Original Article

Stereomicroscopic Evaluation of Marginal Fit of E.Max Press and E.Max Computer-Aided Design and Computer-Assisted Manufacturing Lithium Disilicate Ceramic Crowns: An *In vitro* Study

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Abstract

Objective: The purpose of this study was to compare the marginal gap of E-max press, and E.max computer-aided design and computer-assisted manufacturing (CAD-CAM) lithium disilicate (LD) ceramic crowns fabricated by using conventional technique and CAD-CAM technique.

Materials and Methods: This was an *in vitro* experimental study carried out in Riyadh Elm University and King Saud University. A marginal gap of 30 LD crowns was evaluated by Stereomicroscopy. A total of 15 pressable LD (IPS E.max Press [Ivoclar Vivadent]) ceramic crowns were fabricated by using conventional lost wax pattern method (Group A). Digital impressions of the prepared dies were scanned and transferred to the milling machine. IPS E.max CAD (IPS E-max, Ivoclar, Amherst, NY, USA) LD blocks in shade Vita A2 were then milled by using DWX-50 machine for CAD-CAM crowns (Group B). Descriptive statistics of mean and standard error of marginal gaps for both groups were recorded and compared by applying Mann–Whitney U-test. All the data were analyzed by using statistical analysis software SPSS version 21.0 (Armonk, NY, USA: IBM Corp).

Results: The LD crowns prepared by CAD-CAM technology (26.80 ± 3.4 μm) had significantly lower ($P < 0.001$) marginal gap than the LD pressed crowns (38.8 ± 2.3 μm) fabricated by conventional technique. The marginal gaps between CAD-CAM versus conventional groups exhibited significant differences at (42.68 μm vs. 52.46 μm, U = 51.500, $P = 0.011$), Mesiobuccal (15.94 μm vs. 30.13 μm, U = 45.500, $P = 0.005$), distolingual (26.70 μm vs. 43.86 μm, U = 63.500, $P = 0.042$), and distal (12.38 μm vs 31.45 μm, U = 47.500, $P = 0.006$).

Conclusions: Within the limitations of the study, it can be concluded that LD all ceramic crowns fabricated by using CAD-CAM techniques showed lesser marginal gap and better marginal fit compared to the conventional technique.

Keywords: *Computer-aided design and computer-assisted manufacturing technology, E.max crowns, heat-pressed technique, marginal gap*

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Introduction

Porcelain fused to metal restorations are contemplated as the gold standard restorations because of their excellent mechanical properties of flawless fit, high strength, marginal integrity, and longer duration.[1] However, some problems such as

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periodontitis, cracks, debonding of ceramics, and lack of enamel-like appearance restricts their use.[2,3] For many years, full coverage crown restorations have become the commonly utilized type of prosthetic replacement to restore function and aesthetic.[4] Lithium disilicate (LD) is a ceramic-based material preferred for the fabrication single crowns, and short-span fixed dental prostheses due to their better marginal fit.[5] Nowadays, LD is commonly used, as it combines the biocompatibility, longevity, and good esthetic results.[6-8]

Currently, two techniques are in use for the fabrication of all ceramic crowns. The IPS E.max press technique that utilizes heat-process in which the LD ingots are subjected to hot-pressing by means of pneumatic ram inside the porcelain furnace to press ceramic bars into the molds.[9] Another fabrication technique is the computer-aided design and computer-assisted manufacturing (CAD-CAM) system computer-aided design and computer-aided manufacturing technology introduced in the dental field in the year 1980s.[10] The CAD-CAM technology charge-coupled camera device to obtain an abutment tooth to produce three-dimensional (3D) image, and ceramic block is then milled based on digital information. Restorations and crowns can be fabricated with in a single-patient visit.[11]

The conventional lost-wax pattern technique of crown fabrication is commonly employed and is considered as the gold standard. However, certain disadvantages such as ineffective use of manufacturing time and deficient technical skills are commonly related to the conventional fabrication technique.[12,13] Moreover, experience and expertise are required in fabrication of ceramic restoration by conventional technique as it involves obtaining natural look like appearance and shaping of the final restoration under high shrinkage during baking process at high temperatures. Even after the final product may not be satisfy with high production cost in conventional technique. On the contrary, the fabrication of crowns in porcelain blocks by using CAD-CAM technology less costly due to the mass production and almost no internal defects in the milled crowns. However, the fabrication of the crowns with conventional technique involves wax and baking at high temperature with more likely risk of developing high internal porosities.[14]

The marginal fit is the key element and most important criteria for the longevity of all ceramic crowns. The marginal discrepancy is the vertical measurement from the cervical margin of the casting to the margin of the preparation.[4] The presence of a high marginal gap or discrepancies open up the cement to the oral milieu permitting the plaque accumulation leading to gingival inflammation, deterioration of soft tissues, and periodontal diseases. It also initiates caries and causes bone loss.[15,16] The recent studies have reported that the marginal discrepancies of 91.15–90 μm was observed with heat-press conventional fabrication technique while crowns prepared with CAD/CAM technique showed a marginal discrepancy of 87–111.07 μm. A study by Reiss and Walther suggested that the acceptable margin opening should be between 50 and 120 μm.[2,17] Several methods, ranging from stereomicroscopy, scanning electron microscopy, optical microscopy, and micro-computed tomography were utilized to evaluate the marginal fit of the restorations.[18-21]

Previous studies compared the marginal fit of LD crowns processed by the heat-press technique with the fit of those fabricated by the CAD-CAM technique and observed that CAD-CAM LD crowns yielded poorer marginal fit compared with heat-pressed restorations.[22,23] On the contrary, the latest literature on this subject has reported that the CAD-CAM ceramic restorations having superior fit when compared to the crowns fabricated by heat-press technique.[3,24,25] However, Papadiochou and Pissiotis did not observe any superiority of the of CAD-CAM milling over the casting technique about the marginal adaptation.[26] Inconsistencies in previously reported studies have created a dilemma regarding marginal fit of restoration fabricated by CAD-CAM and conventional techniques. Hence, there is a need to conduct a study on comparative evaluation of marginal fit of the LD ceramic crowns fabricated by conventional technique and CAD-CAM techniques. This study also helps to support the existing literature.

Hence, the purpose this *in vitro* study was to compare the marginal fit of E-max press and E.max CAD/CAM LD ceramic crowns fabricated by using conventional technique and CAD/CAM technique. The proposed null hypothesis was that there are no significant differences between marginal gaps of ceramic crowns fabricated by conventional technique and CAD-CAM technique.

Materials and Methods

Sample size calculation

A sample size of 30 (Group A = 15, Group B = 15) was calculated based on large effect size, alpha error probability of ($\alpha = 0.05$), power (1-β err $P = 0.87$) and allocation ratio (N2/N1 = 1).

Ethical approval

The research proposal submitted to the Research Center of Riyadh Elm University and the Institutional Review Board gave approval for the study (RC/IRB/2016/580).

Master die fabrication and preparation

A prepared tooth # 16 was selected from a demo model (CEREC AC Modell, Ivoclar vivadent, USA). The preparation had a heavy chamfer finish line (135°, 1 mm thickness), a smooth continuous margin, no irregularities, a total convergence angle of 10º, axial surface height of 6 mm, and 2 mm of occlusal reduction. To eliminate the effect of impression and pouring inconsistencies, a cobalt chrome metal die was fabricated and used as the definitive die. The demo model (CEREC AC Modell, Ivoclar Vivadent, USA) was scanned using a 3D-laser scanner (Smart Optical 3D scanner, Open Technology, Italy)®. The data was then transferred into a software (Exocad software, Germany)® to mill a metallic master die (Mteal Alloy, Mesa Italy) in the computer-aided machine (Roland, California, USA)® to generate a definitive die simulating all ceramic preparation. After milling metal, die was smoothened with a rubber wheel and polished with pumice to avoid any interference with the seating of the crowns. This metal die was then used to assess the marginal fit of the crowns fabricated by the CAD-CAM and conventional techniques [Figure 1].

Group A: IPS E.max press crown fabrication

Conventional impression

Impressions of the prepared master die were taken with polyvinyl siloxane (Doublident, Willman and Pein GmbH, Germany). From this impression, 15 stone dies were poured with Type IV dental stone (professional snow rock/die stone type 4/Korea).

Fabrication of wax-patterns

An experienced laboratory technician trimmed each die stone and opened the margins; a die spacer (Durolan/dental future system/Germany) applied to create a space for the cement. Later on, wax build-up and sprue attachment were carried out. The wax pattern fixed to the center of a casting ring at 15° to the investment (Maruvest speed/Megadental/Germany) wax was burned out to eliminate it completely. LD ingots placed in casting ring and heat pressed for 25 min within the furnace. Afterward, the casting ring was trimmed by a diamond disc and sandblasting procedure was carried out. The sprue attachment was cut staining and glazing of the ceramic crown was accomplished.

Figure 1: Definitive die

Group B: IPS E.max computer-aided design crown fabrication

Digital impression and computer-aided design and computer-assisted manufacturing crown fabrication

Optical impressions of the prepared dies were scanned by using the (Exocad smart optical 3D-scanner/open technologies/Italy) and the data have been transmitted to a software program (DWX-50 software/Easy shape by Roland/Australia) to design the crowns, a milling unit (DWX-50 dental milling machine/Roland/North America) used to fabricate 15 IPS E.max CAD-CAM crowns.

Measurement of the marginal fit

All the IPS E.max Press crowns and IPS E.max CAD-CAM crowns were glazed and subjected to measurement of marginal gap [Figure 2].

The vertical distance between the finish line and the most apical part of the crown represented the marginal gap. A custom-made holder with a special pin to lock the specimen in place on the corresponding metal die was prepared [Figure 3]. Eight points (buccal, lingual, distal, mesial, mesiolingual, mesiobuccal, distolingual, and distobuccal) were measured by fixing the specimens into a custom holder loaded horizontally on the stage of a digital microscope (Digital microscope KH-7700 Hirox company/USA) under ×50 magnification. This digital microscope was a stereomicroscope with a microscope camera connected to a software program [Figure 4].

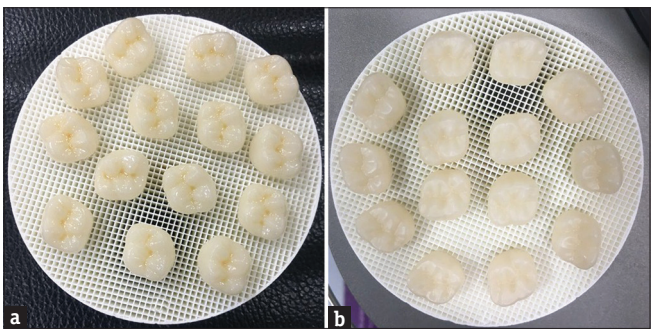

Figure 2: Fabricated crowns of IPS E.max Press by conventional technique (a), and IPS E.max computer-aided design and computer-assisted manufacturing (b)

Statistical analysis

The data obtained from all the measurements were entered into the statistical analysis software SPSS version 21.0 (Armonk, NY, USA: IBM Corp). Descriptive statistics of mean, standard error (SE), and mean ranks were calculated for marginal discrepancy of the crowns. Normality of the checked with Shapiro–Wilk test and the data showed nonnormal distribution ($P < 0.05$); hence, Mann–Whitney U test was applied to compare between the marginal gap of crowns prepared with CAD-CAM and conventional crowns. The level of significance was set at $P < 0.05$ for all statistical purposes.

Results

The marginal gap of each individual specimen was measured at eight sites, and the mean (±SE) value was reported in micrometers (μm).

The mean marginal gap for the conventional crowns was higher than those of the CAD-CAM crowns. Conventional crowns showed the highest and lowest mean marginal gap at buccal surface (52.46 ± 6.48 μm) and at mesial surface (29.22 ± 6.07 μm), whereas, CAD-CAM crowns showed the highest marginal gap at buccal (42.68 ± 19.29 μm) and distal surfaces (12.38 ± 4.42 μm). In general, the crowns produced by conventional technique showed higher marginal gaps compared to that of the crowns fabricated by CAD-CAM technology, as shown in Table 1.

Mann–Whitney U-test applied to compare the mean marginal gap between ceramic crowns prepared by using conventional and CAD-CAM techniques in different surfaces. Mean values of marginal gap between CAD-CAM versus conventional groups exhibited significant differences at buccal (42.68 vs. 52.46 μm, U = 51.500, $P = 0.011$), Mesiobuccal (15.94 vs. 30.13 μm, U = 45.500, $P = 0.005$), distolingual (26.70 vs. 43.86 μm, U = 63.500, $P = 0.042$), and distal (12.38 vs. 31.45 μm, U = 47.500, $P = 0.006$) surfaces. On the contrary, marginal gap did not differ significantly in mesial, mesiolingual, lingual, and distobuccal surfaces of conventional and CAD-CAM groups [Table 2].

In general, crowns fabricated with the CAD-CAM (26.80 μm) technologies demonstrated significantly lower marginal gap compared to the crowns fabricated with the conventional (38.8 μm, $P < 0.001$) technique as shown in Figure 5.

Discussion

Marginal fit is a significant factor in the success and durability of dental restorations.[27] The main aim of this

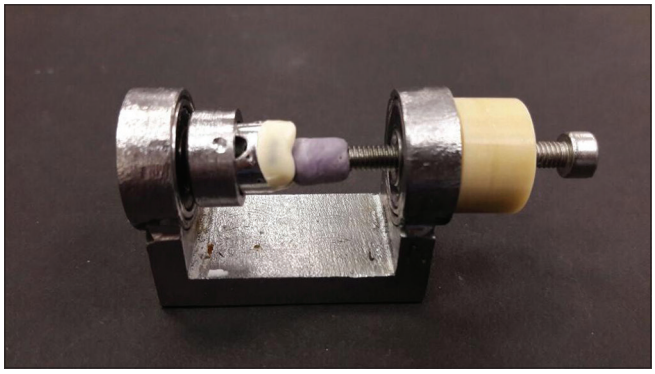

Figure 3: Custom holder with a special pin to lock specimen on the metal die

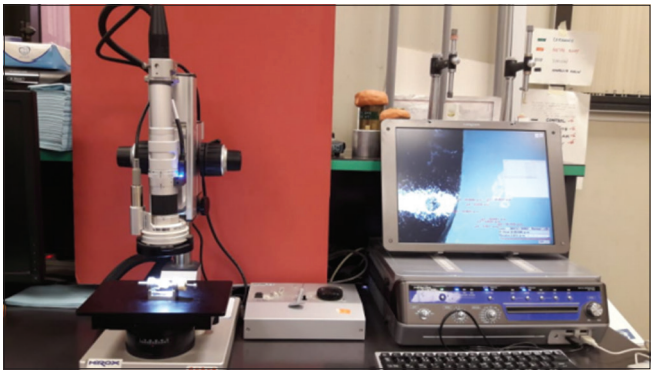

Figure 4: Stereomicroscope (Hirox Company) with a camera connected to a software program

Table 1: Descriptive analysis of marginal gap of the crown groups in micrometers (μm)

Surface	CAD-CAM			Conventional		
	Mean±SEM	Minimum	Maximum	Mean±SEM	Minimum	Maximum
Buccal	42.68±19.29	3.81	300.31	52.46±6.48	19.06	100.29
Mesiobuccal	15.94±7.38	3.81	115.95	30.13±6.25	3.81	77.76
Mesial	21.26±6.41	3.81	84.22	29.22±6.07	3.81	62.87
Mesiolingual	29.59±8.12	3.81	86.01	41.88±5.78	3.81	74.02
Lingual	42.04±8.90	5.39	118.24	42.92±5.82	12.05	76.34
Distolingual	26.70±8.14	3.81	109.17	43.86±6.60	5.39	87.68
Distal	12.38±4.42	3.81	69.57	31.45±5.31	3.81	63.90
Distobuccal	24.11±6.09	3.81	73.33	38.76±7.48	3.81	76.34
Total	26.80±3.4	3.8	300.3	38.8±2.3	3.8	100.3

SEM=Standard error of mean, CAD-CAM=Computer-aided design and computer-assisted manufacturing

Table 2: Comparison of marginal gap between the crowns fabricated by conventional and computer-aided design and computer-assisted manufacturing techniques (μm)

Surfaces	Method	Mean	Mean rank	Sum of ranks	Mann-Whitney U	*P*
Buccal	CAD-CAM	42.68	11.43	171.50	51.500	0.011*
	Conventional	52.46	19.57	293.50		
Mesiobuccal	CAD-CAM	15.94	11.03	165.50	45.500	0.005**
	Conventional	30.13	19.97	299.50		
Mesial	CAD-CAM	21.26	13.87	208.00	88.000	0.306
	Conventional	29.22	17.13	257.00		
Mesiolingual	CAD-CAM	29.59	13.30	199.50	79.500	0.171
	Conventional	41.88	17.70	265.50		
Lingual	CAD-CAM	42.04	14.43	216.50	96.500	0.507
	Conventional	42.92	16.57	248.50		
Distolingual	CAD-CAM	26.70	12.23	183.50	63.500	0.042*
	Conventional	43.86	18.77	281.50		
Distal	CAD-CAM	12.38	11.17	167.50	47.500	0.006**
	Conventional	31.45	19.83	297.50		
Distobuccal	CAD-CAM	24.11	12.83	192.50	72.500	0.097
	Conventional	38.76	18.17	272.50		

*P<0.05, **P<0.01. CAD-CAM=Computer-aided design and computer-assisted manufacturing

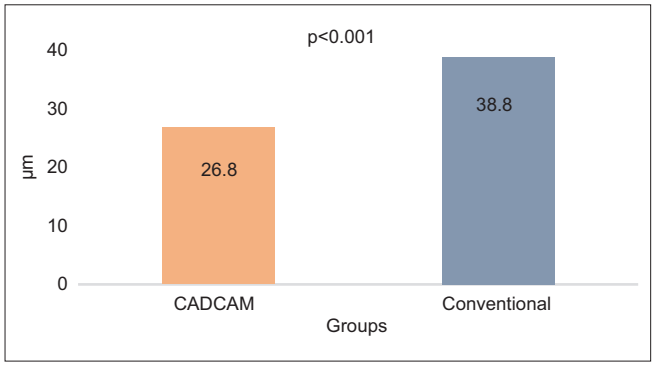

Figure 5: Comparison of overall marginal gap between CAD-CAM and conventional groups

in vitro study was to compare the marginal gaps of LD ceramic crowns fabricated using conventional technique and CAD-CAM techniques. The results indicated that the fabrication technique has a remarkable effect on marginal fit of the crown. E.max CAD-CAM LD ceramic crowns produced the smallest (mean ± SE) marginal gap at (12.38 ± 4.42 μm) and highest marginal gap at (42.68 ± 19.29 μm), whereas conventional technique produced a smallest marginal gap at (29.22 ± 6.07 μm) and highest marginal gap at (52.46 ± 6.48 μm).

In view of above-mentioned findings, the primary outcome measure (marginal gap) was found to be significantly lower in LD ceramic crowns fabricated by using CAD-CAM technique compared to the LD ceramic crown fabricated by conventional technique. Hence, the null hypothesis of no significant difference in marginal gap of LD ceramic crowns fabricated by using CAD-CAM technique and conventional technique was rejected.

A total mean marginal gap for CAD-CAM group was 26.80 μm, whereas the conventional group gave the mean value of 38.83 μm. In spite of the significant differences, both fabrication techniques produced marginal gap of <100 μm. This is considered as an acceptable marginal gap produced during fabrication of the LD ceramic crowns.[14]

When comparing our findings with Neves *et al*.,[28] it can be acknowledged that the marginal gaps resulting from CAD-CAM were lower as compared to conventional technique of crown fabrication. This finding supports the results of our investigations. Similar outcome was revealed in a study conducted by Alqahtani[3] in which marginal fit of crowns prepared by CAD-CAM systems highly improved compared to the conventional procedures. This suggests the effectiveness of using the computer-aided techniques in providing reliable restorations to the patients. In general, the LD crowns fabricated by conventional technique showed higher marginal gap compared to the crowns fabricated by CAD-CAM technology. These differences in the marginal gap could be due to the precision of digital scanning or CAM milling.

Conversely, a laboratory investigation by Mously *et al*. disclosed that the marginal gaps resulting from conventional technique were lower than the gaps produced by CAD-CAM technology.[10] Similar contradicting results were presented in various studies in which marginal gaps produced by conventional press technique was lower than that of the CAD-CAM technique.[29] In addition, few recent studies reported no significant differences in marginal fit of LD ceramic

crowns fabricated either by using conventional or CAD-CAM techniques.[26,30-32]

Our study also compared the mean values of marginal gaps on different surfaces between ceramic crowns fabricated by conventional and CAD-CAM techniques, and the results showed that CAD-CAM crowns had significantly lesser mean marginal gaps at buccal, mesiobuccal, distolingual, and distal surfaces compared to the conventionally fabricated crowns. This may be suggestive of higher precision and milling capability of the CAD-CAM systems. On other surfaces marginal fit was similar to that of the conventional crowns.

The strengths of the study included the *in vitro* experimental study design carried out in a laboratory condition. This removed the possibility of clinical errors such as limited of access, saliva, bleeding, finish lines, and the effect of impressions (conventional or optical) techniques. To avoid manual tooth preparation discrepancies, a demo model simulating all-ceramic crown preparation was scanned and a cobalt-chromium definitive die fabricated to measure against the marginal fit of the crowns. A single-trained investigator performed the tasks of impression making by optical techniques and conventional method. A custom-made holder with a special pin to lock specimen on the metal die was prepared thereby standardizing the all the parameters of measuring the marginal gap. No attempt was made to cement the crowns; instead the special pin locked the specimen on the die thereby eliminating the possibility of marginal errors from underlying thickness of the cement.

Unlike other studies, our study also had some limitations. The study was conducted under *in vitro* conditions. This may not reflect the true intraoral environment. The clinical importance of the study is that CAD-CAM technique of crown fabrication is superior than the conventional preparations due to its accuracy of digital impression and milling quality.

Systematic review and meta-analysis on marginal fit of the ceramic crowns fabricated by using digital and conventional technique showed conflicting conclusions. Tsirogiannis *et al*. systematically reviewed the available studies and evaluated the marginal fit of the restorations fabricated by digital and conventional techniques and reported no significant differences in the marginal fit.[33] On the contrary, Chochlidakis *et al*. reviewed the *in vitro* studies that compared marginal and internal fit of the restorations fabricated by using digital and conventional techniques and concluded that digital technique produced better marginal and internal fit than conventional techniques.[34] However, recent studies on marginal fit of the crowns by CAD-CAM and conventional techniques did not provide a clear conclusion about the superiority of the CAD-CAM over the conventional casting technique. Instead, studies reported clinically acceptable range of marginal gap with the fabrication of ceramic crowns by using both the techniques.[14,26,35]

This *in vitro* study provided further strength to the evidence supporting lower marginal gap of ceramic crowns fabricated by CAD-CAM techniques compared to the conventional fabrication technique. However, future *in vitro* and clinical research is warranted to support the findings of the current study in an era of technological advancements.

Conclusions

Within in limitations of this *in vitro* study, it can be concluded that the E.max LD ceramic crowns prepared by CAD-CAM technologies exhibited lower marginal gap and better fit compared to the E.max press LD ceramic crowns fabricated by conventional techniques. Hence, CAD-CAM technology can be considered as superior and alternative to the conventional method of fabrication of the crowns.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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