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# COMPARING THE FRACTURE RESISTANCE OF DIFFERENT CAD/CAM OCCLUSAL VENEERS MANUFACTURED WITH TWO THICKNESSES. AN IN VITRO STUDY

Zainab Diaa Soliman* *and* Samar Saeed Bedair**


## *ABSTRACT*

**Statement of the problem**: posterior quadrants of the oral cavity are subjected to high occlusal loads. Performance of occlusal veneers is affected by fabrication material and veneer thickness.

**Objective:** This study was conducted to assess the effect of veneer material and thickness on fracture resistance of CAD/CAM occlusal veneers.

**Materials and Methods**: Sixty human premolars were prepared for occlusal veneers manufactured from three CAD/CAM materials; IPS E.max (e.max), Vita Enamic (VE) and Lava Ultimate (LU). Veneers were manufactured in 1 mm and 0.5mm thicknesses. (n=10). After cementation, specimens were subjected to Fracture resistance test and failure mode analysis.

**Results:** Two-way ANOVA showed that both material and thickness had significant effect on the fracture resistance. Significant differences were present between the two thicknesses for VE and LU. For e.max, no significant difference was present between the two thicknesses.

**Conclusion:** e.max showed the highest fracture resistance in both thicknesses followed by LU and the lowest was recorded with VE. Results of 1mm Veneers were significantly higher than 0.5mm.


**KEYWORDS:** All Ceramic, Indirect composite, Hybrid Ceramic, Ultrathin Occlusal Veneers, Mode of failure.

## INTRODUCTION

Loss of contact between upper and lower teeth may occur due to wear, caries or malposition. Wear may be physiological or pathological, in both cases, permanent affection of the chewing capacity of patients especially in advanced cases is due to major loss in tooth structure. Impaired esthetics and function are also major consequences of such loss. [(1)] Management of such cases includes proper

* Associate Professor, Conservative Dentistry Department Faculty of Dentistry Ain Shams University
** Assistant Professor in Egyptian Russian University

diagnosis and identification of causative factor/s, handling the cause, restorative phase to manage lost tissue and finally esthetic phase.[2] Many restorative approaches have been used to restore lost tooth tissues including full coverage crowns, ceramic and resin composite onlays and overlays.[3] In the sense of conservatism, occlusal veneers have evolved with the advantage of minimal preparation [3] thus preserving the remaining amount of tooth structure while maintaining the integrity and vitality of the tooth while restoring occlusion and lost vertical dimension.

Improvements in the fabrication techniques which are nowadays computer based, allowing reproduction of fine details in addition to their combined use with modern high strength ceramic materials resulted in improved precision of partial coverage restoration.[4] Lithium disilicate high strength ceramics have shown promising results in maintaining the structural integrity of teeth with partial coverage restorations including inlays, onlays, occlusal veneers and many other full coverage restorations up to 3-unit fixed prosthesis.[5] The high strength of this ceramic material is due to its microstructure containing needle like crystals interlocked together within a glass matrix. [6] Resin containing ceramic is a new category of CAD/CAM materials designed to combine the advantages of both ceramics and resin composites. According to their manufacturing technique, resin-ceramics could be classified to either ceramic filled resin-based composite that had the advantage of high-temperature polymerization, thus reaching higher degrees of chemical curing and improved mechanical properties or polymer infiltrated ceramics which consists predominantly of ceramic network that was infiltrated with polymer under high temperature/high pressure[7].

Treatment options for occlusal loss of tooth structure is quite challenging since it involves the need for extra tooth structure removal to create a space for the restorative material.[8] Preservation of the remaining tooth structure and the need to advocate minimally invasive procedure became more pronounced in management of such cases with the aim to preserve tooth vitality, decrease post-operative pain, bond to enamel tissue with a bond of higher durability compared to bonding to dentin.[9] These needs combined with the introduction of high strength ceramics and CAD/CAM technology enabled the production of lower thickness ultrathin occlusal veneers. [10]

The oral environment is a complicated medium due to repeated occlusal loading, humidity, pH changes which affects the properties of dental materials serving inside such medium. [11] Ceramics upon acting in the oral medium are subjected to stress-corrosion and initiation of crack propagation with a resultant reduction in strength over time [12] On the other hand, subjecting polymers such as resin composite to the oral environment results in reduction in their flexural strength. [13] Including such effects in in-vitro studies became of prime importance to mimic the performance of occlusal veneers inside the oral cavity.

Accordingly, analysis of fracture resistance while subjecting CAD/CAM occlusal veneers to oral environment like conditions became of prime importance. Also, the use of ultrathin occlusal veneers in the sense of minimal invasive dentistry and comparing their performance to traditional less conservative occlusal veneers became mandatory during preparing and restoration of teeth with lost occlusal tissues. [3] Also, monitoring the mode of fracture might enable dentists to prioritize the use of materials with more favorable modes of fracture that can be repaired later. Thereby, this laboratory study was conducted to evaluate the effect of different CAD/CAM materials used in two different thickness on the fracture resistance of occlusal veneers. A null hypothesis was suggested (1) no differences in fracture resistance are present between occlusal veneers manufactured from different CAD/CAM materials and (2) occlusal veneer thickness will have no effect on the fracture resistance.

## MATERIALS AND METHODS

### Materials

Three different types of CAD/CAM blocks were utilized, one porcelain etchant, one primer, one resin cement, one tooth etchants and one bonding agent were used in the study. Materials composition listed in table 1.

### Methods

This study was accepted and approved by the research ethics committee Faculty of Dentistry Ain shams university with approval number FDASU-Rec ER102306.

Sample size was calculated by Independent t-test using G.power 3.1.9.7. According to a previous study (Emam & A. Aleem, 2020). The minimal sample size needed for the study was 7 specimens per group. The total sample size was increased to 10 specimens per group to compensate for the drop out. Sixty non carious human first premolars were used in the following study. The teeth were obtained from orthodontic department in Egyptian Russian University. Only teeth free from cracks, erosions and hypoplasia were selected in the study.[14] The teeth were disinfected by immersion in 5% sodium hypochlorite solution for 15 minutes before being immersed in water that was changed daily till specimen preparation period.

A dental surveyor was used to mount the teeth in self-cured acrylic resin (Acrostone, Egypt). Teeth were mounted along their long axis, where roots were embedded 1.0 mm apical to cemento-enamel junction using custom-made rubber mold (35x35x20mm). Teeth were randomly assigned to three main groups according to type of CAD/CAM block used as follow; Group 1 (e.max):

TABLE (1) Chemical composition and manufacturer of materials used:

| Material | Composition | Manufacturer |
|---|---|---|
| Lithium di-silicate glass ceramics (IPS E.max CAD) (e.max) | $SiO_2$, $Li_2O$, $K_2O$, $P_2O_5$, $ZrO_2$, ZnO, $Al_2O_3$, MgO, Pigments | Ivoclar Vivadent, Schaan, Liechtenstein |
| hybrid ceramics (VITA ENAMIC) (VE) | Ceramic part: 86% wt. $SiO_2$ (58-63%), $Al_2O_3$ (20-23%), $Na_2O$ (9-11%), $K_2O$ (4- 6%), $B_2O$ (0.5-2%), $ZrO_2$ (<1%), KaO(<1%)<br>Polymer part:14%wt (UDMA, TEGDMA) | VITA Zahn Fabrik, Germany |
| Nano ceramic reinforced resin composite (Lava ultimate) (LU) | Nano Ceramic: 80% wt (silica and zirconia nano particles and zirconia / silica nano clusters)<br>Resin matrix: 20 % wt (BisGMA, UDMA, BisEMA, TEGDMA) | 3M ESPE, St. Paul, Germany |
| Porcelain Etchant | Hydrofluoric acid 5% | BISCO Inc, Schaumburg, USA |
| Porcelain primer | Mps, Ethanol, Water | BISCO Inc, Schaumburg, USA |
| Resin cement (Duo-Link Universal) | Base: Bis-GMA, TEGDMA, urethane dimethacrylate, Glass filler Catalyst; Bis-GMA, TEGDMA, Glass filler | BISCO Inc, Schaumburg, USA |
| Scotch bond Universal Etchant | 37.5% Phosphoric Acid | 3M ESPE, St. Paul Minnesota |
| Bonding agent (All Bond Universal) | Bis-GMA, HEMA, MDP, ethanol, water, initiators | BISCO Inc, Schaumburg, USA |

Lithium di-silicate glass ceramics: IPS E.max CAD blocks (Ivoclar Viva-dent, Switzerland), Group 2(VE): Hybrid all-ceramic material: Vita Enamic CAD/CAM ceramics blocks (VITA Zahnfabrik, Germany) Group 3 (LU): Nano-ceramic reinforced resin composite (Lava Ultimate 3M ESPE) CAD/CAM ceramics blocks. Within each main group, teeth were divided into 2 subgroups according to occlusal veneer thickness; 0.5mm or 1.0 mm thickness (n=10).

A silicon index made from putty and light consistencies (DMG Silagun, Germany) was taken for each premolar to record the occlusal anatomy. The index was cut in bucco-lingual direction to act as a guide during teeth preparation to control teeth reduction and ensure equal and uniform preparation. All teeth were prepared by one operator to create occlusal reduction of 0.5 mm or 1.0mm using tapered diamond stone (Mani DIA TR-12) while following the occlusal anatomy. Prepared surfaces were polished using fine grit diamond stone (8846 KR 314016, KOMET) followed by abrasive rubber points (9608314030, Komet).

Digital impressions for prepared teeth were recorded using Swing 3D scanner (DOF, Korea). EXO-Cad* SW 2018 (Valletta 2.2), was used after 3D-model calculation to create standardized anatomy created by the soft wear. Bio generic anatomy was used in all samples. Homogenous thickness for each specimen was standardized at either 0.5mm or 1mm using the scanned teeth images with the use of spacer of 100$\mu$m thickness. Occlusal veneers were prepared using Dentsply sirona InLab MCXL milling machine after selection of block type. For the e.max group, firing cycles were done using a Programat® P310 following the manufacturer instructions (850°C for 10 minutes). For VE and LU groups, finishing and polishing procedures were done according to manufacturer instructions using recommended polishing set with no additional firing cycle.

After veneers milling, firing, and polishing (according to each group of material and their manufacturer instructions) the veneers were examined to ensure absence of cracks and defects in addition to proper fit and seating evaluation on occlusal surface. For e.max group, fitting surfaces were etched using 5% hydrofluoric acid (BISCO Porcelain Etchant, Bisco Inc, Schaumburg, USA) for 20 seconds followed by rinsing using water spray and drying using compressed air. Silane (BISCO silane, BISCO Inc, Schaumburg, USA) was applied to the fitting surfaces, gently dispersed on the surface using gentle air spray, then left to dry spontaneously for one minute. For VE and LU groups, the fitting surface was sandblasted using aluminum oxide 40 $\mu$m particles at 2 bars (30 Psi) (cojet system, 3M ,St. Paul, Minnesota) till a dull surface was obtained, followed by cleansing with alcohol and gentle dryness using oil free compressed air and silane application as mentioned earlier.

The prepared teeth were cleaned with ultrasonic cleaner followed by dryness. The teeth prepared surfaces were etched for 15 seconds using 37.5%of phosphoric acid gel (Scotch bond Universal Etchant, 3M ESPE, St. Paul Minnesota) and rinsed for 30 seconds followed by proper dryness. Active application of the bonding agent (All Bond Universal, BISCO Inc., Schaumburg, USA) was done in two separate coats each for 10-15 second with no light curing in-between coats. Excess solvent evaporation was done by through dryness of the surface for at least 10 seconds or until no more visible liquid movement was present. Light curing for the adhesive layer was performed for 20 seconds. For cementation of the veneer, auto mixing of resin cement Resin cement (Duo-Link Universal, BISCO Inc, Schaumburg, USA) was done and the cement was applied in the occlusal veneer fitting surface before veneer seating. A static load of 3 kg was applied in the central groove area of the occlusal veneer using universal testing machine to ensure thin and homogenous cement layer thickness. Excess cement was removed using micro-brush, an air barrier (K-Y jelly, Johnson & Johnson) was applied to all margins before final curing to prevent formation of oxygen inhibited layer at the cement margin. Final cement curing was done using 3M ESPE Led (3m, Minnesota, USA) of Wavelength ranges between 450-470 mm for all surfaces 20 seconds each. Specimens were thermocycled at ambient light using digital SD mechatronic thermocycler for 4 days to achieve 5000 cycles between 5±2°c and 55±2°c with a dwell time of 30 seconds in each bath and 20 second interval baths.

The Fracture resistance test was done using Bluehill lite software from Inston®. Each sample was individually mounted in the lower compartment of computer-controlled testing machine (Model 3345; Instron Industrial Products, Norwood, Ma, USA). The loadcell was set at 5 kn, the crosshead speed was set 1mm/min and data was recorded using computer software (Instron® Bluehill Lite software). The compressive fracture test was done as the load was applied occlusally in the middle of the occlusal veneer using a metallic rod with spherical tip of 5.6 mm diameter attached to the upper movable compartment of the testing machine. A tin foil sheet (0.016 mm) was applied in between to achieve homogenous stress distribution and to minimize the transmission of local force peaks. Load failure was identified by an audible crack and confirmed by sharp drop in the lead deflection curve recorded. The load failure values were recorded in newtons.

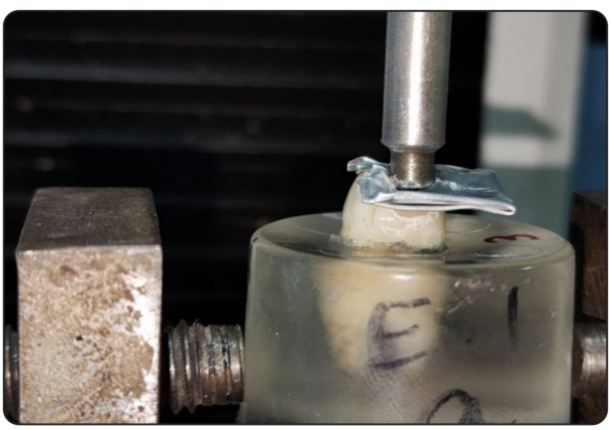

Fig. (1) Fracture resistance test

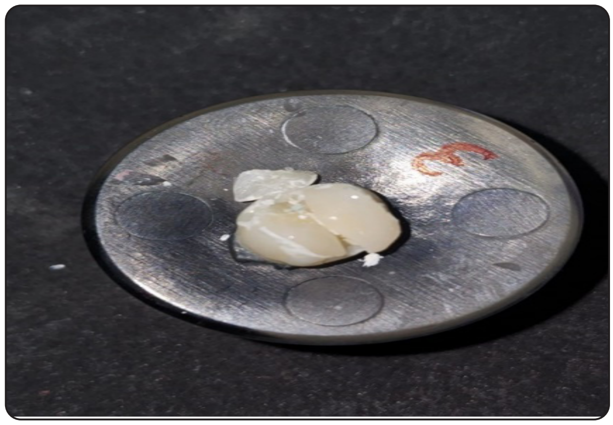

Fig. (2) Catastrophic failur

Failure mode analysis of the occlusal veneers was done using stereomicroscope (SMZ 745T, Nikon, Japan) at 16x magnification. Each failed veneer was captured using the camera supplied by the microscope (WAT-221S, Japan). The mode of failure of each specimen was categorized as follows: [15,16]

1- Repairable failure: when restoration become cracked without complete fracture under load.

2- Catastrophic failure: when restoration become cracked with complete fracture under load.

## RESULTS

The results of the present study were analyzed using Graph Pad instant software. A statistically significant P-value at $P \leq 0.05$ *was set*. Mean and standard deviation were set as continuous variables. Homogeneity of variance and normal distribution of data were confirmed followed by *t-test*. For thickness results, paired test was performed between different thicknesses while Two-way ANOVA was performed to test the effect of material and veneer thicknesses. Chi square test was performed between failure mode patterns. Sample size (n=10) was large enough to detect large effect sizes for main effects and pair-wise comparisons, with the satisfactory level of power set at 80% and a 95% confidence level.

**Fracture resistance test results**

For the overall effect of material within all tested groups, two-way ANOVA test showed statistically significant differences between the three tested materials (p=<0.0001 < 0.05) regardless to occlusal veneer thickness. e.max veneers had the highest fracture resistance followed by LU and the lowest result was recorded with VE (e.max > LU >VE).

For the 0.5 mm ultrathin occlusal veneer thickness, one-way ANOVA followed by Tukey's post-hoc tests (P=0.0054<0.05) revealed statistically significant differences between the three tested materials with the highest fracture resistance mean value recorded with e.max group (490.8N) followed by LU group (432.13N) while the lowest fracture resistance mean value recorded with VE group (267.23N). Similar results were present with the 1mm veneer thickness results where, statistically significant differences were found between the three tested materials with e.max group showing the highest fracture resistance (619.31N) followed by LU group (548.9 N) while the lowest fracture resistance mean value recorded with VE group (349.52N) as shown in table (2) and figure (3)

Regarding the effect of the veneer thickness on mean fracture resistance within all tested groups, Two- way ANOVA test (P=<0.0001 > 0.05) showed that irrespective of material groups, it was found that 1 mm occlusal veneer thickness recorded statistically significant higher fracture resistance mean value than 0.5mm occlusal veneer thickness. Upon comparing the effect of veneer thickness within each material using paired t-test, statistically significant differences were found between the two thicknesses within all tested material. For the e.max material, the 1mm (619.31 N) showed statistically significant (P= 0.0008<0.05) higher fracture resistance compared to 0.5mm thickness (490.8 N). Significant differences (P=0.004< 0.05) were also present in the VE material where 1mm group (349.52 N) had significantly higher mean fracture resistance compared to 0.5mm thickness (267.23 N). Similar results were also presented for the LU material where 1mm thickness (548.9 N) recorded statistically significant (P=0.0002< 0.05) higher fracture resistance mean value than 0.5mm thickness (432.13 N) table (2) and figure (3)

TABLE (2) Fracture resistance results (Mean values ±SDs) for all groups with both occlusal veneer thicknesses

| Variable | | *Occlusal veneer thickness* | | | | | | *Statistics* |
|---|---|---|---|---|---|---|---|---|
| | | *0.5 mm* | | | *1 mm* | | | *t-test* |
| | | *Mean± SD* | *95% CI Low* | *95% CI High* | *Mean± SD* | *95% CI Low* | *95% CI High* | P value |
| ***Material type*** | ***e.max*** | ***490.8$^{A}$±30.66*** | 463.93 | 517.67 | ***619.31$^{A}$±45.64*** | 579.29 | 659.34 | 0.0008* |
| | ***VE*** | ***267.23$^{C}$±27.54*** | 243.09 | 291.37 | ***349.52$^{C}$±36.75*** | 317.30 | 381.74 | 0.004* |
| | ***LU*** | ***432.13$^{B}$±22.27*** | 412.61 | 451.65 | ***548.9$^{B}$±33.65*** | 519.41 | 578.39 | 0.0002* |
| ***Statistics*** | P value | <0.0001* | | | <0.0001* | | | |

***Different letters in same column indicating significant between groups (p<0.05) *; significant (p<0.05)***
***ns; non-significant (p>0.05)***

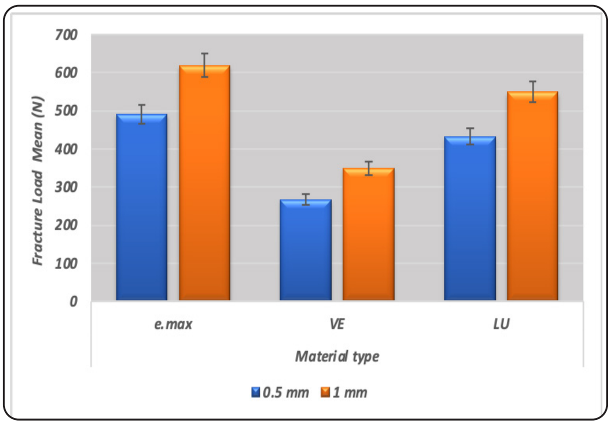


Fig. (3) Column chart of fracture resistance mean values for all groups with both occlusal veneer thicknesses.

## Failure mode pattern

Failure mode of the three tested material were observed and recorded and modes of failure were recorded as repairable failure where the veneer showed cracks only and catastrophic failure where the veneer was cracked with complete fracture. Table (3) and figure (4)

The difference in the failure modes between all groups was statistically significant as revealed by chi square test (p=<0.0001<0.05) as shown in table (3).

Regarding the failure mode, statistically significant differences were present between the VE groups and the LU groups, where both materials showed statistically higher repairable failures with the 0.5mm veneers. With the 1mm veneers, failure modes in the two materials were predominantly catastrophic. No significant difference between the two thicknesses was present with the e.max veneers where all specimens showed repairable mode of failure. Upon comparing the overall results of the 0.5mm and 1mm thicknesses, statistically significant differences were present as revealed by chi square test (p<0.05) except in e.max group where the difference was non-significant (p>0.05) as shown in table (3).

TABLE (3) Frequent distribution of failure mode patterns for all groups as function of thickness

| Variable | | ***Occlusal veneer thickness*** | | | | ***Statistics*** |
|---|---|---|---|---|---|---|
| | | ***0.5 mm*** | | ***1 mm*** | | ***t-test*** |
| | | ***Repairable*** | ***Catastrophic*** | ***Repairable*** | ***Catastrophic*** | P value |
| ***Material type*** | ***e.max*** | 100% | 0% | 100% | 0% | 1 ns |
| | ***VE*** | 80% | 20% | 20% | 80% | <0.0001* |
| | ***LU*** | 60% | 40% | 40% | 60% | 0.0071* |
| ***Statistics*** | P value | <0.0001* | | <0.0001* | | |

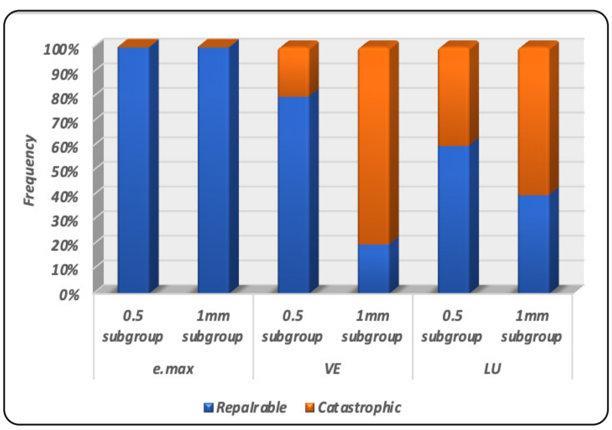


Fig. (4) Stacked column chart for different patterns of failure modes for all groups with both thicknesses.

## DISCUSSION

Minimal invasive dentistry is based on maximum preservation of tooth structure while using simplified preparation design and high strength material to increase longevity of restorations. Continuous improvements in ceramic materials strength properties as well as introduction of hybrid ceramics enhanced the application of minimal invasive dentistry and helped to introduce more conservative preparations such as ultrathin occlusal veneers. The present study was done to investigate the fracture resistance of CAD/CAM milled occlusal veneers manufactured from three different materials namely e.max, LU and VE when manufactured in 1mm and ultrathin 0.5 mm thicknesses after being subjected to thermocycle loading to mimic the complex oral environment.

Fracture resistance of occlusal veneers is an important property for their longevity and is affected by an array of factors including the preparation design, mechanical properties of the material, luting cement, technique of bonding in addition to the nature of occlusal loads to which the restoration is subjected to. (17)

Conservative preparation designs used in minimal invasive dentistry result in preservation of as much enamel and dentin as possible during preparation of occlusal veneers. Including two occlusal veneers thickness in this study aimed to compare the traditional 1 mm veneer thickness with the more conservative ultrathin 0.5 mm occlusal veneers. In a previous study, it was found that the conservative 0.5mm occlusal veneers bonded to enamel tissue have comparable fracture resistance to 2.0mm occlusal veneers bonded to dentinal tissue and manufactured from the same material. (3)

Upon comparing the bond strength of occlusal veneers bonded to enamel and dentin tissues, it was found that occlusal veneers manufactured from high strength ceramic materials done in minimum thickness showed higher bond strength to enamel compared to veneers bonded to dentin. (17) This was also reflected on the fracture resistance of the tooth restoration complex, where thin occlusal veneers bonded to enamel showed comparable fracture resistance to thicker occlusal veneers bonded to dentin. (3, 18). These results highlight the importance of minimally invasive preparations that maintain to enamel tissue to produce the highest possible bond strength which is reflected on the fracture resistance on tooth restoration complex. (3)

Bonding to tooth structure is a crucial step for the success of occlusal veneers. Modern universal adhesives are mostly used nowadays for bonding tooth structures to resinous materials and restorations due to their ability to bond chemically and micromechanically to tooth structure because of the presence of MDP monomer which is responsible for chemical bonding to tooth structure with improved durability of adhesive joint. Unfortunately, most of these adhesives are characterized by a relatively high pH compared to older generations of self-etching adhesives. Sasse et al reported the presence of enamel cracks following thermodynamic loading of ultrathin occlusal veneers bonded to enamel using self-etching primer only, while omitting the use of pre-enamel etching step using phosphoric acid. They reported that self-etching primer had reduced ability for enamel etching. (19) This was also confirmed in other studies when comparing the enamel etching pattern upon using self-etching adhesives versus phosphoric acid etching for prepared enamel surface. Proper etching pattern, better adhesion and higher bond strength were associated with the additional use of phosphoric acid on prepared enamel surfaces. (20, 21, 22). In the present study, All Bond Universal adhesive was used with a pH of 3.2 which put this adhesive in the category of Ultra-mild adhesives. And thereby, an additional step of enamel etching using phosphoric acid gel was done to improve bond strength to enamel based on reports and recommendations of previous studies.

The oral cavity is always regarded as a complex environment due to continuous occlusal loading and thermodynamic changes occurring within.

Restorative materials are thereby subjected to this complex environment with continuous temperature changes and thermal stresses. In vitro studies often use thermo cycling as a mean of mimicking such alternating temperature stresses. Ernst et al validated the use of 5000 cycle with temperatures ranging from 5°C- 55°C for cold and heat provocation alternatively. [23] These thermo cycling settings were used by many other authors including Abou-Madina et al [24]. Saridag et al and Bedair et al [25,26] Similar setting was used in the present study as well to apply thermo cycling challenge to prepared occlusal veneer specimens in addition to using natural human teeth to have the closest clinical relevance to conditions occurring within the oral environment. Also, the preparation design of teeth was determined based on the guidelines for minimal invasive partial coverage ceramic restorations protocol suggested by Ahlers et al and Kern el al [27, 28]

Using high strength ceramic material for the fabrication of ultrathin occlusal veneers is crucial for restoration success and long-term performance. CAD-CAM lithium disilicate ceramic blocks were used due to their high mechanical properties and high rates of survival reported before. [29] Though lithium disilicates blocks are characterized by their high strength, they are also characterized by some disadvantages including their extremely high hardness which is reflected on their increased milling time and bur consumption in addition to the need of post milling recrystallization process and high possibility of cracks and edge chipping during milling. [30] Resin containing CAD-CAM blocks were used in the present study in addition to lithium disilicate blocks due to their easier and shorter milling, smoother surface which reduces the abrasion of opposing natural teeth and their shock absorbing action due to their lower modulus of elasticity. [31, 32] Two types or resin containing CAD-CAM blocks were used in the present study to prepare ultrathin occlusal veneers; VE blocks which are polymer infiltrated ceramic network and considered as hybrid ceramic material due to the presence of the ceramic network. The material was stated to have a high degree of elasticity and the ability to be milled in ultrathin sections while still showing high strength. [33]

The other resin containing blocks used in the present study were the LU blocks. Its chemical composition differs for VE blocks since LU consists of fillers dispersed within a polymer matrix which is considered closer in composition and spatial arrangement to restorative resin composite materials.

According to the results of the present study, regarding the effect of material thickness on the fracture resistance, it was found that occlusal veneers of 1mm thickness had statistically higher fracture resistance than 0.5 mm thickness. These results were in accordance with Tribst et al who stated that thicker occlusal veneers presented superior mechanical performance. Still, authors suggested the use of thicker veneers only in cases of occlusal rehabilitation cases presented with severe occlusal wear and did not recommend increased tooth preparation to obtain thicker veneers. [34]

In a previous study, the results of different veneers thickness (0.5 & 2mm) showed comparable results which contrasted with the results of the present study. The difference between the results could be attributed to the resultant bond strength due to adherence to different tissues which might have compensated the difference in the fracture resistance of the two veneers thicknesses used. In that study, the 0.5 mm veneer was bonded to enamel with high bond strength which had a positive effect on the overall fracture resistance of the tooth/restoration complex, while the 2mm occlusal veneer resulted in more aggressive preparation and thereby, was bonded to dentinal tissue with lower bond strength. Adhesion to different tissues could have compensated for the difference in the fracture resistance of different veneers thickness and was reflected on the fracture resistance of both groups which were not significant form each other. [3] On the other hand, in the present study, both veneer thickness preparations resulted in conservation and bonding to enamel tissue which highlighted the effect of veneer thickness only on the results and disregarded the possibility of bonding to different tissues.

The results of material effect on the fracture resistance showed that the e.max had significantly the highest fracture resistance among all tested materials followed by the LU occlusal veneers. The lowest fracture resistance was recorded with the VE. These results were in accordance with Al-Akhali et al who reported that the e.max had significantly higher mean fracture resistance compared to resin containing CAD/CAM occlusal veneers. [35] Also Majed et al[36] reported similar results for the lithium disilicate occlusal veneers. This could be attributed to the higher mechanical properties of the lithium disilicate material which improved the fracture resistance of the tooth restoration complex under high occlusal loads. [37, 38] Another reason for the high fracture toughness of the e.max veneers are the proper etching pattern reported upon using hydrofluoric etching for the fitting surface of the veneer as was also done in the present study. Proper etching pattern was reported to increase the bond strength to luting cement, and hence improving the mechanical properties of the tooth/restoration complex through acting as monoblock system.[39] Furthermore, it was reported that lithium disilicate glass ceramics, resin composites materials and resin infiltrated glass ceramics exhibited flexural strength of (360MPa), (205MPa) and (150–160MPa) respectively[40] this could explain the results of the fracture resistance in both tested thicknesses in the present study that were correspondent with the flexural strength of the tested materials. This by default could reflect the importance of the mechanical properties of materials used for occlusal veneers fabrication upon reduction of veneer thickness to reach ultrathin veneer sections.

When comparing the results of LU and VE groups, it was found that LU recorded significantly higher fracture resistance in both tested thicknesses. This could be attributed to the composition of LU that contains nano silica particles of 20nm size in addition to zirconia particles 4-11nm in diameters forming nanoclusters. The particles are present in nano-aggregated and nano-agglomerated form with a high filler loading reaching 80% wt of material content resulting in the high fracture resistance of the material. The results were in accordance with both Egbert et al [40] and Albelasy et al [41]. According to Stawarczyk et al [42], the presence of polymer network within the material could decrease the extent of crack propagation. This could also explain the reason behind the significantly higher fracture resistance recorded with LU compared to VE, where the earlier has higher resin content (20 wt %) while VE has 14 wt% of resin in its composition.

The maximum expected occlusal and biting forces in the posterior oral segment was estimated to be around 850 N. These occlusal loads are reached during maximum clenching only. [43] On the other hand, occlusal load values for normal biting forces in the premolar area ranges from 222-445N with an average of 322.4N. [44,45]. According to results recorded in the present study, all tested groups were within the average occlusal loads present on premolar teeth except for the VE 0.5mm occlusal veneer which still reported mean fracture resistance in the lower range of biting forces but did not reach the average biting force value of 322.5 N.

Failure mode results in the present study showed that the e.max group presented only reparable mode of failure in both tested thickness which in combination with the high fracture resistance results of the material highlights the ability of this material to act with high durability in both tested thicknesses. Also, the veneer can be repaired rather than replaced which was in agreement with Yazigi et al [46] who stated that ultrathin occlusal veneer fabricated from lithium disilicates showed the presence of cracks, still the cracks present did not decrease the fracture strength. When occlusal veneers are subjected to occlusal loads, cracks originate but the structure failure does not occur till the stresses exceed the fracture resistance of the material. Due to the presence of needle like crystals in the lithium disilicates, these crystals present difficulty in crack propagation with slower crack growth and this could explain the reparable failures within the lithium disilicates groups. (47)

On the other hand, both VE and LU showed predominantly reparable failures in the 0.5mm but in the 1mm thickness it was predominantly catastrophic. VE showed significantly more reparable than the LU. This was in agreement with Egbert et al. who also compared VE and LU with results showing higher reparability of VE compared to LU. (40) Also, most of failures of ultrathin occlusal veneers were in the form of cracks mostly within the restoration and did not involve the tooth structure(4,48,49) the results of their study showed inconsistency between the fracture resistance and the mode of failure similar to results of the present study. The difference in the mode of failure between the two tested materials is mostly related to the difference in material internal structure. VE has a sintered ceramic structure infiltrated with resin with a porous structure similar to feldspar ceramic. (50) According to previous studies, it was stated that crack propagation occurred predominantly within the ceramic network along the interface between polymer and ceramic which presented the weakest part in the hybrid ceramic network. (51 52) Still, the results of the present study were obtained under monotonic test. The hybrid ceramic materials could have different results under more reliable fatigue test as reported by Homaei et al. (53) Better mechanical performance of hybrid materials was reported by other authors when the material was subjected to fatigue stresses with the failure mode being more repairable than catastrophic (49)

In the present study, simulation of the clinical situation was done using natural teeth and thermo cycling of specimens to mimic changes in the temperature of the oral environment. According to the results of the present study, fracture resistance of CAD/CAM occlusal veneers was affected significantly by the type of the material and the thickness of the veneer and hence, the null hypothesis was rejected. Still, further need for longer term clinical studies is needed to confirm the success of ultrathin occlusal veneers and its performance compared to conventional veneers since the oral environment contains a combination of stresses that are not only compressive in nature, in addition to the fact that failure usually results from cyclic loading rather than single constant axial loading (54) Thus, fracture resistance tests do not give accurate reflection to long term success of occlusal veneers.

## CONCLUSIONS

Based on the findings and limitations of the present study, it can be concluded that

1- Fracture resistance of occlusal veneers is material and thickness dependent.

2- Fabrication of 1 mm occlusal veneers resulted in higher fracture resistance compared to the 0.5 mm occlusal veneers in all tested materials.

3- Ultrathin 0.5mm occlusal veneers showed efficient fracture resistance values that can withstand natural biting forces except for the Vita Enamic material.

4- IPS-E.max is the material of choice for fabrication of Ultra-thin 0.5 mm occlusal veneer with high fracture resistance and favorable failure mode.

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