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ORIGINAL ARTICLE

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In vitro evaluation of marginal fit of zirconia-reinforced lithium silicate laminate veneers at two thicknesses using different CAD/CAM systems

Avaliação in vitro do ajuste marginal de folheados laminados de silicato de lítio reforçados com zircônia em duas espessuras usando diferentes sistemas CAD / CAM

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ABSTRACT

Objective: The purpose of this in vitro study was to evaluate the marginal fit of laminate veneers made of zirconia-reinforced lithium silicate with two thicknesses using different CAD/CAM systems. **Material and methods:** 42 Laminate veneers milled from zirconia-reinforced lithium silicate were divided into three main groups according to milling machine used into: group X5, laminate veneers fabricated by inLab MCX5 milling machine; group CM, laminate veneers fabricated by Ceramill motion 2 milling machine; and group XL, laminate veneers fabricated by inLab MCXL milling machine. Each group was divided into two subgroups according to veneer thickness into: subgroup I, 0.5 mm thickness laminate veneers and subgroup II, 0.3 mm thickness laminate veneers. The marginal fit was measured using stereomicroscope. The results were tabulated and statistically analyzed using two-way ANOVA test followed by Tukey's post hoc test. Comparisons of main and simple effects were done utilizing Bonferroni correction. The significance level was set at ($p \leq 0.05$) for all tests. **Results:** The mean (± SD) highest marginal discrepancy was recorded in subgroup CMII at 85.45 ± 1.82 μm while the least mean marginal discrepancy was recorded in subgroup X5I (71.24 ± 2.64 μm). **Conclusion:** Both thicknesses (0.5 mm thickness and 0.3 mm thickness) and all tested CAD/CAM systems produced zirconia-reinforced lithium silicate laminate veneers with clinically acceptable marginal gaps; however, the closed CAD/CAM systems produced veneers with superior marginal fit than open systems at 0.3 mm thickness. The CAD/CAM system with the 5-axis milling machine produced the best marginal fit with 0.5 mm thickness.

KEYWORDS

Marginal fit; Zirconia-reinforced lithium silicate; Laminate veneers; CAD/CAM; Milling machines.

RESUMO

Objetivo: O objetivo deste estudo in vitro foi avaliar a adaptação marginal de facetas laminadas de silicato de lítio reforçado com zircônia com duas espessuras, utilizando diferentes sistemas CAD / CAM. **Material e métodos:** 42 facetas laminadas fresadas a partir de silicato de lítio reforçado com zircônia foram divididos em três grupos principais de acordo com a fresadora usada em: grupo X5, facetas laminadas fabricados pela fresadora inLab MCX5; grupo CM, facetas laminadas fabricados por Ceramill motion 2; e grupo XL, facetas laminadas fabricados pelo inLab MCXL. Cada grupo foi dividido em dois subgrupos, de acordo com a espessura do laminado, em: subgrupo I, facetas laminadas com 0,5 mm de espessura e subgrupo II, facetas laminadas com espessura de 0,3 mm. A adaptação marginal foi medida usando estereomicroscópio. Os resultados foram tabulados e analisados estatisticamente usando o teste ANOVA de dois fatores seguido pelo teste post hoc de Tukey. Comparações dos efeitos principais e simples foram realizadas utilizando a correção de Bonferroni ($P \leq 0,05$). **Resultados:** A maior discrepância marginal média (± DP) foi registrada no subgrupo CMII em 85,45 ± 1,82 μm, enquanto a menor discrepância marginal média foi registrada no subgrupo X5I 71,24 ± 2,64 μm. **Conclusão:** Ambas as espessuras (0,5 mm e 0,3 mm) e todos os sistemas CAD / CAM testados produziram facetas de laminado de silicato de lítio reforçadas com zircônia com lacunas clinicamente aceitáveis. No entanto, os sistemas CAD / CAM fechados produziam facetas com adaptação marginal superior aos sistemas abertos com 0,3 mm de espessura. O sistema CAD / CAM com a fresadora de 5 eixos produziu a melhor adaptação marginal com 0,5 mm de espessura.

PALAVRAS-CHAVE

Adaptação marginal; Silicato de lítio reforçado com zircônia; Facetas laminados; CAD / CAM; Fresadoras.

INTRODUCTION

Laminate veneers are now widely accepted as one of the most conservative treatments for esthetic problems such as correction of tooth shape or position, closure of diastema, correction of poor incisal embrasures, repair of incisal fractures, repair of enamel alterations (abrasion, attrition, abfraction) and correction of teeth discoloration [1].

Concepts regarding tooth preparation for porcelain laminate veneers have been changed over the last few years. It was found that minimal preparation for the tooth structure could remove the superficial aprismatic enamel that offers low bonding strength with the composite resin [2]. Moreover, care must be taken during preparation to maintain it completely within enamel that offers a higher bond strength compared to dentin [2]. Enamel thickness is assumed to range from 0.4 to 0.7 mm, so the authors recommended 0.5 mm thickness for porcelain laminate veneer [3].

Ceramics is a non-metallic material made from raw minerals heated at high temperatures [4]. Generally, ceramics are brittle materials that have high compressive strength and low tensile strength. They also display low fracture toughness when compared with metals [5].

Ceramic laminate veneers are mostly fabricated from glass-based ceramics as they are best mimic the optical properties of enamel and dentin [6]. Zirconia-reinforced lithium silicate is a new group of glass-ceramic material enriched with highly dispersed zirconia.

The long-term success of any ceramic restorations depends on the marginal fit of the restoration. Marginal gap between the restoration and the tooth exposes the luting cement to the oral environment and leads to plaque accumulation, recurrent caries, gingival inflammation and so a failure of restoration [7,8].

McLean and Von Fraunhofer [9] found a maximum marginal gap of 120 μm to be clinically accepted. Fransson and Kashani [10,11] reported a maximum marginal discrepancy of 100 μm to be ideal for the success and longevity of indirect restorations.

The manufacturer claimed a high edge stability of zirconia-reinforced lithium silicate during milling process and so preserving the delicate structures.

Many studies have been made to evaluate the effect of different CAD/CAM systems on the fit of the produced restorations. Hamza et al. [12] found that 5-axis milling machine can produce restoration with better marginal fit. However, Cho et al. [13] stated that the fit of a CAD-CAM restoration is not affected by the number of milling axes but is influenced by data processing, and production process.

In the present study, the marginal fit of zirconia reinforced-lithium silicate laminate veneers was evaluated at two thicknesses using different CAD/CAM systems. The first null hypothesis was that the marginal fit of fabricated laminate veneers would not be affected by the material thickness. The second null hypothesis was that the CAD/CAM milling machine would not influence the marginal fit of the produced laminate veneers.

MATERIAL AND METHODS

In the current study zirconia-reinforced lithium silicate (Celtra duo, DeguDent GmbH, Dentsply, Germany, 18027977) blocks were used. Two acrylic central incisors of a protype (NISSIN, Japan) were prepared for laminate veneer using depth cutter stones (figure 1) with depth 0.3 mm (Brasseler, USA, 834-31-016) and 0.5 mm (Brasseler, USA, 834-31-021) and then a taper with round end stone was used to refine the preparation. The facial reduction was 0.3 mm for tooth #11 and 0.5 mm for tooth #21 . The preparation for both teeth was not extended to the interproximal contact and with no incisal or palatal extensions (figure 2). Then, twenty-one impressions were made for each central incisor using addition silicone rubber base impression material (Panasil, kettenbach, Germany,185821). A non-shrink epoxy resin (KemaPoxy 150, CMB International, ARE) was used to pour the impressions and fabrication of epoxy dies.

Figure 1 - Depth oriented grooves made by depth cutter stone.

Figure 2 - Preparation for both central incisors was not extended to the interproximal contact and with no incisal or palatal extensions.

The model was scanned using inEos X5 (Sirona, Bensheim, Germany) extraoral scanner (figure 3). The veneers were designed on software inLab 15.0 and the restoration parameters were adjusted, the spacer thickness was set to 60 μm and the minimal thickness is made at 300 μm for tooth #11 (figure 4) and 500 μm for tooth #21 (figure 5). The restoration was created, the slicing tools and cursor details options were used to ensure the veneer thickness. The design was saved as inLab file and then the file was imported to CAM software for milling of the first group (X5) using inLab MCX5 (Sirona, Bensheim, Germany) milling machine. The same file was exported to STL (standard triangulation language) then this STL file was sent to Ceramill mind software for milling of the second group (CM) using Ceramill motion 2 (Amann girrbach, Vorarlberg, Austria) milling machine. The saved inLab file was used to mill the third group (XL) using inLab MCXL (Sirona, Bensheim, Germany).

Figure 3 - Scanning of the model using inEos X5 extraoral scanner.

Figure 4 - Selection of restoration parameters for 0.3 mm thickness veneer. Note the minimal thickness selected to be 300 microns.

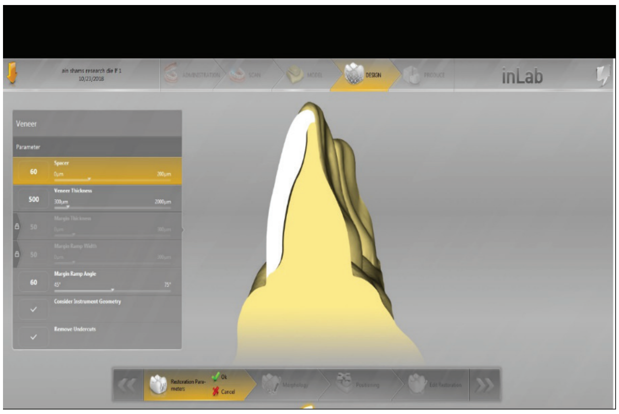

Figure 5 - Selection of restoration parameters for 0.5 mm thickness veneer. Note the minimal thickness selected to be 500 microns.

Each veneer was finished using a tapered round end stone and then polished using polishing system (Celtra twis tec, DeguDent, Germany). The green coded polishing stone, then the yellow coded and finally the grey, were used to reach the maximum surface finish.

The veneers were treated with hydrofluoric acid etch gel (Ceramic etch, Bisco, Illinois, U.S.A, 1700003266) for 20 s and rinsed with air water oil free spray then the ceramic silane primer (Porcelain primer. Bisco, Illinois, U.S.A1700003403) was added for 60 s.

Each sample was cemented to its corresponding die (figure 6). The resin cement (Mojo veneer cement, Pentron, U.S.A, 5628126) was applied to tooth surface of epoxy dies and each veneer was seated on its corresponding epoxy die. A steady pressure was applied then a blast of 2 s light was done and a sharp bard parker blade #11 was used to remove the excess cement. Final curing was done with a LED light cure (output intensity 1200 mw/cm^2, Elipar Deep Cure- S, 3M ESPE) for another 40 s.

For each specimen, four stereomicrographs, one for each surface (incisal stereomicrograph, gingival stereomicrograph, mesial stereomicrograph and distal stereomicrograph), were captured by a digital camera (DP10, Olympus, Japan) mounted on a zoom stereomicroscope (SZ-PT, Olympus, Japan) at magnification 30X. Images were then transferred to computer system for analysis.

Using the image analysis software (ImageJ software, 1.46r, NIH, USA), phase analysis was calculated automatically to measure the gaps between margins of the veneer and the outer end of finish line at five equidistant points in each stereomicrograph (figure 7) (E: epoxy die, G: marginal gap, L: Laminate veneer). Therefore, the measurements were carried out at 20 points for each veneer. The collected data were tabulated using Microsoft Excel (Microsoft office 2016). For each sample, a mean value was calculated in microns and tabulated for statistical analysis.

Figure 6 - Each veneer was cemented to its corresponding die.

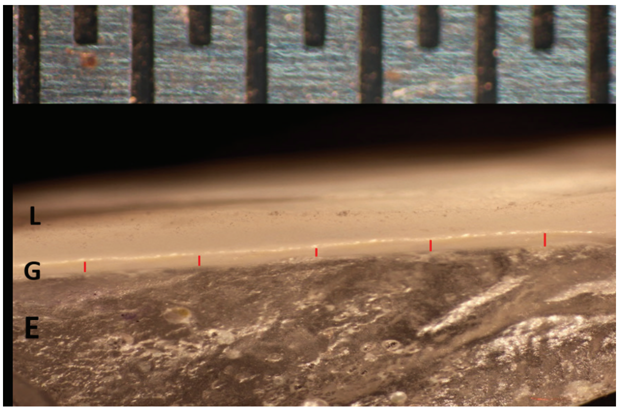

Figure 7 - Stereomicrograph showing the measured gaps between margins of the veneer and the outer end of finish line at five equidistant points. E: epoxy die, G: marginal gap, L: Laminate veneer.

RESULTS

Numerical data were explored for normality by checking the data distribution, calculating the mean and median values and using (Kolmogorov-Smirnov and Shapiro-Wilk tests). Data showed parametric distribution so; it was represented by mean and standard deviation (SD) values. Two-way ANOVA was used to study the effect of different tested variables and their interaction on marginal gap followed by Tukey's post hoc test. Comparisons of main and simple effects were done utilizing bonferroni correction. The significance level was set at P ≤ 0.05 for all tests. Statistical analysis was performed with IBM(IBM Corporation, NY, USA) SPSS(SPSS, Inc., an IBM Company) Statistics Version 25 for Windows.

Two-Way ANOVA of CAD/CAM systems and finish line and their interactions on marginal gap (μm). were presented in table (I).

Table I - Two-Way ANOVA of CAD/CAM systems and finish line and their interactions on marginal gap (μm).

Source	Type III Sum of Squares	df	Mean Square	F	P-value
CAD/CAM system	129.62	2	64.81	9.37	0.001*
Finish line thickness	725.00	1	725.00	104.87	<0.001
System* Finish line	83.72	2	41.86	6.05	0.005*
Error	248.87	36	6.91	248.87	

df=degree of freedom*; significant (p ≤ 0.05) ns; non-significant (p>0.05)

Mean, Standard deviation (SD) for Marginal fit (μm)for different CAD/CAM systems and finish line thicknesses were presented in table (II).

Table II - Mean ± standard deviation (SD) of marginal fit (μm) for different CAD/CAM systems and finish line thicknesses

CAD/CAM system	Finish line thickness (mean ± SD)		P-value
	0.5 mm thickness (I)	0.3 mm thickness (II)	
Inlab MCX5 (X5)	71.24 ± 2.64^{B}	82.15 ± 2.72^{B}	0.014*
Ceramill motion 2 (CM)	75.82 ± 2.74^{A}	85.45 ± 1.82^{A}	<0.001*
Inlab MCXL (XL)	77.97 ± 3.53^{A}	82.35 ± 1.91^{B}	<0.001*
P-value	0.002*	0.019*	

Different superscript letters within the same vertical column indicates a statistically significant difference*; significant (p ≤ 0.05) ns; non-significant (p > 0.05)

Regardless of CAD/CAM system, the thickness of the veneer affects the marginal fit of the restoration. The lowest marginal discrepancy was recorded in subgroups X5I, CMI and XLI with mean marginal gaps 71.24 ± 2.64 μm, 75.82 ± 2.74 μm, 77.97 ± 3.53 μm respectively.

Regarding the effect of CAD/CAM system within each finish line thickness; for samples fabricated with 0.5 mm thickness finish line, the marginal gap for subgroup X5I (mean 71.24 ± 2.64 μm) was lower than the other two subgroups CMI (mean 75.82 ± 2.74 μm) and XLI (mean 77.97 ± 3.53 μm) (figure 8a, 8b, 8c respectively). While for samples fabricated with 0.3 mm thickness finish line, the lowest marginal gaps were achieved in subgroups X5II (mean 82.15 ± 2.72 μm) and XLII (mean 82.35 ± 1.91 μm) (figure 8d, 8e respectively) which achieved significant gap values lower than subgroup CMII (mean 85.45 ± 1.82 μm) (figure 8f).

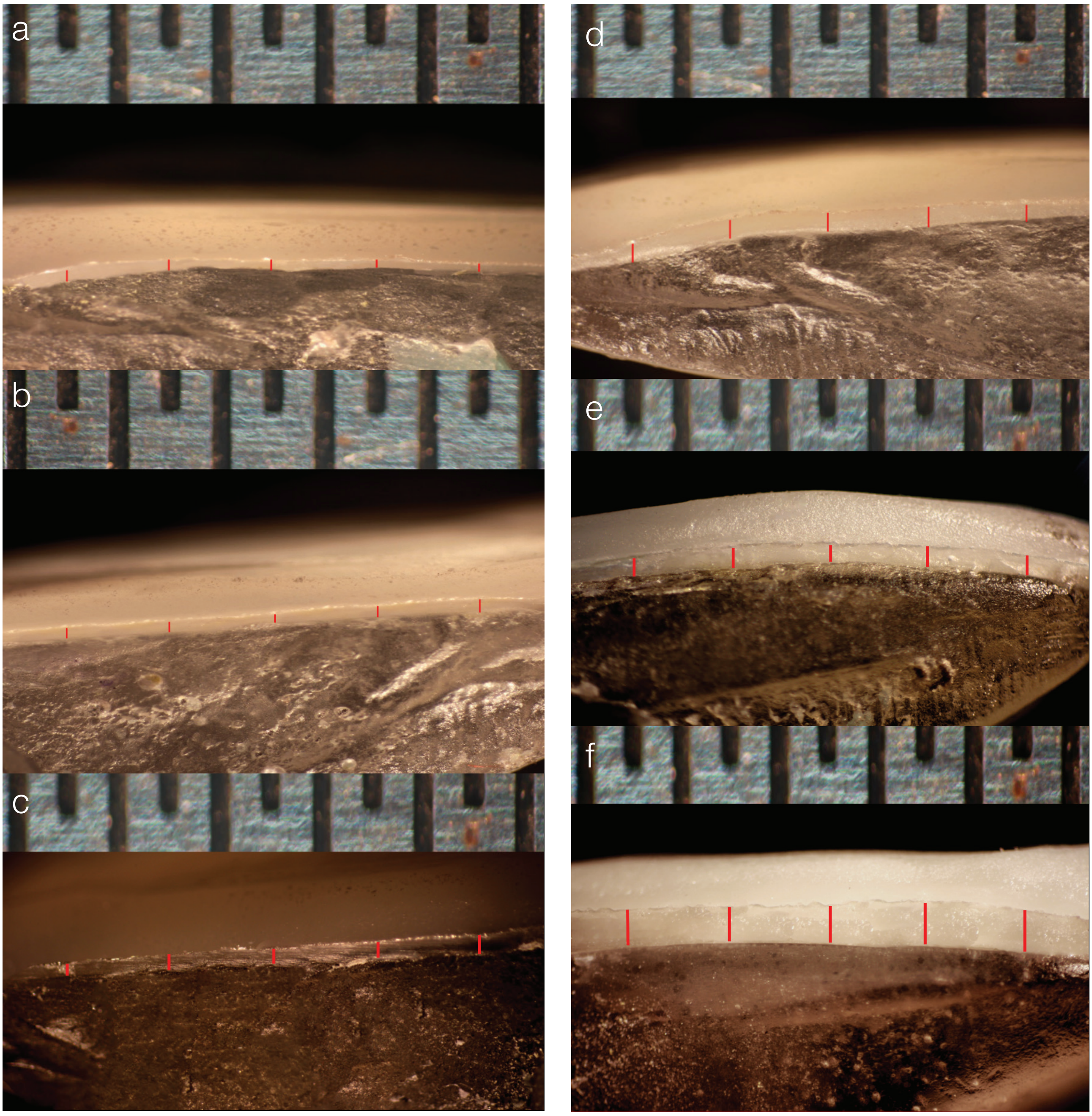

Figure 8 - Stereomicrographs showing the marginal gap of each subgroup: a; X5I subgroup. b; CMI subgroup. c; XLI subgroup. d; X5II subgroup. e; XLII subgroup. f; CMII subgroup.

The Bonferroni post hoc test showed that 0.5 mm thickness veneers in subgroups X5I, CMI and XLI differed significantly from each other and from other tested subgroups ($p < 0.05$). While 0.3 mm thickness veneers in subgroups X5II and XLII differed significantly from subgroup CMII. No significant difference was found between X5II and XLII ($p > 0.05$).

DISCUSSION

Ceramic laminate veneers are now considered one of the most conservative esthetic treatments, especially with the advances of new ceramic materials that can fulfill the required high esthetics, good strength and marginal fit for long term success of dental restorations [1].

Moreover, CAD/CAM technology has become an established fabrication technique for dental restorations, especially all-ceramic restorations [14]. Apart from the constant improvement of digital technologies, new restorative materials that are optimized for CAD/CAM processes were developed for full digital workflows. Among others, a new group of machinable glass-ceramics has recently been introduced called zirconia-reinforced lithium silicate ceramics.

Many factors were reported in the literature to be responsible for the success of all ceramic restorations namely; esthetic appearance of the restoration and how much it looks natural, the restoration resistance to fracture and the good marginal fit between the restoration and the tooth [15].

Therefore, the main-focus of the present study was based on evaluation of the marginal fit for zirconia-reinforced lithium silicate fabricated with two thicknesses using different CAD/CAM milling machines.

Zirconia-reinforced lithium silicate (Celtra duo, Dentsply ,Germany) was selected for the current study as one of newly introduced CAD/CAM ceramic that the manufacturer claimed its high edge strength at fine edges and delicate structure as it contains 10% zirconia submicron grains and hence it can be milled in thin thickness without affecting the restoration marginal fit [16].

Additionally, Azarbal et al. [17] stated that this material has the advantage of eliminating the need for post-milling firing process. It was stated that this firing process may lead to restoration distortion, shrinkage and consequent marginal misfit.

In this research a protype model (NISSIN, Japan) was used instead of the natural teeth which would guarantee standardization through a caries and restoration free teeth which might affect the measurements of the study [18]. Anterior tooth preparation more than 0.5 mm might cause dentine exposure[19,20]. Another previous study showed that the least enamel thickness was found to be in the gingival third of the incisors with approximately 345 μm, so minimal preparation as less as 0.3 mm was advocated for ultra-conservation [21].

Regarding the results of this research, all groups in this study showed a clinically acceptable marginal fit below 100 μm [10,11] The results proved that regardless the type of the milling device used, there was a significant increase in the marginal fit with 0.5 mm thickness laminate veneers in X5I, CMI and XLI subgroups. This finding was consistent with results showed by Yu et al. [22], who concluded that the increased thickness of the ceramic can contribute to reducing the crack initiation within the ceramic and so increasing the marginal fracture resistance during milling. So, the first null hypothesis was rejected.

Regarding the effect of CAD/CAM system within each finish line thickness the second null hypothesis was also rejected, as at 0.5 mm thickness, there was a significant increase in the marginal fit with X5I subgroup than CMI and both showed significant higher results than XLI subgroup. This might be the increased number of the axes for the milling machines used in X5I and CMI subgroups which could mill the restorations in the 3 spatial directions, tension bridge and milling spindle. On the other hand, four-axis milling machine in subgroup XLI mills the restorations in only the 3 spatial directions and tension bridge [23]. The results agreed with those of Hamza et al. [12], who stated that 5-axis milling device can produce restorations with better quality. Although both inLab MCX5 and Ceramill motion 2 are 5-axis milling devices the mean marginal gap value for X5I subgroup was significantly lower than that of CMI subgroup and this might be due to the reliable compatibility between the CAD and CAM software that ensuring accurate data transfer without any kind of data loss. Additionally, the difference in instrument geometry between different systems [24,25]. For any design software, each restoration design data is described in form of triangles to be read by many other software. The size of those triangles is not equal in all software and so when a design is sent to a different software, some data loss occurs. [26].

This also explains why X5II and XLII subgroups should have a significant better marginal fit than CMII group.

A limitation for this study is that the marginal fit of dental restoration might also be affected by thermocycling and occlusal stresses. Further assessment of the marginal discrepancy is recommended after artificial aging.

CONCLUSION

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

1 - All tested zirconia-reinforced lithium silicate thicknesses (0.5 mm and 0.3 mm) and CAD/CAM systems produced laminate veneers restoration within clinically acceptable marginal fit, below 100 μm;

2 - Five-axis milling machines produced restorations with better marginal fit at 0.5 mm thickness;

3 - Closed CAD/CAM systems produced restorations with better marginal fit than open systems at 0.5 mm thickness.

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