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Abstract

Purpose: To assess the marginal accuracy and fracture resistance of occlusal veneers constructed from four different pressable ceramics. **Materials and methods:** Typodont lower second molar tooth was chosen and prepared using CNC. The tooth was duplicated to produce 40 epoxy-resin dies and divided into four groups according to pressable ceramic, group 1: LiSi, group 2: Celtra, group 3: Ambria, group 4: e.max. The marginal accuracy of each sample was evaluated by measuring the marginal gap using a digital microscope, all veneers bonding to their corresponding epoxy-resin dies, and exposure to the ROBOTA chewing simulator. After that, the marginal accuracy was evaluated again after cementation and thermo-mechanical aging. The fracture resistance was measured by a universal testing machine. Data was performed using ANOVA and then Tukey's *post-hoc* test ($P < 0.05$). **Results:** The four ceramic materials showed an acceptable marginal accuracy value. Regardless of measurement stage, the highest marginal gap was recorded by LiSi then e.max and Ambria groups the lowest marginal gap was recorded by Celtra group. There were statistically significant differences among groups. Regarding fracture resistance, it was found that the highest value was recorded with e.max then Celtra and Ambria groups, the lowest value was recorded by LiSi group and this difference was statistically significant. **Conclusions:** Different pressable ceramics used for the construction of occlusal veneer significantly affect their marginal accuracy. However, the occlusal veneers constructed from e.max, LiSi, Ambria, and Celtra provide clinically acceptable marginal discrepancy but the marginal discrepancy after thermo-mechanical fatigue recorded a statistical increase significantly. Different pressable ceramic materials have an effect on the fracture resistance of occlusal veneers.

Keywords: Marginal gap, Fracture resistance, Occlusal veneers, Pressable ceramic

1. Introduction

Minimal intervention dentistry may be utilized for the provision of successful and more durable treatment modalities for cases presented by occlusal contact problems. Occlusal veneers are extra-coronal conservative restorations that require minimal tooth reduction suitable to interocclusal space and anatomical variances. The occlusal veneer restorations that re-enamel the occlusal surfaces are considered a substitute to the conventional onlays and full coverage restorations for posterior teeth within thickness as in cases of severe erosion [1,2].

Provision of the best equilibrium between esthetic, functional, as well as biological fundamentals while restoring eroded teeth can be successfully fulfilled by an esthetic conservative alternative such as the ceramic occlusal veneers which offer a minimal amount of reduction for the offending teeth. Occlusal veneer restoration is formed of thin overlay coverage with a non-retentive form [3].

Various types of ceramic materials can be utilized for the fabrication of occlusal veneers. Remarkably, the ultimate mechanical features for an occlusal veneer restoration are gained by lithium disilicate ceramics; owing to its unique microstructure which comprises interwoven needle-like crystals encased

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in a glassy matrix as well as the incorporation of 10% Zirconia which further improves the mechanical properties such as flexure strength, and interestingly gives better esthetics [4–7].

Marginal integrity and accuracy are among the most important factors that contribute to the durability and clinical efficiency of dental restoration. Minimal marginal discrepancies could subject the cement line to oral environmental fluids, while more advent marginal gap contributes to increased plaque deposition, leading to the dissolution of cement and marginal leakage with subsequent development of ingress of caries-causing bacteria, recurrent caries, pulpitis, and deterioration of periodontal health [8].

The resistance to fracture is an essential determinant that indicates to what extent the dental restoration can respond to intensive loads of the oral environment [9]. There was limited published data on the influence of various pressable ceramic materials on the resistance to fracture and marginal accuracy of this type of restoration, following the simulation of clinical oral conditions through a thermo-mechanical fatigue procedure. Therefore, the current study aimed to assess the marginal accuracy as well as fracture resistance of occlusal veneers which were fabricated from several pressable ceramics.

This study hypothesized that different pressable ceramics do not influence the marginal accuracy and fracture resistance of occlusal veneer restorations.

2. Patients and methods

2.1. Sample size calculation

To calculate the influence of various pressable ceramics on resistance to fracture and extent of precision at the margins of occlusal veneers constructed, sample size was calculated. It was found that a total sample size of 40 (N = 40), 10 samples for each group (n = 10) were needed to achieve a power of 90% [10,11].

2.2. Tooth selection and preparation

A typodont lower second molar tooth was selected and used in this study. Ethical approval for the use of artificial tooth was obtained by the guidelines of the Research Ethics Committee of the Faculty of Dental Medicine for Girls, Al Azhar University, code (REC-CR-23-06).

The tooth was embedded in a plastic container (2 cm high and 1.5 cm wide) filled with epoxy resin (East Coast, USA) to produce a resin block. The inner wall of the cylinder was painted with a separating medium. The tooth was aligned to be parallel to the walls of the plastic cylinder by using a milling surveyor (Bego Paraskop M, Germany). Epoxy resin was mixed according to the manufacturer's instructions, then poured into the plastic container.

The tooth received a minimally invasive preparation for occlusal veneer restoration using CNC (Centroid CNC, milling machine, USA) according to the following guidelines.

2.2.1. Guidelines of minimally invasive occlusal veneer preparation with deep chamfer

The occlusal surface received a 1 mm uniform, anatomical reduction using a tapered round stone of short-shank design (855D314016, Komet, Germany), applied vertically to the occlusal surface, while a guide-grooves with a 1 mm depth were prepared. Occlu-Shaper stone (370 Komet-medium grit) was utilized to remove the tooth structure intervening between the grooves [10,12].

Anatomical finishing stones (8370 Komet) were utilized to complete the preparation. A special tapered bur with a non-cutting guidance pin tip design (6856 P314018 Komet) and a fine-grit finishing bur were utilized for final finishing. Polishing of the resultant preparation was performed via rubber points (9608314030 Komet) [13,14].

The tooth was prepared with a deep chamfer finishing line (1 ± 0.1 mm) by a tapered round stone of short-shank design (855D314016, Komet, Germany). The finishing line was located 5 mm occlusal to the CEJ, while the proximal reduction 1 mm circumferential deep chamfer finish line and 1 mm ferrule with an angle of 6-degree axial walls tapering [9,10,14]. Confirmation of the finish-line diameter was donebefore duplication through digital calibration of the exocad designing software (exocad, GmbH, Germany).

2.3. Production of epoxy resin dies

Molds made up of additional silicon (Replisil 22 N. Germany) for the aim of duplication were made and then the typodont was duplicated using epoxy resin (Kemapoxy 150, ARE) to produce 40 epoxy resin dies (N = 40).

2.4. Experimental design

The forty epoxy dies were randomly allocated into four groups (n = 10) based on type of pressable ceramic utilized for the fabrication of occlusal veneers, as follows; group 1: LiSi Press, group 2: Celtra Press, group 3: VITA Ambria, and group 4: IPS e.max Press.

2.5. Fabrication of occlusal veneers

2.5.1. Fabrication of CAD/CAM veneer wax patterns

Each die was sprayed with scanning liquid (Scan–Lac, Protechno, Spain), and then optically scanned using a smart optics scanner (Scan Box Pro, Germany). The pattern of each occlusal veneer was designed using exocad software (exocad, GmbH, Germany) to produce standardized forty occlusal veneer patterns (N = 40) [14]. Then the design was sent to computed aided design/computer aided manufacturing (CAD/CAM) milling machine (Roland_Dwx-510_Japan) for milling of the wax disc (Yamahachi Wax Diskα, Japan) to produce 40 wax patterns.

2.5.2. Fabrication of ceramic veneers using heat-pressing technique

All patterns were sprued, invested, and burnt then the ceramic ingots were heat-pressed in an EP600 press furnace (Ivoclar, Schaan, Liechtenstein, Germany) according to the manufacturers' instructions. After that, the pressed veneers were retrieved from the investment rings, finished, and polished in accordance with the instructions of the manufacturer.

2.5.3. Checking the constructed veneers

All veneers were inspected and checked over their corresponding dies for marginal accuracy and proper seating by using a digital video microscope (EASY view 3D) (Renfert, Germany), and any defective restoration was discarded.

2.6. Measuring the marginal accuracy before cementation

The marginal accuracy of all samples was evaluated by measuring the marginal gap distances via a computerized, digital camera-connected microscope (U500×, Guangdong, China) using a fixed magnification of 40×.

Each veneer was photographed at predetermined points on buccal, lingual, mesial, and distal surfaces. Numerical computerized image analysis software (Image J 1.43U, USA) was utilized for measurement and evaluation of gap dimension. Each site was measured three times and a mean value was calculated, the data was collected, tabulated, and statistically analyzed.

2.7. Cementation of occlusal veneers

The occlusal veneers were then luted to their corresponding dies using a dual-cure adhesive resin cement (Nova resin, Imicryl, Turkey), according to the following steps.

Step 1: The fitting surface of veneers was etched using 9% hydrofluoric acid gel (Porcelain etchant, BISCO, USA) for 10 s then washed and air-dried. Step 2: A layer of silane coupling agent (Porcelain primer, BISCO, USA) was applied using a micro brush and left for 60 s. Step 3: The resin cement was manipulated, loaded in the fitting surfaces of the veneers, and light-cured (Woodpecker light cure I led, China). The cementation procedure was carried out in a specially designed cementation device, under 5 kg of static load. Excess cement was removed after 2 s of initial light curing by a sharp scalar. The resin cement was left to set chemically for about 2 min after that final light curing was carried out for 40 s for each surface [15].

2.8. Thermomechanical fatigue

Aging was carried out through the utilization of ROBOTA (a programmed logic controller device that comprises four multi-mode stations for chewing simulation). ROBOTA is equipped with a thermocycling convention, driven by a servomotor (Model ACH-09075DC-T, AD-TECH TECHNOLOGY CO., LTD., GERMANY). Chewing was undertaken with 49 N force. The procedure was carried out repeatedly in 37 500 cycles in attempt to resemble 3 months of oral chewing [15].

2.9. Testing procedures

2.9.1. Measuring the marginal accuracy

Marginal gap distances (Fig. 1), were measured after cementation and thermo-mechanical aging at the same pre-determined points on each surface. A numerical computerized image analysis software (Image J 1.43U, USA) was used to measure the gap width using the same procedure used for gap determination before cementation.

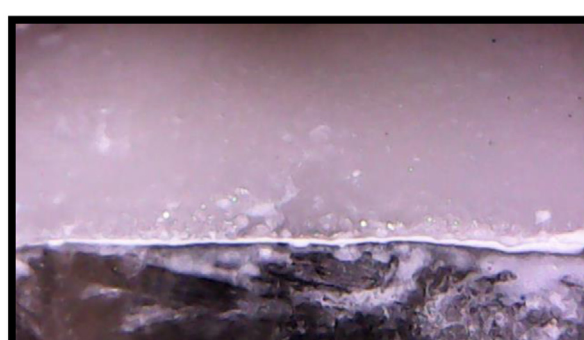

Fig. 1. Marginal gap distances.

2.9.2. *Measuring the fracture resistance*

The resistance to fracture was measured through the utilization of Instron Blue-hill Lite package. A computerized material testing device (version 3345; Instron, Norwood, USA) (Fig. 2) which was integrated with a 5 KN loadcell, was employed to measure the fracture resistance for each sample separately. Failure was demonstrated by an acoustic signal and proved by an abrupt decline of the load-deflection graph in the Instron Blue-hill software. Measurement data (the value of the load at the point of fracture) was recorded in Newton [3].

2.10. *Statistical analysis*

Data were tabulated and displayed in the form of means and standard deviations (m±SD). Normality tests were performed and data were found parametric (showed normal distribution). Thus, one-way analysis of variance test was undertaken with subsequent application of Tukey's *post-hoc* test upon significance. The study power was set at 80% and 95% confidence level ($P < 0.05$). Data analysis was done by the utilization of Graph Pad Instant package for windows (Graph Pad Incorporation).

3. Results

3.1. *Statistical analysis of marginal accuracy*

The four pressable ceramic materials showed acceptable values ranging between 33.27 and 103.95 μm, (Table 1). Regardless of measurement stage, the highest marginal discrepancy was recorded with LiSi group (103.95 ± 8.41 μm), followed by e.max group (79.42 ± 17.1 μm), followed by the Vita Ambria group (70.68 ± 9.58 μm), while the lowest marginal discrepancy was recorded by Celtra group (51.89 C ± 11.9 μm). There was a statistically significant difference among groups.

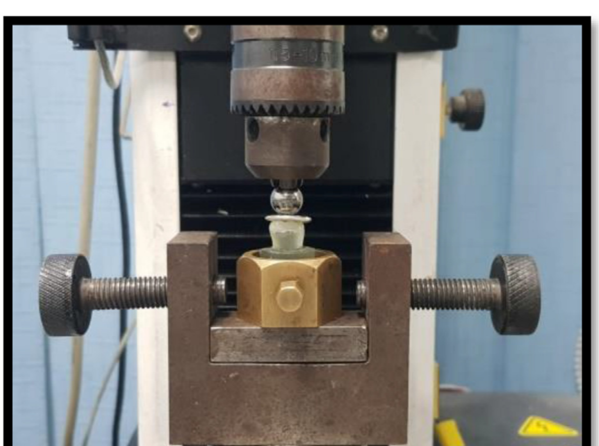

Fig. 2. Universal testing machine.

Table 1. Comparison between marginal gaps before and after procedures in each group.

Variable	Aging		Statistics
	Before	After	*t*-test
	Mean ± SD	Mean ± D	*P* value
Material type			
LiSi group	33.92 ± 5.59	103.95 ± 8.41	<0.0001*
V Amb group	38.21 ± 1.96	70.68 ± 9.58	<0.0001*
Celtra group	37.26 ± 2.96	51.89 ± 11.9	0.0285*
e.max group	33.27 ± 4.82	79.42 ± 17.1	0.0004*
Statistics			
P value	0.1934 ns	<0.0001*	

Different letters indicate a significant difference between groups.
*Significant ($P < 0.05$).
ns, nonsignificant ($P > 0.05$).

Before cementation, the difference in marginal gaps between groups was statistically insignificant (0.1934) while after procedures (i.e., cementation and thermo-mechanical aging), the difference was statistically significant (0.0001). The marginal accuracy after thermo-mechanical aging recorded a statistically significant increase in all groups, as shown in Table 1.

3.2. *Statistical analysis of fracture resistance*

It was found that e.max group recorded the statistically significant highest fracture resistance mean value (786.81 N) followed by the Celtra group (691.324 N) and then the V Ambria group (584.866 N) meanwhile the lowest mean value recorded with the LiSi group (575.918 N) as proven by analysis of variance test ($P < 0.05$). Pairwise Tukey's *post-hoc* test showed a non-significant difference between LiSi and V Ambria groups, ($P > 0.05$), as shown in Table 2.

4. Discussion

The minimally invasive approach in the management of attrition or erosion-affected teeth offers the

Table 2. Comparison between the different groups regarding fracture loads (N).

Variables	Mean ± SD	Statistics
		P value
Material type		
LiSi group	575.918^{C} ± 73.02	
V Amb group	584.866^{C} ± 86.76	0.0038*
Celtra group	691.324^{B} ± 25.13	
e.max group	786.81^{A} ± 67.53	

Different letters indicate a significant difference between groups.
*Significant ($P < 0.05$) ns; non-significant ($P > 0.05$).

least amount of reduction of teeth that were already compromised by occlusal defects; to preserve much amount of tooth tissue essential for the provision of biocompatible, and durable final occlusal veneer restoration.

In this research, the marginal accuracy and fracture resistance of minimally invasive preparation with deep chamfer finish line design of occlusal veneer fabricated from four kinds of pressable dental ceramic materials had been investigated.

Two frequently measured an *in vitro* criterion that reveals the adequate efficiency and durability of dental prosthetic restoration are the marginal fit and fracture resistance. Accurate marginal fit can protect the cement region from being exposed to oral environmental factors and subsequent failure due to secondary caries [16].

Marginal fit of the restoration can be assessed by measuring the gap distance between the margin of the restoration and finish line of the prepared tooth [17]. The optimal approach for measuring marginal gaps is still debatable. Several strategies have been reported in the research, it can be as direct detection using mirrors and probes, replica technique, light, and scanning electron microscopy, and micro-computed tomographic evaluation [18,19].

The most popular technique is the sectioning of restorations and measurement of discrepancies with a light or a Scanning Electron Microscope. While the most recent detecting and analyzing approach is micro-computed tomography (micro-CT) that provides a nondestructive evaluation of prostheses and it is applicable for use nowadays [20].

Fracture resistance assessment was done using the universal testing machine [13,21] with the same indenter at a crosshead speed of 0.5 mm/min subjecting the specimen of the tested material to compressive load until fracture.

For occlusal veneer preparation, the minimally invasive design with a deep chamfer finish line was used in the present study as it yielded better results and obtained satisfactory performance than other types of finish lines [12].

In this study, dies were used to achieve standardization because it was difficult to find forty natural molars with the same anatomy, form, size, and storage period after extractions, they also might have invisible cracks that may weaken the tooth and affect the results. Epoxy resin was used as it has the same modulus of elasticity as natural teeth [22].

Four different types of pressable glass ceramics were selected for fabrication of occlusal veneers because of their well-documented bonding potentiality, good strength properties, and finally being etchable; to provide a successful strong durable bonded prosthetic restoration. Furthermore, glass-ceramics have exceptional esthetic features as well as their ability to protect the opposing teeth from further wear due to their comparable hardness to that of enamel. Moreover, a better marginal adaptation of pressable glass ceramic restorations, and superior mechanical durability via preventing propagation of cracks if compared with milled ones [3].

The results of the present study revealed that regardless of measurement stage, the statistically highest marginal gap (i.e., the least adaptation group) was recorded with LiSi, followed by e.max and Vita Ambria groups, while the lowest marginal gap (i.e., the best adaptation) was recorded by Celtra group, (Table 1). Therefore, the first part of the hypothesis that the different pressable ceramics do not influence marginal accuracy of occlusal veneer, was rejected.

In this study, the least marginal gap measurements (the best marginal adaptation) were recorded by Celtra Press group (51.89), about the study of the Influence of fabrication techniques on vertical marginal gap distance and internal adaptation of zirconia-reinforced lithium silicate all-ceramic crowns [23]. Who studied the vertical marginal distance as well as interior adaptation of heat-pressed and CAD-CAM zirconia reinforced lithium disilicate all ceramic full coverage restorations. One of the newly introduced promising types of lithium ceramics is the lithium disilicate Celtra Duo and Celtra Press that has the same constituents in addition to 7.6% germanium dioxide that enhances many features of the final restoration such as thermal expansion, refractive indices, density, castability, and superior mechanical properties. As specified by the manufacturer, these materials have strength values ranging from 370 to 420 MPa. A more homogenous, fine crystalline structure (0.5−0.7 μm average crystal size) of lithium disilicate ceramics has been developed by the addition of 10% zirconia to that type of ceramics, in comparison to the ordinary lithium disilicate which contains 1.5 μm needle like crystalline structures. It was named ZLS or zirconia-reinforced lithium disilicate. This unique micro-crystalline feature gives high flexural strength. Besides, it comprises a sufficient amount of glass matrix that allows for adequate polishing and esthetic characteristics [23].

On the other hand, the results of the present study were not in agreement with Emam *et al.* [10]. A study that proved that there were no statistically significant differences in vertical marginal gap distance measurements amongst the three different materials utilized in conjunction with minimally invasive reduction designs before and following cyclic loading.

A statistically significant rise in marginal gap distances of all groups, following thermo-mechanical aging, was revealed by the current study. This finding agreed with the study of the Influence of conventional versus digital workflow on marginal fit and fracture resistance of different pressable occlusal veneers after thermomechanical fatigue loading [3] which described that there is an increase in the thickness of cement film occurs following final cementation that subsequently leads to higher marginal gap distance. Testing of marginal accuracy via measuring gap distance was done after cementation to simulate oral environmental conditions. Thermo-mechanical aging was performed as a mandatory step prior to taking marginal gap distance recordings in order to show the influence of cyclic loading and temperature change on the marginal accuracy. Besides, previous studies have demonstrated that there is a negative influence of thermo-mechanical aging upon the marginal integrity of dental restorations. There was a statistically significant difference between them before and after procedures [3].

Regarding fracture resistance, in this study, a highest statistically significant load of fracture (786.81 N) was recorded by the group of IPs e.max, followed by the group of Celtra (691.324), the group of V Ambria (584.866 N), and finally, the group of LiSi which recorded the lowest statistically significant value (575.918 N). A statistically significant difference among the study groups was revealed Table 2. Thus, the second part of the study hypothesis which assumes that the different pressable ceramics do not affect the resistance to fracture of occlusal veneers, was not accepted.

Regarding the amount of biting force in posterior teeth region (for young women and men population) ranges from 500 to 900 N, respectively. Previous studies stated that normal forces of mastication always range from (37−40%) of the biting load [3,13]. Interestingly, the fracture loads mean values in the current study for the four occlusal veneers were above the range of usual posterior occlusal forces (575N−786 N). Thus, the optimum type of such forces can be well tolerated by all the tested specimens in the present study.

The highest fracture loads (786.81) were recorded by IPS e.max Press group. This finding could be attributed to the structural monolithic configuration feature of the Lithium Disilicate which further afford it with an appropriate etching pattern (with hydrofluoric acid), achieving tighter bonds with the adhesive resin cement [21].

The average crystal count, as the filler phase, of ceramic material, influences the mechanical properties, such as strength, of the material to a great extent [24]. Celtra press material has lesser crystal content (36% volume of Lithium disilicate and lithium disilicate) as compared with IPS e.max (70% volume of lithium disilicate). The existence of zirconia in Celtra material results in a reduction of the quantity of the intervening glassy matrix that disintegrates over etching procedures. Thus, the adhesion potential of the restoration is decreased while the grain boundaries are increased. This in turn raises the probability of crack initiation and propagation, and consequently reduces the resistance of the material to fracture versus the IPS e-max press, which possess a crystalline structure of a tightly packed pattern that highly resists the propagation of cracks [24].

Lately, the evolution of superior esthetic all-ceramic restoration was offered by utilizing the heat pressing strategy upon the high strength zirconia strengthened lithium disilicate ceramic. The newly developed material possesses superior mechanical characteristics and enhanced translucent features. In addition, because of the tiny size of the crystals, the material has an exceptional polishability [19].

These findings agree with the study of Influence of different materials and preparation designs on marginal adaptation and fracture resistance of CAD/CAM fabricated occlusal veneers [10] in which the results showed that different materials had a statistically significant influence on the fracture resistance mean values. On the other hand, the preparation designs regardless of the material kind did not elaborate any statistically significant influence on the fracture resistance mean values.

This study's findings were not in agreement with a previous study [3] which assessed the fracture resistance of occlusal veneers fabricated from lithium disilicate glass ceramics (following repeated thermal and mechanical loading) versus those fabricated from zirconia-reinforced lithium disilicate glass ceramics (built with two different methods of wax pattern construction). About the fracture resistance measurement, there were no statistically significant differences between Celtra press and IPS e.max groups for either wax pattern techniques. In the same way, the zirconia-strengthened lithium disilicate group was not significantly different from IPS e.max press.

Limitations of the Study the current study is an *in vitro* assessment which lacks the simulation of many environmental conditions that is difficult to be reproduced due to human variations. Only single occlusal thickness and one finish line have been tested.

4.1. Conclusions

Within limitations of this study, the following could be concluded:

(a) Different pressable ceramics used for the construction of occlusal veneer restorations significantly affect their marginal accuracy. However, the occlusal veneers constructed from IPS e.max Press, GC Initial LiSi Press, VITA AMBRIA Press, and Celtra press provided an appropriate marginal integrity.
(b) A statistically significant increase of the marginal discrepancy, following thermomechanical fatigue, has been recorded.
(c) The fracture resistance of occlusal veneers is greatly influenced by the type of pressable ceramics.

4.2. Recommendations

Further *in vitro* as well as clinical trials should be performed to evaluate and compare the marginal accuracy as well as fracture resistance of different pressable ceramics with two different preparations (no preparation and minimally invasive preparation occlusal veneers).

Ethics information

Ethical approval for the use of artificial tooth was obtained by the guidelines of the Research Ethics Committee of the Faculty of Dental Medicine for Girls, Al Azhar University, code (REC-CR-23-06).

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Conflicts of interest

There are no conflicts of interest.

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