrepancy (a) (MD) and Absolute marginal discrepancy (b) (AMD).

MATERIAL AND METHODS

A total of 30 custom-made, prefabricated, maxillary right first molar, typodont teeth (FLUX 8634; Columbia Dentoform) were prepared for crowns with the following parameters: occlusal reduction of 2.5 mm, axial total convergence of 6 degrees, and a shoulder margin width of 1.2 mm.

For the CAD-CAM group, the 15 typodont teeth were inserted into a typodont jaw and scanned with an intraoral scanner (CEREC Omnicam scanner; Dentsply Sirona), followed by conversion to a 3-dimensional (3D) virtual model (CEREC AC software 4.3; Dentsply Sirona). The crown design and finish line marking were planned with this software. The CAD-CAM parameters were as follows: virtual die spacer: 90 μm, occlusal milling offset: –175 μm, proximal contact strength: 25 μm, occlusal contact strength: –50 μm, radial minimal thickness: 500 μm, occlusal minimal thickness: 1000 μm, and marginal thickness: 50 μm. A milling unit (CEREC MC XL; Dentsply Sirona) was used for CAM processing of the designed crowns from lithium disilicate (IPS e.max CAD; Ivoclar Vivadent AG) ceramic blocks (Fig. 2). Milling of the lithium disilicate blocks was completed in a precrystallized state, followed by 24 minutes in a furnace (Programat CS2; Ivoclar Vivadent AG) to fully crystallize the crowns. Fifteen typodont teeth were sent to a dental laboratory (H. Koifman, Haifa, Israel) to fabricate crowns using the hot-press technique, which made the use of an impression unnecessary. An experienced technician fabricated ceramic crowns using the lost-wax technique with a spacer of 60 μm. Lithium disilicate (IPS e.max Press Ivoclar Vivadent AG) ingots were used to fabricate the 15 crowns in a pressing furnace (Programat EP 3000; Ivoclar Vivadent AG).

The crowns were cemented with a self-adhesive resin cement (Rely X U-200; 3M ESPE) according to the

Figure 2. Representative typodont tooth and CAD lithium disilicate crown before cementation.

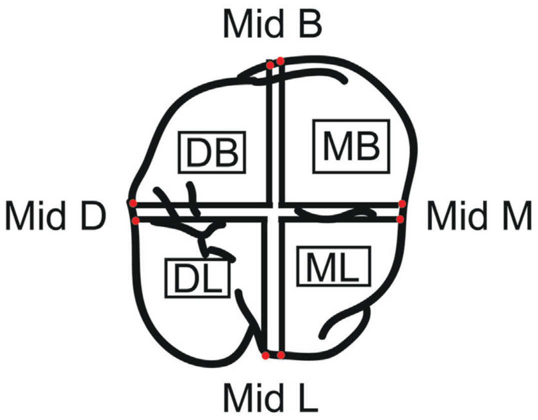

Figure 3. Schematic drawing of sectioned maxillary right first molar. Red dots represent 8 locations where marginal fit was measured.

manufacturer's directions, applying finger pressure for 3 minutes. Lines were marked on the center of the buccal, lingual, mesial, and distal surfaces of all typodont teeth. Then, the cemented crowns were embedded in a 10×10 mm cube of acrylic resin (Unifast TRAD; GC Corp) to avoid separation of the crown from the typodont teeth during cutting. The center line markings were then copied to the acrylic resin surface, which resulted in a continuous line from the typodont tooth to the acrylic resin that represented the buccal, lingual, mesial, and distal center line surfaces. This marker oriented the disk during cutting.

All 30 embedded crowns were sectioned into 4 specimens with a cutting machine (Izomet Plus precision saw; Buehler) with a 150-mm diameter and a 0.5-mm-thick disk (Buehler). Four specimens were obtained from each crown: mesiobuccal (MB), distobuccal (DB), distolingual (DL), and mesiolingual (ML). In each specimen, 2 points were detected in the finish line area, which represented the marginal fit. As a result, the marginal fit was measured at 8 locations on each crown (Fig. 3).

The AMD and MD were examined and measured with a light microscope (Axioplan 2; Zeiss) under ×110 magnification, and images were transferred to an image analysis program (BioQuantOsteo 2009; BIOQUANT Image Analysis) by using a microscope-connected camera (Optronics Engineering Ltd).

The data from the measurements were collected, and statistical analyses were performed to examine significant differences among groups. One-way ANOVA with a 1-way repeated measurements statistical test was used (α=.05).

RESULTS

The mean values with standard errors of the AMD and MD measurements for the CAD-CAM and hot-press crowns measured at 8 locations in each crown are displayed in Figure 4. As expected, the MD values were lower than the AMD values because the AMD is an angular combination of the MD and the extension error. As shown in Figure 4A, the mean AMD values were lower for the crowns fabricated using the CAD-CAM technique, except at the Mid-L/ML and Mid-D/DL locations. As shown in Figure 4B, the values of the crowns fabricated with the CAD-CAM technique were lower in 3 locations: Mid-B/DB, Mid-M/MB, and Mid-M/ML.

The CAD-CAM technique produced an overall mean ±standard error (SE) AMD width of 115 ±4 μm, whereas the hot-press technique produced an overall mean ±SE AMD width of 130 ±5 μm. The overall mean ±SE MD values were similar: 87 ±3 μm for the crowns fabricated by CAD-CAM and 90 ±4 μm for the crowns fabricated by the hot-press technique. One-way ANOVA found no significant differences in AMD (*df*=1, F=1.658; *P*=.208) and MD (*df*=1, F=0.108; *P*=.745) between the CAD-CAM and hot-press fabrication methods. The 95% confidence intervals of the MD showed lower bound values of 74 μm for the CAD-CAM technique and 77 μm for the hot-press technique and upper bound values of 101 μm for the CAD-CAM technique and 105 μm for the hot-press technique.

DISCUSSION

The null hypothesis was not rejected because no statistically significant differences in marginal fit were identified between the 2 methods. Marginal fit is an important factor in the success and longevity of dental restorations.[4,5] Neves et al[8] reported no significant difference in MD between IPS e.max press crowns and IPS e.max CAD crowns fabricated by the CEREC inLab MC XL. In both the present study and that of Neves et al[8], no significant difference in MD was found between the CAD-CAM and hot-press techniques. However, both studies used different methods for fabrication of the IPS

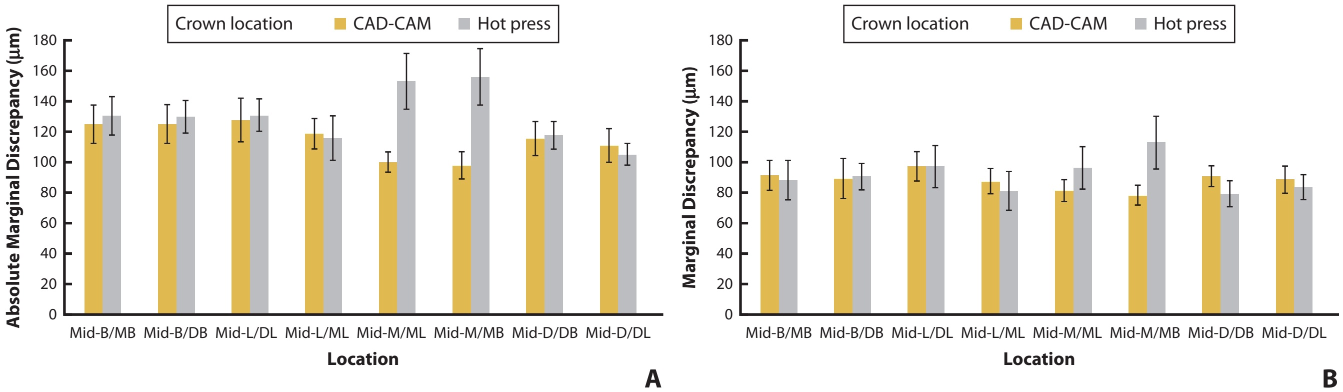

Figure 4. Mean and SE values measured at 8 locations in each crown. Mid-buccal location, Mid-B/MB, represents mesial side of measurement point. Mid-B/DB represents distal side of measurement point. Mid-lingual location, Mid-L/ML, represents mesial side of measurement point. Mid-L/DL represents distal side of measurement point. Mid-mesial location, Mid-M/ML, represents lingual side of measurement point. Mid-M/MB represents buccal side of measurement point. Mid-distal location, Mid-D/DB, represents buccal side of measurement point. Mid-D/DL represents lingual side of measurement point. SE, standard error. A, Absolute marginal discrepancy. B, Marginal discrepancy.

e.max CAD crowns. The present study used a chairside CAD-CAM milling machine with an integrated system, including a scanner, software, and a milling device from the same company (Dentsply Sirona), whereas Neves et al[8] used a CEREC inlab MC XL. When using a chairside CAD-CAM milling machine, the dentist performs the scanning, plans the restoration, determines the finish line, prepares the tooth, and directly visualizes the abutment tooth and the finish line. Therefore, the dentist should be able to determine the finish line more accurately than a laboratory technician who has not seen the prepared tooth.

However, another study that did not use a chairside CAD-CAM milling machine found significantly smaller mean MD values in IPS e.max CAD crowns, 33.30 µm, than in crowns produced by traditional impression and press manufacturing, 51.88 µm.[17]

Anadioti et al[15] compared the marginal fit of IPS e.max press crowns with that of IPS e.max CAD crowns fabricated with an E4D milling engine CAD-CAM using digital (Lava C.O.S.) and conventional polyvinyl siloxane impressions. The combination of the conventional impression method and the press fabrication technique resulted in a significantly smaller MD, 48 µm, than that of crowns fabricated by CAD-CAM, 84 µm. Comparisons of the 2 fabrication methods should be interpreted with caution, as the manufacturing techniques are highly different.[15] Anadioti et al[15] used an E4D milling engine, whereas a chairside CAD-CAM CEREC MC XL milling device was used in this study. The CEREC milling device uses a cylindrical diamond rotary instrument with a small diameter tip in a step rotation, which enables high-precision grinding.[22] Crowns fabricated by the hot-press technique require multiple steps, including a complete contour wax pattern and pressing of ceramic ingots into the resulting cast to the full extent of the wax pattern. These steps were combined, but errors in preparation design, particularly involving the margin, are easier to manage when the lost-wax technique is used.[8]

In this study, the crowns were cemented to simulate clinical conditions. Studies examining marginal fit before and after cementation have found that cement has a negative effect and that marginal fit is worse after cementation.[4,12,23] Neves et al[8] and Anadioti et al[15] reported lower mean MD values for IPS e.max press crowns and IPS e.max CAD crowns than the present study. However, these previous studies did not include crown cementation.

Another factor that may have affected the marginal fit values was the use of finger pressure in the cementation process. Weaver et al[24] reported a mean finger pressure seating force of 78.5 N, whereas the force exerted with a cotton roll during cementation was estimated to be 137 N.

Different values have been obtained in studies examining the marginal fit of ceramic crowns. The differences between these results may be due to differences in how marginal fit was measured, as different methods can be used, including sectioning crowns with a disk,[19,20] microcomputed tomography,[4,21] and the silicone paste technique.[7] Alternatively, the differences may be due to the definition of marginal fit, as marginal fit can involve more than one parameter, according to Holmes et al.[13] Therefore, it is difficult and inaccurate to compare data from different studies.

According to McLean and von Fraunhofer,[9] a marginal fit less than 120 µm is clinically acceptable. The MD values obtained in the present study were within the clinically acceptable range. The 95% confidence interval ranged from 74 µm for the lower bound to 101 µm for the upper bound for IPS e.max CAD crowns. For IPS e.max press crowns, the lower bound was 77 µm, and the upper bound was 104 µm.

The literature is conflicting regarding the marginal fit of CAD-CAM systems compared with that of other fabrication methods. In studies examining the marginal fit of CAD-CAM, the MD range was from 50 to 100 μm,[10,11] and the clinically acceptable MD was 90 μm.[12,14] The present research met these requirements for clinically acceptable gaps according to the mean values and 95% confidence intervals.

This study has some limitations. The study was conducted in vitro. Tooth models were used as abutments, and finger pressure was used to lute crowns. The hot-press crowns were fabricated without an impression, as the prepared tooth models were sent directly to the dental laboratory. These features are highly different from those observed in the intraoral environment. Marginal fit was measured after the specimens had been cut with a disk, which could have affected the quality of the specimens. In addition, the cement thickness in the occlusal area, which reflects the seating quality of the crowns and could have influenced the MD, was not measured. The clinical relevance of the findings is that both techniques are good treatment options. However, further in vitro and in vivo research is needed to support the conclusions regarding the clinical performance of these crowns.

CONCLUSIONS

Within the limitations of this in vitro study, the following conclusions were drawn:

1. No statistically significant differences in MD and AMD were observed between the CAD-CAM and hot-press fabrication methods.
2. Both methods for fabricating monolithic lithium disilicate crowns, CAD-CAM and hot-press, yielded MD values of less than 120 μm, within the clinically acceptable range.

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