October University for Modern Sciences and Arts University

MSA Dental Journal

https://msadj.journals.ekb.eg/ PRINT ISSN: 2812 - 4944 VOL. 1, 11-19 July, 2022

# Assessment of Marginal Adaptation of Two CAD/CAM Glass Ceramic Occlusal Veneers at Different Thicknesses After Thermodynamic Aging

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**ARTICLE INFO.**

*Keywords:*
Occlusal veneers; Glass Ceramic; Marginal adaptation; Marginal gap.

## Abstract

**Background:** Occlusal veneers fabricated with different materials and thicknesses can reveal different marginal adaptation after thermodynamic aging.

**Methodology:** Extracted maxillary premolar teeth (n=28) were collected and embedded in epoxy resin block with light body material then randomized according to materials into two groups (n=14): Lithium disilicate IPS e.max CAD (A) and Zirconia reinforced lithium silicate Celtra Duo (B) then further randomized into four subgroups (n=7) according to occlusal veneer thicknesses 1 mm and 1.5 mm. Teeth were prepared by a customized milling machine then the exposed dentine was immediately sealed by dentine bonding agent. Fabrication of the occlusal veneers was done by CAD/CAM milling machine. Occlusal veneers were adhesively cemented by dual cure resin cement (Panavia F 2.0). All samples were subjected to thermocycling and cyclic loading equivalent to one year of service (150,000). Marginal gap measurements then were done with A digital microscope at 35x magnification was used to photograph each specimen. Marginal gap was measured and evaluated using a computerized image analysis system.

**Results:** two-way ANOVA showed that the materials only IPS e.max CAD (39.30±5.14) had significantly higher value than Celtra Duo (31.52 ± 5.69) ($p<0.001$). While regarding the thicknesses 1 mm thick samples (36.78 ± 6.06) had significantly higher value than 1.5 mm thick samples (34.04 ± 7.02) ($p=0.020$).

**Conclusion:** Zirconia reinforced lithium silicate (Celtra DUO) occlusal veneers showed better marginal adaptation than lithium disilicate (IPS e.max CAD) in different thicknesses. Zirconia reinforced lithium silicate (Celtra DUO) marginal adaptation was influenced by occlusal veneer thickness (the thicker 1.5 mm showed better adaptation than 1mm.



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## 1 Introduction

One of the most critical predictors of rehabilitation success is how well the prosthetic crown matches the dental preparation. Computer-aided design and manufacturing (CAD/CAM) technology provides a significant advantage in the production of accurate restorations. This approach removes multiple laboratorial processes that could cause complications during the manufacturing process and lowers the distortions generated by traditional methods. [1-2]

Intraoral digital scanners and computer-assisted design and manufacture (CAD-CAM) have grown popular as alternatives to traditional impression and casting procedures, especially with the advent of a new variety of digitalization tools and scanners. [3] Scanning the abutment tooth, designing the prosthesis, and milling the restoration in a centralized milling facility, laboratory, or chairside are all part of the fabrication process. [4]

The ability of CAD-CAM to improve prosthesis accuracy is based on the elimination of multiple manufacturing steps, and CAD-CAM may provide comparable or better results than traditional approaches. [5] The quality of the peripheral and internal adaption are two aspects that influence the lifetime of an indirect restoration. [6,7]

Marginal adaptation is often evaluated by comparing the perpendicular distance between the prepared tooth and the margin of the restoration. [8] Optimal marginal adaptation is one of the most important features of prosthetic restoration success. Marginal adaption failure can lead to the accumulation of bacterial plaque, gingival irritation, caries, pulp and periodontal diseases, and eventually restorative failure. [9]

Occlusal veneers, which are advised for teeth with occlusal wear and reduced the need of full-coverage crowns, have become a conservative alternative to restoring lost tooth structure. Occlusal veneers are made up of a thin overlay with a non-retentive design. [10,11] Recovery of masticatory function with maximum dental structure preservation is one of its properties. [12]

A variety of factors, including the preparation design, restoration geometry and thickness, mechanical properties of the material, occlusal forces, type of cement, bonding technique, antagonist dentition and occlusal scheme, can all influence the success of this type of restoration. [13,14] For teeth where a considerable amount of dental tissue has already been lost due to wear and erosion, minimally invasive designs or the "no-preparation" method have been advocated, as further tooth preparation may be detrimental in these circumstances. [10]

Ceramic restorations' marginal edges are crucial locations that play a significant influence in the effectiveness of this sort of cosmetic restoration in addition to the accurateness of fit of these margins either vertically or horizontally. Edge quality is reflected by smoothness and the absence of inconsistencies and irregularities in the form of chipping cracks has been shown to significantly influence clinical success. [15]

IPS e.max CAD showed superior mechanical properties. [(16)] Lithium disilicate crystals (IPS e.max CAD, Ivoclar Vivadent) microstructure consists of approximately 70% fine-grain lithium disilicate crystals embedded in 30% glassy phase, resulting in needle-shaped lithium disilicate crystals of (one-two) m in length that are randomly oriented. [17,18]

Zirconia-reinforced lithium silicate, on the other hand, is a glass-ceramic material enriched with highly dispersed zirconia. Due to the high silica content of 55-65 wt percent, lithia (15-21 wt percent), and particularly zirconia (8-12 wt percent). [17-19]

The most appropriate thickness for occlusal veneers for maximum longevity and success, taking into account the manufacturer's recommendations for various ceramic material is one - two mm to obtain optimum mechanical and optical qualities. [20,21]

The aim of the study is to assess the marginal adaptation of zirconia reinforced lithium silicate (Celtra DUO) occlusal veneers compared to lithium disilicate (IPS e.max CAD) at different thicknesses after thermodynamic aging. The first null hypothesis is that there will be no significant difference regarding the marginal adaptation of occlusal veneers made of different glass ceramic materials. The second null hypothesis is that there will be no significant difference regarding the marginal adaptation of occlusal veneers at different thicknesses.

## 2 Materials and Methods

### 2.1 Sample size

A power analysis was devised to have enough power to test the null hypothesis that there will be no statistically significant difference in the fracture resistance of occlusal veneers composed of different materials and thicknesses during cyclic loading. Using an alpha ($\alpha$) level of 0.05 (5%), a beta ($\beta$) level of 0.05 (5%), i.e. power=95%, and the effect size (f=0.806) estimated based on the results of Andrade, J. P., et al [(2)] the anticipated sample size (n) was found to be a total of (28) samples Sample size calculation was performed using G*Power version 3.1.9.2.

### 2.2 Ethical approval

Informed consent was obtained from patients to collect 28 human maxillary extracted premolars were acquired through the Outpatient Clinic of the Department of Oral Surgery Faculty of Dentistry of October University for Modern Sciences and Arts. The research ethics committee approved this research (ethical approval no: ETH17).

### 2.3 Selection of teeth

The teeth were inspected using a 10x magnification clinic microscope (Leica M320 F12 Leica microsystems, GERMANY) for the presence of any cracks or cavities using a caries detecting dye. Using a digital caliper, selected teeth were picked to be as comparable in dimension BL and MD (0.5 mm) as feasible (Digital Caliper, Adoric, CHINA). During the research, the teeth were cleaned and disinfected by immersing them in a 5 % sodium hypochlorite solution for 15 minutes and then storing them in distilled water at room temperature. A custom-made paralleling technique: disc and mandrill* was used to allow precise vertical centralization of the long axis of each tooth parallel to the long axis of the block mold. To make sure of the centralization and the tooth was at the long axis of the epoxy block. A disc and mandrill were used because of the angulation between the disc and mandrill and also the disk can hold the sample in the right position all the samples were fixed in epoxy base with proper orientation with light body (elite HD + light body fast set Zhermack dental, Poland) to stimulate periodontal membrane **Figure (1)**.

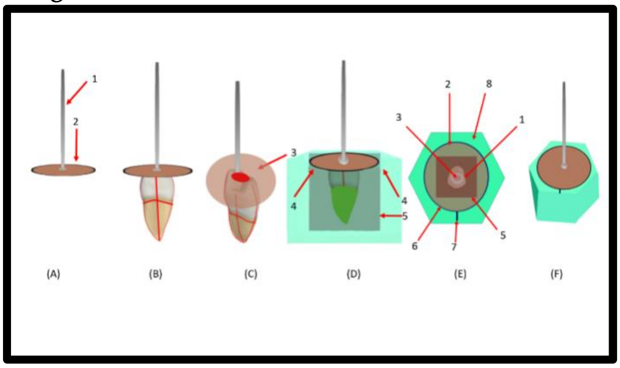


**Figure 1**. Schematic Diagram of the custom-made paralleling technique: A) 1- Mandrel, 2-disc. B) Lateral view with the tooth. C) Lateral view with the mold ,4-the arrows show how the disk holds the tooth to the correct position into the mold.,5-the cubic space that will receive the epoxy resin. D) Occlusal view ,1- mandrel,2-disc.3-resin to fix the tooth to the disc, 5-the cubic space that will receive the epoxy resin,6-blue line drawn to represent the disc,7- blue vertical line to represent the buccal side of the tooth. E) The whole assembly.

### 2.4 Randomization of the samples

The mounted teeth were randomly assigned to each group in this study by simple randomization forum, the randomized samples were allocated equally into two main groups according to materials then further randomized into four subgroups according to the thicknesses of the occlusal veneers (www.random.org).

#### 2.4.1 Allocation concealment

After randomization each group will be put in sealed plastic bag with different number allocation ratio were 1:1.

#### 2.4.2 Blinding

Blinding ends after the tooth preparation and occlusal veneers fabrication and cementation steps begin, to avoid detection bias the statistician was working blindly (double blinding).

### 2.5 Preparation design

A customized milling machine (AF30 Nouvag, Switzerland) was utilized to standardize the preparation. The high-speed handpiece was held horizontal to the sample with the water coolant perpendicular to the milling platform using a custom-made adapter. Using guided preparation with a sequence of stones for 1 mm depth two wheel stone (Tiefenmarkierer depth maker 834A(000) Öko DENT Gruppe, Germany), the occlusal reduction was set at 1 mm and 1.5 mm measured from the fissure.After connecting the depth with a double cone stone (Dia.doppelkegel 811 (038) C FG, Öko DENT Germany) for the extra 0.5 mm, the same processes are repeated with an additional three wheel stone (Tiefenmarkierer depth marker 834 (552) Öko DENT Gruppe Germany) to acquire the 1.5 mm. The double cone was then utilized to join the depth cuts once more.

#### 2.5.1 Immediate dentine sealing

The prepared surfaces were dried such that exposed dentin surfaces could be easily identified. Dentin is easily distinguished by its glossy appearance, whereas enamel is frosty. Phosphoric acid 37 % (META ETCHANT, META BIOMED, Korea) was used to etch the freshly cut and uncontaminated surfaces as it was applied to the exposed dentin.

The etchant was allowed to react on the dentin for 15 seconds before washing well and air drying for 3 to 5 seconds without dehydration. The bonding agent

(Adaper single bond 2, 3M ESPE, USA) was applied to the exposed dentine of all groups using a dental loupe with 3.5x magnification and a gentle brushing motion for at least 15 seconds before being cured for 20 seconds, to avoid the creation of an oxygen-inhibited layer, a thick coating of glycerin gel (KY Jelly 50 gm Johnson & Johnson, USA) was applied to the sealed surface, followed by additional 10 seconds of light curing. The glycerin coating was then rinsed away, and the samples were preserved until the occlusal veneers were made.

### 2.6 Occlusal veneers fabrication

#### 2.6.1 Immediate dentine sealing

Using an intraoral scanner, each preparation was scanned to create a three-dimensional picture of each prepared tooth (TRIOS 3, 3Shape, Copenhagen, Denmark).

#### 2.6.2 Occlusal veneers design

The STL files were sent to a professional dental laboratory for processing. In CAD-software, the virtual die spacer was placed at 50 μm for the occlusal veneer restorations 30 μm for clearance of cement thickness, and the remaining 20 μm for potential distortion in the restoration caused by the production. [22] (Exocad GmbH, Darmstadt, Germany). In order to achieve a homogeneous ceramic thickness, the veneers were semi-anatomically shaped in software. The restoration thickness was consistent across all groups, ranging from 1 mm to 1.5 mm depending on the group.

#### 2.6.3 Milling process

A 5-axis milling machine was used to create the restorations (CORiTEC 250i, imes-icore, Germany) **Table (1)**. After milling, each veneer was given an initial try-in with a dental loupe to ensure that the margins were intact, and the occlusal veneers were cleaned with water steam.

#### 2.6.4 Firing protocols

The IPS e.max CAD groups went through a crystallization cycle first, and glaze cycle (Programat EP 3010, Ivoclar Vivadent. Schaan, Liechtenstein). The Celtra DUO groups were fired and went through a glaze cycle according to the manufacturer's specifications before being glazed by brush on the occlusal surfaces of the restorations. Glazing was done on the samples (GC Initial Spectrum Glaze powder and liquid) (GC AMERICA INC, USA).

| Commercial name of the material | Description | Company | Batch number |
|---|---|---|---|
| IPS e.max CAD HT A2 / C14 (Lithium disilicate) | $SiO_2$, $Li_2O$, $K_2O$, $P_2O_5$, $ZrO_2$, ZnO $Al_2O_3$, MgO, Coloring oxides. | Ivoclar Vivadent. Schaan, Liechtenstein | REF:626408 LOT: Z018J6 |
| Celtra Duo HT \| A2 \| C14 (Zirconia reinforced lithium silicate | $SiO_2$, $P_2O_5$, $Al_2O_3$, $Li_2O$, $ZrO_2$, $Tb_4O_7$, $CeO_2$, 10% $ZrO_2$ Diluted completely in glass-matrix (no crystals | Dentsply Sirona, Germany | REF: 5365411215 LOT:160046997 |

**Table 1**. List of the main materials used in the study as well as their batch numbers.

### 2.7 Bonding procedure

The IPS e.max CAD restorative veneers' intaglio surface was etched with a 5% hydrofluoric acid gel for 20 seconds while the Celtra DUO was etched for 30 seconds, washed with water spray for 60 seconds, and properly dried with oil-free air. Occlusal veneers were cleaned after etching with phosphoric acid in a brushing motion for one minute, then rinsed for 20 seconds; silane was then applied with a microbrush to the pretreatment surfaces and allowed to react for 60 seconds.

The sealed dentin was cleaned with 29 μm alumina intraoral air abrasion (AquaCare Single, Velopex international, UK) at a distance of ten mm under 2 bar pressure until the surface became dull. Following that, the entire surface of the preparation was routinely treated for 30 seconds with 37 percent phosphoric acid washed and dried. The bonding agent was applied to the prepared surfaces and kept uncured until the luting resin was applied.

A dual-curing luting resin cement (Panavia F 2.0) was mixed according to the manufacturer's directions and applied to the prepared teeth's surface. Then, with the aid of a designed loading device, each restoration was seated to its corresponding prepared tooth with light finger pressure, and then a consistent weight of 1 kg was applied to the occlusal surface of the restoration for one minute.

Excess resin was carefully scraped with a brush, and the margins were coated with (OXYGUARD II before being light cured for 20 seconds at a five mm distance from each surface of the repair to polymerize the luting resin. The restorations were kept in distilled water at 37°C for one week to guarantee complete autopolymerisation of the luting resin and thorough curing.

### 2.8 Thermodynamic aging

To mimic mastication, the samples were subjected to thermodynamic loading, thermocycling (Thermocycler THE-1100, SD sd-mechatronik, Germany) 10000 cycle between five and 55◦C in distilled water with a 30 s dwell time at each temperature transfer time 20 s **Figure (2)**, in which each epoxy block was fixed inside the chewing simulator chamber (Chewing Simulator

CS4, SD Mechatronik, Feldkirchen-Westerhan, Germany) , 6 mm diameter steatite ceramic ball was used to represent the antagonistic tooth, which was positioned so that it initially contacted the supporting cusp before sliding down for 0.3 mm. The secured samples were subjected to cyclic load in a chewing simulator for 150,000 cycles **Figure (3)** The samples were examined with magnification loupes 3.5 times and LED light after ageing, and all samples survived the chewing simulator cycles without fractures or cracks.


**Figure 2**. Thermocycling machine.

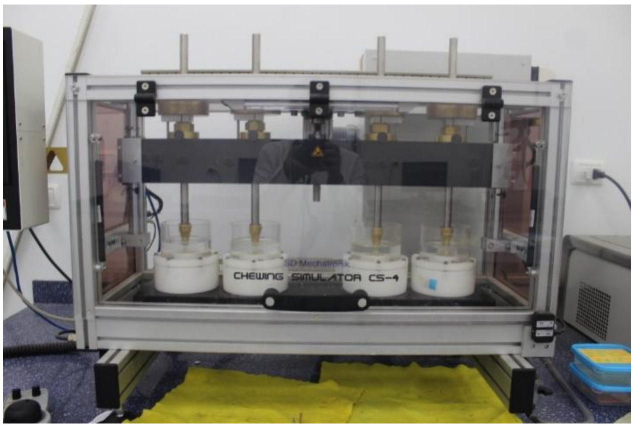


**Figure 3**. Chewing simulator.

### 2.9 Marginal Gap Measurements

A digital microscope with a 35x magnification was used to photograph each specimen (U500x digital microscope, Guangdong, China). The gap was measured and evaluated using a computerized image analysis system (Image J 1.43U, National Institute of Health, USA) **Figure (4)**. Each specimen had its edges photographed, with a scale bar of 2mm. Then, for each photo, morphometric measures were taken. For each surface of the specimen, five equidistant landmarks points along the cervical circumference (Mesial, labial, distal, and palatal, a total of 20 points for each sample). Each measurement was carried out five times. The information gathered was then compiled and statistically examined.

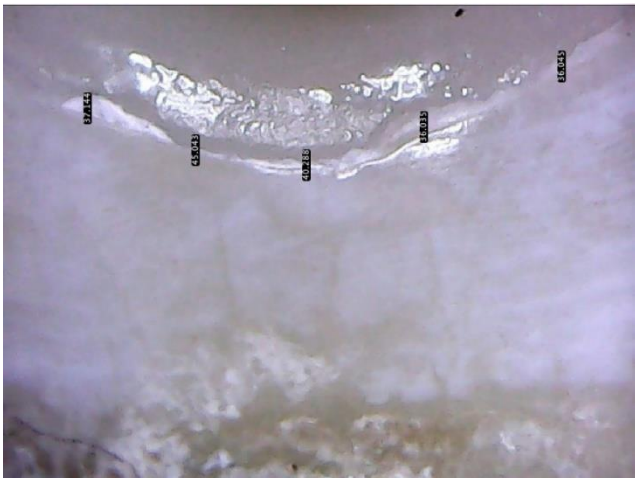

**Figure 4**. Measurement of the marginal gap at mesial surface.

### 2.10 Statistical analysis

Numerical data were presented as mean and standard deviation (SD) values. They were explored for normality by checking the data distribution, and using Shapiro-Wilk test. Data showed parametric distribution so two-way ANOVA was used for the analysis. Comparison of main and simple effects were done utilizing independent t-test. P-values were adjusted for multiple comparisons utilizing Bonferroni correction. The significance level was set at $p \leq 0.05$. Statistical analysis was performed with R statistical analysis software version 4.1.3 for Windows.

## 3 Results

Regarding the materials only IPS e.max CAD (39.30±5.14) had significantly higher value than Celtra Duo (31.52±5.69) ($p<0.001$). While regarding the thicknesses 1 mm thick samples (36.78±6.06) had significantly higher value than 1.5 mm thick samples (34.04±7.02) ($p=0.020$).

### 3.1 Effect of material within each thickness

1 mm: IPS e.max CAD (39.36±5.55) had significantly higher value than Celtra Duo (34.21±5.54) ($p=0.002$).1.5 mm: IPS e.max CAD (39.25±4.84) had significantly higher value than Celtra Duo (28.84±4.54) ($p<0.001$). **Table (2) Figure (5)**

### 3.2 Effect of thicknesses within each material

IPS E.max CAD: 1 mm thick samples (39.36±5.55) had a higher value than 1.5 mm thick samples (39.25±4.84) yet the difference was not statistically significant (p=0.944). Celtra Duo: 1 mm thick samples (34.21±5.54) had significantly higher value than 1.5 mm thick samples (28.84±4.54) (p=0.001). **Table (3) Figure (6)**

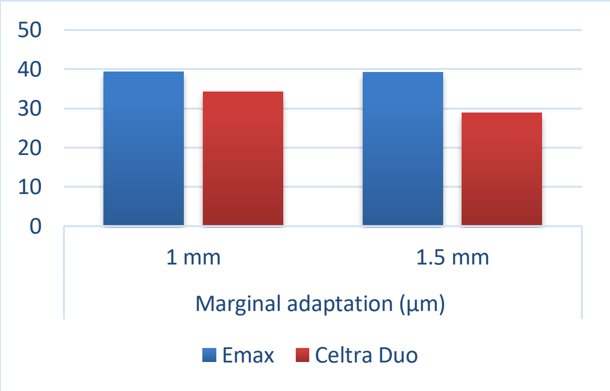


**Figure 5**. Bar chart showing average marginal adaptation (µm) for different materials within each thickness.

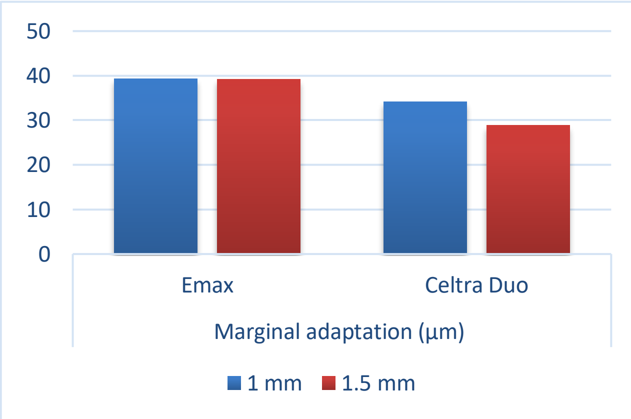


**Figure 6**. Bar chart showing average marginal adaptation (µm) for different thicknesses within each material.

| Thickness | Marginal adaptation (µm) (Mean±SD) | | p-value |
|---|---|---|---|
| | Emax | Celtra Duo | |
| 1 mm | 39.36±5.55 | 34.21±5.54 | 0.002* |
| 1.5 mm | 39.25±4.84 | 28.84±4.54 | <0.001* |

**Table 2**. Mean, standard deviation (SD) values of marginal adaptation (µm) for different materials within each thickness.

| Material | Marginal adaptation (µm) (Mean±SD) | | p-value |
|---|---|---|---|
| | 1 mm | 1.5 mm | |
| Emax | 39.36±5.55 | 39.25±4.84 | 0.944ns |
| Celtra Duo | 34.21±5.54 | 28.84±4.54 | 0.001* |

**Table 3**. Mean, standard deviation (SD) values of marginal adaptation (µm) for different thicknesses within each material.

## 4 Discussion

Human natural teeth were chosen for this investigation to stimulate the clinical scenario. Natural teeth possess elastic properties, bonding ability, and strength, which is better able to mirror the clinical conditions. [23] All teeth were stored in distilled water during the study to prevent them from drying out and becoming brittle, the distilled water was changed every week throughout the duration of the study. [2,24]

Planar occlusal veneer preparation or non-retentive design was chosen in the current study as it has gained popularity over the years as a conservative minimally invasive treatment in severely worn dentition cases. [25,26] The substrate in this study was dependent on the amount of reduction as one mm reduction resulted in less dentine exposure and more enamel substrate while the 1.5 mm reduction resulted in more dentine exposure but all exposed dentine was sealed with immediate dentine sealing.

Immediate dentine sealing was done immediately after preparation with dentine bonding agent to seal freshly exposed dentine. Immediate dentin sealing allows stress-free dentin bond development. Immediate dentine sealing was done as it proved to be an effective way to improve bond strength in case of tensile bond strength or shear bond strength. Other advantages were patient comfort, less dentine sensitivity with temporary restoration and also protection of the patient from bacterial and fluid leakage, and reduce post cementation sensitivity. [27-29]

Two glass ceramic materials, lithium disilicate (IPS emax CAD) and zirconia-reinforced lithium silicate (Celtra Duo) were used to construct the occlusal veneers which possess a good adhesive quality, improved polishing ability and excellent optical properties. [17,18,30,31]

Thickness of one mm was chosen in this study as most of the published literature. Albelasy, et al. 2020 [(31)] stated that lithium disilicate glass ceramic showed more favorable results in terms of fracture strength of occlusal veneers at a thickness of 0.7–1.0 mm according to their systematic review. However, 1.5 mm thickness was chosen in this study because of the usual recommendation for porcelain restoration thickness is 1.5 to 2.0 mm. [20,21] The restorations were milled with a five axis milling machine, CAD/CAM technology was chosen due to its ability to control thickness and anatomy of restorations during the fabrication process. [33]

The first null hypothesis was rejected as there was significant difference regarding the marginal adaptation of occlusal veneers made of different materials. Celtra Duo showed lower marginal gap compared to IPS e.max CAD occlusal veneers, this result came in accordance with Ahmed, et al., (2020) [(34)] and Basheer, et al., (2017) [35]. Celtra Duo microstructure as claimed by the manufacturer to present high edge stability providing acceptable margins. [(36)] The inferior marginal adaptation of lithium disilicate may be due to the dimensional changes that occur during crystallization firing of e.max CAD. IPS e.max CAD is more vulnerable than zirconia regarding dimensional changes taking place during firing and compromising the marginal fit of the milled restorations. [37,38] The authors propose that Celtra Duo 10 % zirconia might be the cause of the less dimensional changes. Another reason may be attributed to difficulties during restoration designing regarding scanning, digitization, and the milling process, milling burs size and the condition of the material during the milling procedure. [(34)] The difference in marginal gap between the two materials could be attributed also to the fact that the Celtra Duo was milled in a fully crystallized form and IPS e.max CAD was milled in a partially crystallized form. Therefore, IPS e.max CAD is expected to have had more shrinkage as compared to Celtra Duo after heat treatment due to densification of the ceramic material increasing marginal gap in the IPS e.max CAD. The similarity of the composition and the slight differences in the microstructure as in e.max CAD the microstructure consists of approximately of 70% fine-grain lithium disilicate crystals, which are embedded in 30% a glassy phase resulting in needle shaped lithium disilicate crystals of (1-2) μm in length randomly oriented. Celtra Duo consists of approximately of 58% crystals an additional 10% Zirconium Dioxide which is completely diluted in amorphous glass is added to the composition of Celtra Duo to create a unique fine-grained structure of (0.5 – 1 μm) in length The difference in crystal size between the two ceramic materials could be another factor. The crystallites embedded in the glass phase of IPS e.max CAD are 2000-4000 nm in size, which is four to eight times larger than Celtra DUO. [17,18]

The results of the current study are in disagreements with El Sayed et al. (2019) [39], Taha et al. (2018) [40] and Abd Elmonam et al. (2017). [41] This could be explained by the similarity of the composition and the slight differences in the microstructure. [17,18] The different testing and aging protocol might be another factor.

Preis et al. [42,] showed that the lithium disilicate proved better marginal adaptation zirconia reinforced lithium silicate by using different protocols of the thermocycling and mechanical loading and the interface is investigated by scanning electron microscope. Ashour et al. (2019) [43] stated that Lithium disilicate provided better marginal fit than polished and glazed Celtra Duo without aging.

The second null hypothesis was partially accepted; there was no significant difference regarding the marginal adaptation of occlusal veneers made at different thickness, the 1.5 mm showed lower marginal gap than the 1 mm in Celtra Duo while in IPS e.max CAD there is no different between the two thicknesses. Jalalian et al. (2018) [44] stated that, increasing the thickness in zirconia core will result in less marginal gap and that's showed in the Celtra Duo group. Increasing the thickness in IPS e.max CAD showed no differences because its partially crystalized and softer to the milling machine All the groups showed marginal adaptation less than 120 μm which is clinically accepted. [45]

## Limitations

1) In vitro studies attempt to mimic clinical conditions, but they will never be able to accurately reflect real-life clinical situations.
2) The limited number of tested samples and the use of distilled water rather than artificial saliva during dynamic loading present limitations in the current study.
3) Aging was limited to one year, in most published work performed longer periods between (2.5-5 year).
4) Only uniform ceramic thicknesses with semi anatomic design were tested, anatomic design with different thicknesses may account for different results.

## 5 Conclusion

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

1) Zirconia reinforced lithium silicate (Celtra DUO) occlusal veneers showed better marginal adaptation

than lithium disilicate (IPS e.max CAD) in different thickness.

2) Zirconia reinforced lithium silicate (Celtra DUO) marginal adaptation was influenced by occlusal veneer thickness the thicker 1.5 mm showed better adaptation than one mm.

## 6 Conflicts of Interest

**Declarations of interest:** none.

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