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Research Article

Marginal Adaptation and Internal Fit of All Ceramic Crowns Fabricated with Pressed Versus Milled Zirconia Reinforced Lithium Silicate (An *In-vitro* study)

Fahmi Y[1]*, Taymour M[2] and El Naggar G[3]

[1]MSc Degree Student, Fixed Prosthodontics Department, Faculty of Dentistry, Cairo University, Cairo, Egypt

[2]Associate Professor, Fixed Prosthodontics Department, Faculty of Dentistry, Cairo University, Cairo, Egypt and Associate Professor, Fixed Prosthodontics Division, School of Dentistry, Newgiza University, Giza, Egypt

[3]Professor, Fixed Prosthodontics Department, Faculty of Dentistry, Cairo University, Cairo, Egypt

***Corresponding Author:** Fahmi Y, MSc Degree Student, Fixed Prosthodontics Department, Faculty of Dentistry, Cairo University, Cairo, Egypt.

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Abstract

Aim: Evaluate the marginal adaptation and internal fit of Zirconia reinforced Lithium silicate crowns fabricated with heat pressed "Celtra Press" ingots compared to crowns fabricated with milled "Celtra Duo" blocks.

Methodology: Ten zirconia reinforced lithium silicate crowns were studied and divided into two groups according to fabrication method; heat pressed group and milled group. A stainless-steel die was prepared according to the all-ceramic tooth preparation criteria. The metal die was scanned by intraoral scanner (CEREC Omnicam). Group I ($n = 5$) was constructed by means of heat pressing of milled wax patterns into Celtra Press ingots. Group II ($n = 5$) was milled from Celtra DUO blocks. Each crown was placed on the metal die and the vertical marginal adaptation was measured by direct viewing method using a stereomicroscope. The internal fit of crowns was measured using silicone replica technique. Data were statistically analysed by 1-way ANOVA, followed by the Tukey honestly significant difference test ($P < 0.05$).

Results: The mean values of vertical marginal gap were 24.69 ± 1.28 µm for the heat-pressed group and 24.23 ± 1.26 µm for the milled group, with statistically non-significant difference between both groups. The mean values of internal gap were 60.77 ± 6.3 µm for the heat-pressed group and 93.94 ± 1 µm for the milled group. There was statistically significant difference between both groups in terms of internal fit.

Conclusions: Within the limitations of this in-vitro study, it can be concluded that the manufacturing technique of zirconia reinforced lithium silicate has no effect on the vertical marginal adaptation of the crowns. Heat pressing of zirconia reinforced lithium silicate crowns produced more favorable internal fit compared to milling technique. The marginal and internal gaps achieved by the crowns across all groups were within a clinically acceptable range.

Keywords: Zirconia Reinforced Lithium Silicate; Milled; Heat Pressed; Marginal Adaptation; Internal Fit

Introduction

The popularity of esthetic dentistry has evolved in recent decades resulting in an increase in demand for all-ceramic dental restorations. All-ceramic restorations provide both esthetics and biocompatible results that are hardly achieved by metal or metal ceramic restorations [1].

Lithium disilicate ceramic restoration is one of the all-ceramic systems that have gained popularity in the dental field due to its superior physical properties and adequate strength. Zirconia reinforced lithium silicate (ZLS) glass ceramic was then introduced into the dental market and were categorized as lithium disilicate glass ceramic derivatives. This glass ceramic is enhanced with zirconia (10% by weight) to strengthen the ceramic structure by preventing crack propagation and thereby increasing fracture resistance [2].

Heat press technique and CAD/CAM technology are the two most prevalent manufacturing procedures for all ceramic restorations [3,4]. Heat press technique is based on lost wax principle where a pattern is formed for the desired restoration. This pattern is then invested and casted to obtain the final restoration. The heat-press method is easily handled, and has been producing restorations with optimal biological, mechanical and esthetic properties for a long time in dentistry [3]. CAD/CAM technology utilizes computer aided scanning, designing and milling of final restorations. It has been developed to eliminate the need for the traditional impression-taking, model-pouring, and multiple laboratory steps for fabricating crowns [4].

The marginal adaptation and internal fit are two of the most important criterion for long term success of the restoration from the biological and mechanical points of view. Cement dissolution, marginal discoloration, microleakage, hypersensitivity, increased plaque retention, and secondary caries are possible consequences of poor marginal fit [5-7]. Poor internal fit leads to excessively thick cement layer which causes residual stresses on the tensile surface of the restoration as a result of the viscoelastic deformation of the cement material under cyclic loading. These increased tensile stresses may damage the veneering porcelain and initiate chipping of the veneering layer [8,9] Therefore, it is crucial to minimize marginal and internal gaps to decrease the incidence of associated complications.

Information regarding the marginal adaptation and internal fit of zirconia reinforced lithium silicate material is scarce. Therefore, the current study was conducted to investigate the effect of two techniques of manufacturing, heat pressing and CAD/CAM technology, on the marginal adaptation and internal fit of zirconia-reinforced lithium silicate crowns.

The first null hypothesis of the study was that within the clinical acceptable range, there would be no significant differences between heat pressed and CAD/CAM milled zirconia reinforced lithium silicate crowns in terms of marginal adaptation. The second null hypothesis of the study was that within the clinical acceptable range, there would be no significant differences between heat pressed and CAD/CAM milled zirconia reinforced lithium silicate crowns in terms of internal fit.

Materials and Methods

The materials investigated in the current study are Celtra Press ceramic ingots by Dentsply Sirona DeguDent GmbH, Germany and Celtra DUO ceramic blocks by Dentsply Sirona, Degu Dent GmbH, Germany. A total of ten full anatomical crowns were designed and fabricated in the present study. The crowns were divided into two main groups according to material selection; Group I included heat pressed zirconia reinforced lithium silicate: Celtra Press (n = 5). Group II included milled zirconia reinforced lithium silicate: Celtra DUO (n = 5).

Metal die construction

A maxillary first premolar metal die was milled according to the customary all-ceramic tooth preparation. The metal die was machined using an engineering lathe machine. The die had a 1 mm circumferential deep chamfer finish line with a total occlusal convergency of 10 degrees. The occlusogingival height was 4 mm with planar occlusal reduction [10].

Fabrication of ceramic crowns

The stainless steel die was sprayed by CEREC optispray powder by Sirona Dental Systems and scanned by a CEREC Omnicam intraoral scanner Sirona Dental Systems. The clarity of the scan was checked and the scan was stored as a Standard Tessellation Language (STL) file. For the heat pressed group; The STL file was transferred to the exocad plovdiv 2.4 software, exocad GmbH. The crown was designed with the virtual spacer setting of 50 µm. The design was transferred to the K_{5+} milling machine and was milled from BiLKim CAD wax blank. The wax patterns were reflowed through the marginal wax over a band of 1 mm width to ensure optimal wax adaptation at the margin [9] The wax pattern was sprued and invested in Celtra press investment phosphate-bonded material. Burnout procedure was carried out then the celtra press ingot was pressed into the mold using Ivoclar Programat EP 3010 Ivoclar Vivadent. Segmenting and divesting of the investment were done and the Celtra Press crown was checked on the metal die. For the milled group; the same STL file was used to design the crown on the CEREC premium 4.4 software. The cement space was set to 50 µm and the Celtra DUO blocks were milled using CEREC MC XL, four axis milling unit, Sirona Dental Systems. Dentsply Sirona universal stain and glaze kit was used for glazing of the ceramic crowns in both study groups.

Marginal adaptation measurements

Each specimen was placed on the stainless steel die and fixed in place using special holding jig [11] (Figure 1). Specimens were photographed using measuring Stereomicroscope Nikon Eclips E600 connected with an IBM compatible personal computer using a fixed magnification of 45x. Morphometric measurements were done for each shot where 3 equidistant landmarks along the circumference for each surface of the specimen (mesial, buccal, distal, and lingual), with a total of 12 points across the entire circumference of the crown. Measurement at each point was repeated five times [12] The data obtained were collected, tabulated and then subjected to statistical analysis.

Internal fit measurements

Internal fit was measured using the silicone replica technique. Each crown was filled with Elite HD+, light body silicone by Zhermack Spa and placed on the metal die under a constant load (750 g) for 10 min as guided by Korsel (2018) [13]. After the light-body silicone had set, the crown was removed and a heavy-body silicone Elite HD+, Zhermack Spa was used to stabilize the light-body silicone and prevents its distortion upon removal. The silicone replica was then obtained and placed on a graph paper with vertical and horizontal lines intersecting precisely at 90 degrees. Using a razor blade (n°. 15c), the replicas were carefully sectioned into four equal segments. From the four sections obtained from each replica, two opposite sections were used to measure internal fit, with 7 regions measured on each section (finish line, axial wall and occlusal), yielding 14 internal measurements for each coping [10]. Measurement at each point was repeated five times.

Figure 1: Crown supported on a holding metal jig.

Statistical analysis

The results were analyzed using Graph Pad Instate (Graph Pad, Inc.) software for windows. A value of $P < 0.05$ was considered statistically significant. Continuous variables were expressed as the mean and standard deviation. After homogeneity of variance and normal distribution of errors had been confirmed, one-way ANOVA was done for compared surfaces followed by Tukey's pair-wise if showed significant. Student t-test was performed to compare main groups. Sample size (n = 5) was large enough to detect large effect sizes for main effects and pair-wise comparisons, with the satisfactory level of power set at 80% and a 95% confidence level.

Results

Marginal adaptation results

The mean and standard deviation results of the effect of manufacturing technique (pressing versus milling) on the marginal gap are presented in (Table 1). Regardless to the measurement surface, it was found that Heat pressed group recorded higher marginal gap mean value (24.69 ± 1.28 µm) than Milled group mean value (24.23 ± 1.26 µm). There was statistically non-significant difference between both groups as indicated by t-test ($p = 0.7755 > 0.05$).

Regarding the effect of manufacturing technique (pressing versus milling) on the marginal gap at different surfaces, the mean and standard deviation are presented in (Figure 2). For the Heat pressed group, it was found that mesial surface recorded statistically non-significant highest marginal gap mean value (26.18 µm) followed by buccal surface mean value (25.51 µm) then lingual surface mean (24.81 µm) while distal surface recorded statistically non-significant lowest marginal gap mean value (22.29 µm). For the Milled group, it was found that buccal surface recorded statistically non-significant highest marginal gap mean value (26.67 µm) followed by mesial surface mean value (25.09 µm) then lingual

Variables		Mean	± SD Min.	Range		95% CI		Statistics
				Max.	Low	High	P value	
Manufacturing Technique	Heat Pressed Group	24.69	1.28	23.28	26.3	23.57	25.82	0.7755 NS
	Milled Group	24.23	1.26	22.59	25.5	23.1	25.46	

Table 1: Results of the effect of the manufacturing technique (pressing versus milling) on the marginal gap (Mean values ± SDs).
*; significant ($p < 0.05$) ns; non-significant ($p > 0.05$).

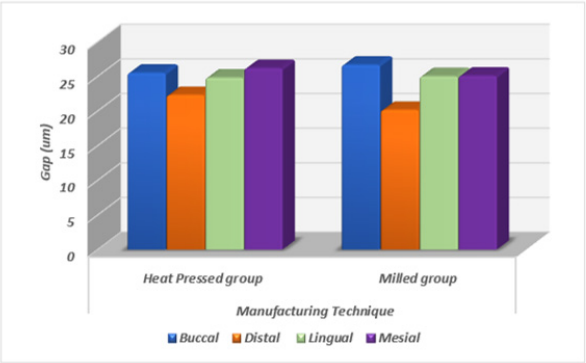

Figure 2: Column chart showing the effect of manufacturing technique (pressing versus milling) on the marginal gap at different surfaces.

surface mean (25.01 µm) while distal surface recorded statistically non-significant lowest marginal gap mean value (20.14 µm) as indicated by one-way ANOVA test (p = 0.5591 > 0.05).

Internal fit results

The mean and Standard deviation results of the effect of manufacturing technique (pressing versus milling) on the internal fit are presented in (Table 2). Regardless to the measurement site, totally it was found that Milled group recorded higher internal gap mean value (93.94 ± 1 µm) than Heat pressed group mean value (60.77 ± 6.3 µm). There was statistically significant difference between both groups as indicated by t-test (p = < 0.0001 < 0.05).

Regarding the effect of manufacturing technique (pressing versus milling) on the internal fit at different surfaces, the mean and standard deviation are presented in (Figure 3). For Heat pressed group; it was found that occlusal site recorded statistically significant highest gap mean value (77 µm) followed by axial site with intermediate gap mean value (62.85 µm) while the lowest statistically significant gap mean value recorded with margin site (42.46 µm). For Milled group; it was found that occlusal site recorded statistically significant highest gap mean value (105.3 µm) followed by axial site with intermediate gap mean value (90.81 µm) while the lowest statistically significant gap mean value recorded with margin site (85.72 µm) as indicated by one-way ANOVA followed by pair-wise Tukey's post-hoc tests (P = 0.0003 < 0.05).

Variables		Mean± SD P value	Statistics
Manufacturing Technique	Heat Pressed Group	60.77 ± 6.3	< 0.0001*
	Milled group	93.94 ± 1	

Table 2: Results of the effect of the manufacturing technique (pressing versus milling) on the internal gap (Mean values **± SDs).**
*; significant ($p < 0.05$) ns; non-significant ($p > 0.05$).

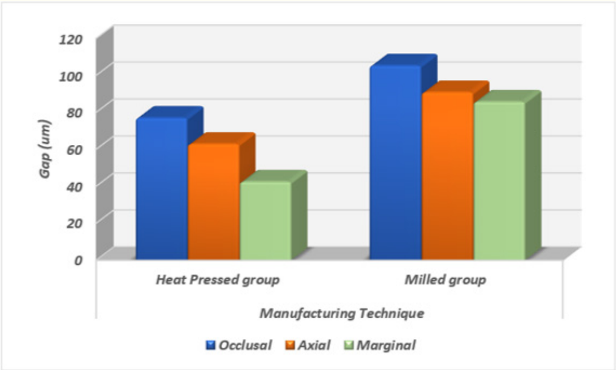

Figure 3: Column chart showing the effect of manufacturing technique (pressing versus milling) on the internal gap at different sites.

Discussion

Two of the most commonly used techniques are heat pressing and CAD/CAM technology. Both techniques are able to produce all ceramics restorations with favorable longevity and clinical performance [11]. The present study was conducted to evaluate which technique produces zirconia reinforced ceramic crowns with more favorable marginal adaptation and internal fit.

In the present study, a metal stainless-steel die was used as an abutment as it offers a standardized preparation and prevents wear of the die during the manufacturing processes and measurement taking [14,15]. The metal die preparation was made with a 1 mm circumferential deep chamfer finish line as it allows more precise seating and avoids tensile stresses and therefore prevents fracture of the brittle material [16,17]. The metal die had a total occlusal convergence of 10 degrees [18,19]. The occlusal preparation of the metal die was anatomical allowing proper seating of the crown on the die upon measurements and providing a uniform thickness of ceramic material thereby allowing enhanced ceramic flow during heat pressing [20,21].

The scanner used in the current study was the CEREC omnicam intraoral scanner which provides higher precision and trueness values compared to the extraoral scanners [22]. A single die scan was used for crown fabrication of all ceramic crowns in both study groups to ensure standardization and to eliminate errors due to difference in powder thickness between multiple scans [10]. The virtual spacer setting was set to 50 μm [23-25]. The choice of milling the wax pattern through CAD/CAM technology in the heat pressed ceramic group enabled standardization in the spacer setting parameter to 50 μm rather than the freehand wax build up with arbitrary spacer thickness application on the die. Additionally, milled wax patterns eliminates dimensional inaccuracies resulting from the release of thermal stresses generated in the pattern during previous heating and cooling of the wax [26,27,10].

In the present study, the direct view technique was used to assess the vertical marginal adaptation of the crowns on the metal die. It is the most widely used method in the literature [4] This method does not incorporate any procedures on the crown-die assembly such as sectioning or duplication of dies before measuring the gap, hence reducing the chance of error accumulation that may result from multiple procedures [28].

The internal gap was measured using the silicone replica technique. This technique has been widely used for its proven validity. It is a non- invasive method that replicates the complete cement space without destroying the sample. It was preferred over the cross sectioning technique, since the cross sectioning requires duplication of die, sacrifice the samples and increase variables that might affect the measurement mean value [29,30]. Moreover, cross sectioning technique requires the cementation of the restoration on the corresponding dies which may lead to additional variables and inaccuracies [4,31].

According to the results of the present study, the first null hypothesis was accepted whereas the second null hypothesis was rejected since fabrication technique (heat pressing versus milling) affected the internal fit of the zirconia reinforced lithium silicate crowns but showed no effect on the marginal adaptation.

With regards to the marginal adaptation, a marginal gap between 100-120 μm is considered clinically acceptable [7,25,32,33]. In the present study, there was statistically insignificant difference between the marginal adaptation of the heat pressed and the milled crowns. The marginal gap mean value recorded for the milled group was (24.23 ± 1.26 μm) while the heat pressed group was (24.69 ± 1.28 μm) which were both within the clinically accepted range. The statistically insignificant difference between the two techniques of manufacturing in terms of marginal adaptation may be attributed to the high accuracy of milling in CAD/CAM technology as well as the optimal wax adaptation at the margin in the heat pressing technique.

These findings were in agreement with several previous studies that stated that there is no significant difference in marginal adaptation between the CAD/CAM and heat pressing techniques of manufacturing of ceramic restorations [34,35].

On the contrary, Elrashid., *et al*. (2019) [11] and Vasiliu., *et al*. (2020) [10] reported better marginal adaptation of CAD/CAM fabricated all ceramic crowns compared to heat pressing technique, with statistically significant difference. The difference in findings obtained in these studies and the present study may be due to differences in the milling machines used and differences in sample size.

On the other hand, Neves., *et al*. (2014) [36] and Azar., *et al*. (2018) [37] reported better marginal adaptation of crowns fabricated by heat pressing technique compared to CAD/CAM technology. The discrepancies in results might be due to difference in ceramic material tested or differences in the method of marginal gap measurement.

In the present study, the heat pressed group revealed no significant difference in the marginal gap between buccal, distal, lingual and mesial surfaces, 25.51, 22.29, 24.81, 26.18 μm respectively. The same was found for the milled group, mean values were 26.67, 20.14, 25.01, 25.09 μm for the buccal, distal, lingual and mesial surface respectively. This is in agreement with several previous authors who stated that marginal gap values do not differ significantly among different meausement surfaces tested [11,34].

With regards to the internal fit, the acceptable internal gap ranges between 50 to 100um [7,9]. In the present study, the heat pressed group showed statistically significant smaller internal gaps compared to the milled group. The internal gap mean value recorded for heat pressed group was (60.77 ± 6.3 μm) while the mean value for the milled group was (93.94 ± 1 μm) which were both within the clinically accepted range. The findings of the present study may suggest that the flow of ceramic material under high pressure into the mold when pressed by the plunger leads to superior internal fit. The findings may also be attributed to the presence of software limitations in designing restorations and hardware limitations in the milling machine resulting in shortcomings of the CAD/CAM technique in terms of internal fit.

These findings were in agreement with several studies in literature [23,38]. Contradicting results were stated by Beyari (2014) [39] and Vasiliu., *et al*. (2020) [10], who reported that milled all-ceramic crowns showed significantly smaller internal gaps compared to heat pressed crowns. The discrepancies in results might be due to difference in the method internal gap measurement or differences in milling units. Another factor contributing to the difference in results may be the difference in method of wax pattern fabrication.

In the present study, the heat pressed group revealed significant difference between the internal gap at the occlusal, axial and marginal sites with mean values 77, 62.85 and 42.46 um respectively. The same was found for the milled group, with mean values of 105.3, 90.81 and 85.72 um for the occlusal, axial and marginal sites respectively. The occlusal internal gap recorded the highest internal gap values in both study groups with statistically significant difference. This may be attributed to the presence of retentive areas such as angles and grooves at the occlusal site affecting the ability of flow of ceramic in heat pressing procedure and limiting the ability of proper scanning and milling in CAD/CAM technique of manufacturing [5].

It is worth mentioning that a relation between internal and marginal gaps exist as smaller internal gaps may cause binding of the crown with the die which may interfere with the complete seating of the restoration. This is in agreement with the present study in which the heat pressed group exhibited smaller internal gaps and slightly larger marginal misfit. On the other hand, the CAD/CAM group which showed a larger internal gap exhibited better marginal fit [40].

Some limitations exist in the current study. Firstly, this is an in-vitro study and therefore it does not simulate the conditions of the oral cavity precisely. Moreover, the crowns were not cemented on their corresponding dies and were not subjected to an artificial aging process such as thermomechanical fatigue to simulate the clinical situation.

Conclusion

Based on the findings of the present *in vitro* study and within its limitations, it could be concluded that manufacturing technique (heat pressing and milling) of zirconia reinforced lithium silicate has no effect on the marginal adaptation of the tested crowns. Heat pressing of zirconia reinforced lithium silicate crowns produced a more favorable internal fit compared to milling technique. Marginal adaptation does not vary among different surfaces of the tested crowns whereas the internal fit is least favorable at the occlusal surface. The marginal adaptation and internal fit of both heat pressed and milled zirconia reinforced lithium silicate crowns were within the clinically acceptable range.

Conflict of Interest

The authors have no conflict of interest to disclose.

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