Micro-computed tomography measurement of the marginal gap of different types of glass-ceramic veneers fabricated by heat-pressed technique

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Background and Objective: This study was conducted to measure the marginal gap size of two different glass-ceramics fabricated by heat-pressed technique with micro-computed tomography scanning and analysis.
Methods: Twenty sound human maxillary central incisors were prepared in window preparation design for the fabrication of laminate veneers. The samples were divided into two equal groups of Ten for each group. The impression for all the samples of each group was made by a conventional one-step impression technique using Impregum™ Penta medium-bodied polyether impression material. The auto-mixing unit (pentamix) was used to ensure a standardized mixture for all the samples. Laminate veneers were fabricated using a heat-pressed method with two different types of glass-ceramics (IPS Emax press and Empress esthetic, Ivoclar Vivadent). IPS Emax ceramic was used for restorations of the first group, and IPS Empress esthetic was used for restorations of the second group. The finished restorations were cleaned and polished to be prepared for cementation. All of the restorations of each group were separately bonded to the samples of the corresponding groups using a light-cured cement. A dental surveyor with a fixed weight of 200g for standardization was used during the procedure. After the completion of the cementation procedure, the samples were cleaned and polished to be ready for a quantitative micro-computed tomography scanning and analysis for marginal gap size measurement.
Results: The mean(±SD) value of IPS Emax was 0.056(±0.023)mm^3, and the same value for IPS Empress was 0.128(±0.195)mm^3. No statistically significant difference was found between in marginal gap size of both types of the glass-ceramic (p = 0.261).
Conclusion: Within the limitations of this study, both IPS Emax and IPS Empress have comparable marginal accuracy.
keywords: Micro-computed tomography, Marginal gap, Glass-ceramic, Veneer.

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Introduction

Esthetics has become crucial in the personal improvement of the 21st-century generation. New advances in dentistry, increased the willingness of people to lean towards dentistry to improve their smile esthetically.[1] It combines beauty and function according to the individuals' needs and desires, and not only deal with the smile rehabilitation but correction of the jaw and profile.[2] The esthetic rehabilitation and restoration of six anterior teeth are considered as one of the most problematic and challenging procedures of creating a new smile in restorative dentistry, the most popular treatment option in this context is porcelain veneers.[3,4] Utilization of adhesive systems enabled to establish a conservative treatment of porcelain veneer with preservation of the maximum sound tooth structure to provide patient's satisfaction and esthetic needs.[5] The porcelain veneer is indicated to use as a treatment for esthetic problems showing modifications of tooth morphology, color, size, shape, volume, contour, and position.

Improvements of adhesive systems in bonding ability to both enamel and dentin tooth structures allowed for more conservative techniques to restore the unaesthetic appearance of anterior teeth. Ceramic laminate veneer has proven to be a durable and esthetic treatment option for anterior teeth.[6] it is recommended as a permanent restoration with higher esthetics. Though, due to countless variations in clinical cases of ceramic veneers, not all the types of ceramic perform as desired. Therefore, proper selection of the correct ceramic material is fundamental for clinical success.[7] There are many different types of ceramics systems in terms of composition and fabrication techniques. Most ceramic veneers are made up of lithium disilicate ceramic. Lithium disilicate is a glass-ceramic with a high flexural strength up to 440 MPa. IPS E.max lithium disilicate, introduced in 2005 by Ivoclar Vivadent (AG, Schaan, Liechtenstein).[8] The longevity of the ceramic veneer is related to several significant factors like the internal and marginal adaptation of the ceramic veneer to the tooth structure.[9] Closely adapted margins of the ceramic veneer to the tooth structure prevents the degradation of the adhesive material due to its exposure to the oral fluids, the lesser possibility of microleakage, and formation of secondary caries.[10] An accurate accepted measure for marginal fitness does not exist yet. Still, some studies suggest that a marginal fit 120 µm is clinically acceptable,[11] but others have concluded that a marginal fit 100 µm is more suitable.[12,13] A marginal fit of between 25 and 40 µm for cemented restorations has been suggested as a clinical goal, but these levels are rarely achieved.[14]

There are a variety of techniques used to measure the internal and marginal adaptation and fitness of the restoration to the tooth structure such as direct measurement, profilometry, sectioning method, silicon replica technique, stereo microscopy, and micro-computed tomography (micro CT).[15] micro-computed tomography is a non-destructive method of studying marginal adaptation.[16] This 3-dimensional, high- resolution imaging system provides detailed cross-sectional information concerning the crown-to-die fit without damaging the specimen.[17]

In the last decades, the glass-ceramic veneers became popular among the dentists; the accuracy of the materials used in fabrication is one of the most critical factors for an ideal long-lasting restoration. This research was conducted due to the lack of studies comparing the accuracy of the different ceramic types of veneers at the margins.

Methods

More than 20 sound human maxillary central incisors extracted for orthodontic treatment in patients age ranged (15-25) years that are free from caries, restorations, hypoplastic defects, and cracks, with comparable mesio-distal and occluso-gingival dimensions were used for this study plan. All of the samples were individually mounted in a plastic dental arch during preparation. The long axis of the teeth was parallel in the socket area and was embedded up to (2mm) apical to the cemento-enamel junction to simulate the natural biological width. A layer of wax were added at the mesial and distal sides of all the specimens in the arch for fixation of the teeth during preparation. Before tooth preparation, a silicone index was reconstructed over each of the specimens using a polyvinyl siloxane impression material as a guide for preparation to ensure even tooth reduction.[18] The design of the preparation was window preparation with the diameters of (5x5 mm, 0.5 mm depth). The preparation was on the center of the labial surface of all the specimens to ensure a standardized enamel thickness preparation on all of the specimens. It started by using a high-speed handpiece with a water coolant by using a three-tiered diamond bur of 0.5 mm; the high-speed handpiece was attached to a dental surveyor to ensure a standardized preparation, as shown in (Figure 1). Facial surfaces of the teeth were initially prepared by placing a depth-orientation groove (0.5 mm in depth) with a self-limiting depth-cutting bur with continuous irrigation.[19] Then the preparation was continued without exceeding the depth-orientation groove by using round end tapered diamond bur to reduce the remaining labial tooth structure between the depth cut to provide a flat enamel surface area. The final preparation margin was (5mm length × 5 mm width, 0.5 mm depth) in dimension with a chamfer finish line,[20] since this type of finishing line design provide superior marginal seal compared to shoulder finishing line design.[21]

The impression of all the specimens was taken conventionally using (Impregum Penta Soft Medium Body- 3M ESPE) impression material. One-step impression technique was performed for all the specimens following the manufacturer's instructions using an auto-mixing unit (pentamix). To standardize the seating load for each impression, a 5 kg weight was placed over the trays during material polymerization.[(22)] The impression materials were allowed to polymerize and then removed from the dental arch.

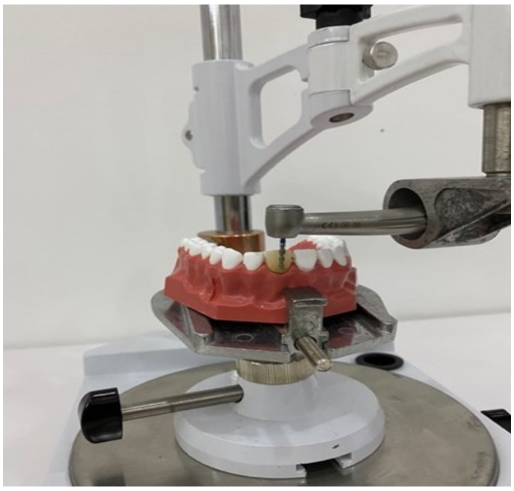

Figure. 1. A tooth sample fixed on the plastic dental arch attached to the dental surveyor.

In the dental laboratory, the model casts were scanned by an extra-oral digital scanner (DOF full HD) to import the 3D image of the model casts into the computer-aided/ design machine (CAD). The design of the restorations was done for each of the specimens in the CAD machine. The film thickness of each of the restorations was 0.45µm; the thickness was 0.5mm. The wax blocks were used to mill the wax-up model of the restorations. The milling started in the computer-aided manufacturing (CAM) machine (DWX.52DC, DG SHAPE) using a milling software (Vpanel for DXW) for up to 25 minutes for each unit with diamond cutting diamond instrument (bur 2.5 mm, 1.25 mm, 0.6 mm). After finishing the milling process, the wax models were removed individually from the blocks.Two different types of pressable glass-ceramic (IPS E.max press, lithium disilicate glass-ceramic) and (IPS Empress, leucite glass-ceramic) ingots were used for all the wax models of both groups, and the restorations were fabricated using the heat-pressed technique. Ceramic ingots were placed into the pre-heated investment ring, and placed into the pressing oven (programmat EP 5010) for (15-20) minutes starting from 700°c up to 825°c for pressing of the ceramic into the investment material and crystallization of the ceramic occurred. The finished restorations of each group were carefully removed from the investment material and cleaned and glazed separately and were ready for cementation.

A light-cured cement (RelyX™ veneer, 3M ESPE) was used for cementation of the restorations on the samples. The dental surveyor was used during the cementation procedure. The dental plastic arch was fixed on the surveyor, and a static load of (200) gm was applied by using the straight surveyor rod that attached at the surveyor's arm as standardization for fixed pressure during cementation. The cementation procedure was completed for all of the samples according to the manufacturer's guidelines, and any excess cement left on the surface of the samples were cleaned and polished prior to scanning.

All of the samples were scanned by a quantitative micro-computed tomography scanner for marginal gap analysis (Bruker, SKYSCAN 1272). Tagged image file format (TIFF) was generated by using the following scanning parameters, which were:

* Accelerating voltage of 80 kV
* Current of 125 µA
* Exposure time of 2200 ms per frame
* Al + Cu filter
* Rotation step at 0.44 degree (360-degree rotation).

During the scanning procedure, all teeth were affixed in a specimen holder within the device without moving during scanning. Then the x-ray beam was irradiated perpendicular to the long axis of the tooth, and it was scanned on a vertical rotating axis by a stationary X-ray source (Fig. 2).

The image pixel size and slice width were both (9) microns, and the scanning time was approximately 1 hour. The X-ray projections were reconstructed using Sky-

Scan's volumetric reconstruction software (NRecon). Reconstructed slices were saved as a stack of BMP-type. SkyScan software Micro-CT (version 1.1.19) was used to obtain cross-sectional slices. The reconstructed images were transferred to CT analyzer software (version 1.18.4.0) to delimit and measure the volume of the marginal space between the prepared tooth and the restoration.

Volumetric quantitative analysis was done for all of the slices inside the ROI (region of interest) at all four margins (incisal, cervical, mesial, and distal) of each specimen to measure the total volume of the gap between the tooth and the restoration. The results of the measurements were statistically analyzed with independent samples t-tests to analyze if there is a significant difference between and within the groups. All the results were included.

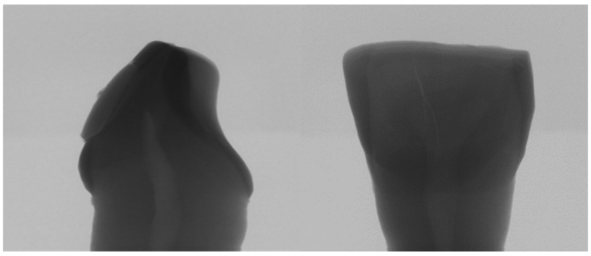

Figure 2. Reconstructed x-ray images in frontal and lateral view

Results

A total of 20 samples (Two groups, ten samples per group) were scanned by a micro-CT scanner, and the total marginal gap in all of the slices inside ROI was measured using CT analyzer software (version 1.18.4.0). The overview of the total marginal gap volume, along with t-tests results, was summarized in (Table 1 and 2).

The mean gap volume of both lithium disilicate glass-ceramic (IPS Emax, Ivoclar Vivadent) was 0.056 mm^3, and leucite-reinforced glass-ceramic (IPS Empress Esthetic, Ivoclar Vivadent) was 0.128 mm^3 (Table 1). The independent samples t-tests did not find evidence of a significant difference between the groups (p = 0.261). The mean±SD gap measurements were greater in leucite-reinforced (IPS Empress esthetics, Ivoclar Vivadent) compared to the lithium disilicate glass-ceramic (IPS Emax press, Ivoclar Vivadent) about 0.072 mm^3 of difference (Table 2). However, this difference did not reach the significance level (p > 0.05). A bar chart of both ceramic types shows no significant difference in marginal gap size, as shown in (Figure 3).

Table 1. The total marginal gap volume (mm^3) overview (mean, standard deviation (SD), Min. and Max.

Group Statistics					
		N	Mean	Std. Deviation	Std. Error Mean
Gap Analysis	Emax	10	.056325029000	.0239647252945	.0075783115431
	Empress	10	.128530444000	.1950982297651	.0616954773524

Table 2. Independent samples *t*-test results of difference between groups

Independent Samples Test								
		Levene's Test for Equality of Variances		t-test for Equality of Means				
		F	Sig.	t	df	Sig. (2-tailed)	Mean Differ-ence	Std. Error Difference
Gap Analy-sis	Equal vari-ances as-sumed	11.662	.003	-1.162	18	.261	-.0722054150000	.0621591725459
	Equal vari-ances not assumed			-1.162	9.272	.274	-.0722054150000	.0621591725459

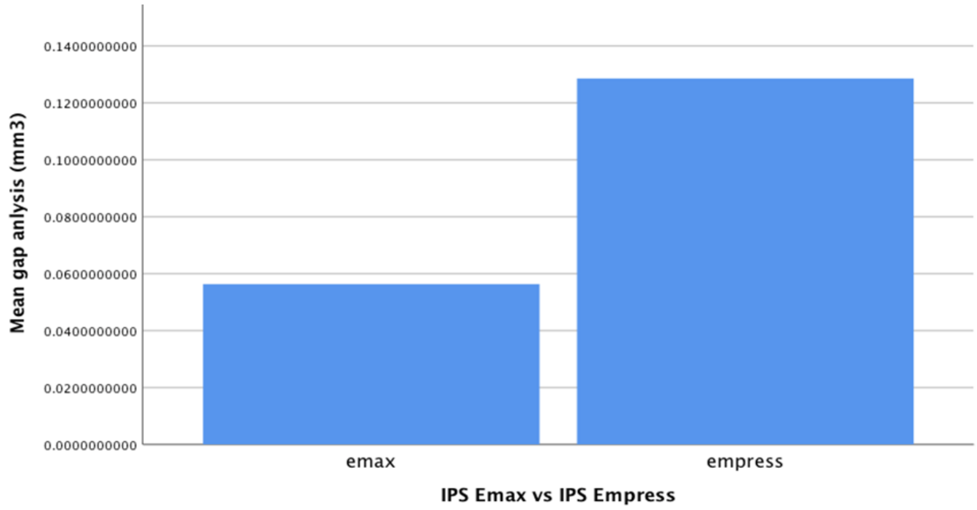

Figure 3. Bar charts of gap volume analyzed by the type of the ceramic used

Discussion

In this study, marginal gap volumes between two different glass-ceramic materials (IPS Emax press and IPS Empress esthetic, Ivoclar Vivadent) used for the fabrication of laminate veneers through conventional one-step impression technique were measured and statistically analyzed with independent samples t-test. The purpose of this study was to compare the accuracy of different glass-ceramic materials fabricated with heat -pressed technique through the measurement of the marginal gap size of the samples for each group. The ceramic systems used in this study were lithium disilicate glass-ceramic and leucite-reinforced glass-ceramic systems. Within the limitations of this study, the results supported the null hypothesis that there is no statistically significant difference in the marginal gap size between the two groups. Though, lithium disilicate (IPS Emax press) ceramic showed smaller marginal gap size than leucite-reinforced (IPS Empress esthetic) ceramic. Besides the ceramic type, There are other variables that affect the marginal gap value of the final restoration, such as fabrication technique, the preparation site, impression technique, and design of the preparation.[23]

There are numerous studies in the literature that have used different methods to evaluate and measure marginal accuracy, which resul

-ted in different variations in marginal gap values for different ceramic restoration materials. Micro-CT scanning for evaluation and 3-dimensional (3D) analysis in the marginal region of ceramic restorations is a new technology and a non-destructive method compared to other conventional techniques that require sectioning of the samples. This technology allows for a precise 3D, both linear and volumetric measurements in all the gaps between the restoration and tooth interface.[(24)] Majority of the gap analysis and marginal fitness studies in the literature regardless of the measurement method have done linear measurements of the gap (space) located in restoration/tooth interface, and calculated only the gap width.[25–28]

In this study, the marginal gap space reconstructed and measured in 3D using Skyscanner reconstruction software of micro-CT, and the total gap volume in (mm^3) was calculated for each sample, which is the most distinctive aspect of this study compared to the previous studies mentioned above. Therefore, a comparison of the results of this study with previous studies that have been done before with similar topics is challenging due to the difference in measurement techniques of the marginal gap size. Nevertheless, the results of the present study shows that total marginal gap value of the lithium disilicate glass-ceramic (IPS Emax press) is lower than that of leucite-reinforced glass-ceramic (IPS Empress esthetic), which is comparable to a similar study done by Gold et al.[29] The study compared marginal gap value of lithium disilicate and leucite-reinforced glass-ceramic crowns. According to the results mean marginal gap of the leucite-reinforced crowns was 49.2 μm, and lithium disilicate crowns before crystallization were 42.9 μm and after crystallization increased to 57.2 μm, which indicates that crystallization firing procedure of the CAD/CAM milled glass-ceramics increases the marginal gap size. This increase in the gap value was described in the literature as the result of shrinkage and densification due to the firing stage of the glass-ceramic, causing an increase in the marginal gap size.[30] The factor of smaller marginal gap size of lithium disilicate compared to leucite-reinforced glass-ceramic veneers of the current study could be the difference in the chemical composition of both materials. However, this difference is statistically non-significant. The laboratory procedures used in the fabrication of ceramic restorations could affect the final marginal accuracy of the restorations. A study done by Neves et al.[31] compared the marginal fitness of lithium disilicate glass-ceramic crown fabricated with two different methods (heat-pressed and CAD/CAM milled) that have a significant difference in marginal fit values. Results showed that the mean marginal misfit of crowns milled using two different CAD/CAM machines was 39.2, 66.9 μm, and for the crowns fabricated by heat-pressed technique was 36.8 μm. Another study by Oz and Bolay et al.,[28] compared the marginal gap of inlay restorations fabricated by different ceramic materials with both CAD/CAM and heat-pressed techniques. Results showed a significant difference mean marginal gap value of leucite-reinforced ceramic inlays fabricated by CAD/CAM milling machine and heat pressed techniques. The marginal gap value of IPS Empress CAD was 32.71 μm mesially, and 31.94 μm distally, and marginal gap value of IPS Empress esthetic was 88.64 μm mesially and 86.80 μm distally. Overall, the results of the present study demonstrated that lithium disilicate glass-ceramic system veneers were more accurate in the marginal area than a leucite-reinforced glass-ceramic system. Yet this difference is statistically non-significant, which is supported by the studies mentioned above. The dental practitioners should be aware of the effect of the difference in the composition of the glass-ceramic systems on the marginal gap size and take this into consideration during dental treatment with laminate veneers.

Conclusion

Under the limitations of this study, we conclude that different types of glass-ceramic systems fabricated by heat-pressed technique did not have a statistically significant difference in marginal gap value. Also, the micro-computed tomography scanning was a precise method for 3D visualizing and measurement of the gap size at margins.

Conflicts of interest:

The authors report no conflicts of interest.

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