

## IMPACT OF TWO DIFFERENT DESIGNS AND MATERIALS ON FRACTURE RESISTANCE OF OCCLUSAL VENEERS (IN VITRO STUDY)

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### ABSTRACT

**Statement of the problem:** Occlusal veneer restorations represent a minimal invasive alternative to traditional crowns in treatment of severely worn dentition. However, the data regarding the mechanical performance of occlusal veneers designs and materials are still controversial.

**Aim of study:** Evaluation of the effect of using two different designs and materials on fracture resistance of occlusal veneer restorations.

**Materials and Methods:** Thirty-two freshly extracted premolars were randomly divided into two main groups (n=16) according to preparation design: Group B: butt joint preparation design and Group M: Modified occlusal veneer design. Each main group was further subdivided into two subgroups (n=8) according to type of restorative material used for occlusal veneer fabrication: Lithium disilicate and polymer-infiltrated ceramic network. Occlusal veneer restorations were fabricated by CAD/CAM technology and then cemented to their corresponding teeth using dual cured adhesive resin cement. Fracture resistance test was done using universal testing machine. The load needed for fracture of each specimen was registered automatically in Newtons (N) by a special software. Data were collected, tabulated and statistically analyzed.

**Results:** Student's *t*-test results revealed that there was no statistically significant difference regarding the two variables (preparation design and material type). Also, Two-way ANOVA test results showed that there was no statistically significant difference regarding the interaction between the two variables in this study (P=0.309).

**Conclusion:** There was no effect of preparation designs and material types on fracture resistance of occlusal veneers. The fracture resistance for all study groups exceeded the reported range of human masticatory forces.

**KEY WORDS:** Occlusal veneer, preparation designs, fracture resistance, Lithium disilicate, Polymer-infiltrated ceramic network.

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## INTRODUCTION

Loss of tooth substance could be attributed to several causes such as: dental caries, erosion, abrasion and attrition. Clinically, tooth wear could have drawbacks such as loss of vertical dimensions, pulpal complications, esthetic and functional impairments.<sup>(1)</sup>

Preservation of tooth structure was the main aim of restorative dentistry, so great attention had been paid to conservative and esthetic restorations such as indirect partial coverage restorations (inlays, onlays, overlays or partial crowns).<sup>(2)</sup>

Occlusal veneers were suggested as an alternative to more invasive treatment modalities for occlusal surface reconstructions to restore the musculoskeletal harmony, occlusal stability and to achieve patient satisfaction.<sup>(3,4)</sup>

Various designs for occlusal veneers were introduced such as: straight-beveled finish line design, butt joint preparation design, modified occlusal veneer preparation design with circumferential finish line, with two proximal slots or with intracoronal cavity, 90°-rounded shoulder design, minimal invasive chamfer preparation design, buccal occlusal veneer preparation design, occlusal and lingual coverage design, occlusal, lingual and mesial coverage design, occlusal, lingual, mesial and distal coverage design, occlusal reduction with central groove design and occlusal reduction with round shoulder and central groove design, but data regarding the effect of the preparation design of occlusal veneers on their fracture resistance were controversial.<sup>(5)</sup>

Moreover, occlusal veneers were fabricated from plenty of restorative materials such as: (Feldspathic ceramics, Leucite-reinforced ceramic, Zirconia-reinforced lithium silicate, Zirconia, Resin Nano Ceramic, Zirconia-silica ceramic in a resin-interpenetrating matrix, Lithium disilicate and Polymer-infiltrated ceramic network) using computer-aided design/ computer-aided manufacturing

(CAD/CAM) technology that became popular during the last decade for restorations fabrication, but data regarding the proper occlusal veneers restorative material were controversial.<sup>(6,7)</sup>

Lithium disilicate was a synthetic glass-ceramic that had been considered the strongest glass-ceramic due to the high number of microstructural, interlocking, needle-like lithium disilicate crystals embedded in the glassy matrix.<sup>(8)</sup> It was widely used in dentistry because of its excellent biocompatibility, the continuous development of its mechanical properties through using better microstructures and new processing techniques, its adhesive characteristics that allowed preservation of sound tooth structure and its good esthetic quality.<sup>(9-12)</sup>

Polymer-infiltrated ceramic network (Vita Enamic) was a hybrid ceramic CAD/CAM material comprised of 86% pre-sintered porous feldspathic ceramic network (silicon dioxide, aluminum oxide, sodium oxide, potassium oxide, zirconia, calcium oxide) infiltrated with 14% polymers such as: urethane methacrylate (UDMA) and triethylene glycol dimethacrylate (TEGDMA).<sup>(13)</sup> It had low elastic modulus close to dentin that enabled it to dissipate stresses evenly during mastication resulting in high damage tolerance. Also, It could be repaired easily by composite resins and could be milled easily.<sup>(14,15)</sup>

CAD/CAM technology allowed overcoming most of the difficulty and technical complexity of fabricating these veneers and enabled professionals to make restorations easily and quickly in a single session.<sup>(5)</sup>

Due to the controversy among researches regarding occlusal veneers preparation designs and materials and their effect on fracture resistance, which was an essential factor that predicted the restorations success and survivability, this study was performed to provide more data about their effect on fracture resistance especially with premolars as there were few data regarding premolars restored

by occlusal veneer restorations. The hypothesis of this study was that both the preparation designs and the materials would have a significant effect on the fracture resistance of occlusal veneer restorations.

## MATERIALS AND METHODS

Thirty-two extracted premolars were collected from Maxillofacial and Oral Surgery department clinic, faculty of dentistry, Mansoura University. Teeth were cleaned from calculus and soft tissue remnants by ultrasonic scaler and then examined carefully under 3.5x magnification using (Galilean dental loupes, Gain Express, China) to make sure that they were free from caries and cracks. Digital caliper was used to make sure that all selected teeth had comparable dimensions. The selected teeth were immersed in 5% sodium hypochlorite for 15 minutes and stored in saline till used.<sup>(16)</sup>

Each tooth was embedded in epoxy resin 2 mm below cemento-enamel junction to facilitate handling, using a teflon ring with the dimensions (2.5 cm in diameter and 2cm in height) and a custom-made paralleling device to ensure its centralization.

Specimens were randomly divided into two main groups according to preparation design: **Group B:** Butt joint design, **Group M:** Modified occlusal veneer design.

Each main group was further subdivided into two subgroups according to type of restorative material used for occlusal veneer fabrication: Subgroup BL: Butt joint design and lithium disilicate, Subgroup BH: Butt joint design and hybrid ceramic, Subgroup ML: Modified occlusal veneer design and lithium disilicate, Subgroup MH: Modified occlusal veneer design and hybrid ceramic.

### Teeth Preparation:

Dental surveyor (Marathon 103, Korea) with low speed handpiece, depth grooves and indices were used to standardize teeth preparation. Teeth were prepared into two designs: Butt joint design which included only occlusal reduction 1.5 mm at cusp tips and 1mm at central grooves and Modified occlusal veneer design which included occlusal reduction 1.5 mm at cusp tips and 1mm at central groove along with 1mm circumferential deep chamfer finish line. (Figure 1)

### Fabrication of the occlusal veneers

An optical impression was performed by scanning of the prepared teeth by an optical scanner (Identica Hybrid series GmbH, Germany).

Exocad chairside CAD software, version 2.2 Valetta, exocad GmbH was used for designing occlusal veneer restorations. The thickness of occlusal veneers were adjusted to be 1 mm at central grooves and 1.5 mm at cusp tips.<sup>(17)</sup>

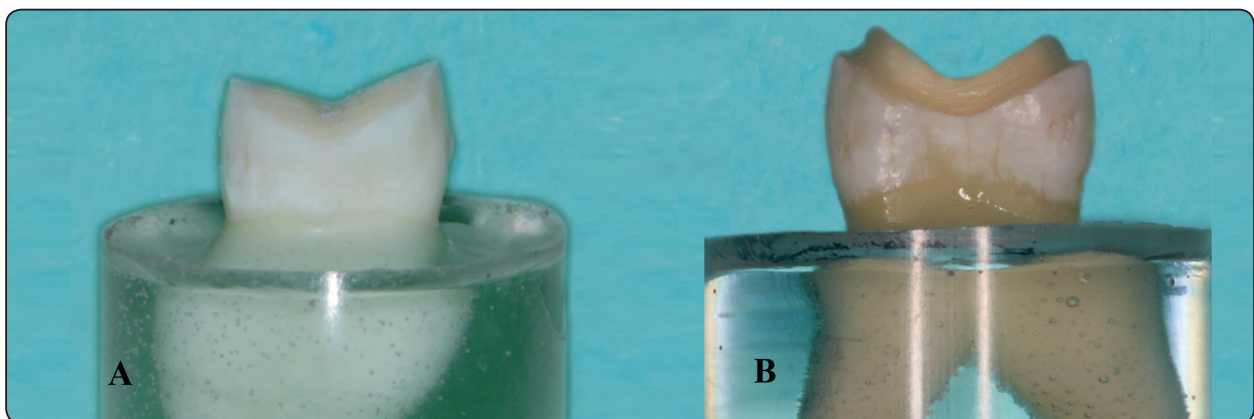


Fig. (1): A) Butt joint design preparation. B) Modified occlusal veneer design preparation.

All lithium disilicate and polymer-infiltrated ceramic network occlusal veneer restorations were milled out of IPS e.max CAD blocks and Vita Enamic blocks respectively using a wet 5-axis milling machine (Imes-Core GmbH, Germany, CORTEC 250 i ).

After finishing and polishing, all occlusal veneers were checked for adaptation and thickness.

All IPS e.max CAD occlusal veneer restorations were crystallized at 840 °C for 20 min to reach their maximum strength and esthetics using Programat P500 Ivoclar Vivadent furnace.

### Cementation

The fitting surfaces of Lithium disilicate (IPS e.max CAD) restorations were conditioned with 9% hydrofluoric acid (Ultradent, USA) for 20 sec, while the fitting surfaces of polymer-infiltrated ceramic network (Vita Enamic) restorations were conditioned for 60 sec.<sup>(3)</sup> The conditioned surfaces were rinsed with water spray properly and air-dried gently. Then, silane coupling agent (Ultradent, USA) was applied with a microbrush on the fitting surfaces for 60 sec and then air dried for 5 sec.<sup>(3)</sup>

Prepared teeth were conditioned with 37% phosphoric acid (Travlin etching gel, Technodont) for 30 sec. Then, the etched surfaces were rinsed carefully with water spray for 10 sec and air-dried gently to avoid desiccation.<sup>(18)</sup> The bonding agent (Prime & bond, Dentsply) was applied with a

microbrush and agitated for 20 sec, dried gently for 5 sec and light cured for 10 sec.

Dual cured adhesive resin cement (Calibra Ceram, Dentsply, USA) was applied to the fitting surfaces of the restorations using syringe tip.

Each occlusal veneer restoration was seated on its corresponding tooth with finger pressure and excess cement was removed by an explorer after light curing by (Foshan J, China) light cure apparatus for 5 sec (tack curing).

Each specimen was inserted into specially designed cementation device to guarantee obtaining a uniform cement layer thickness for all specimens by subjecting all specimens to the same seating load 1Kg during cementation procedures.<sup>(18)</sup> All surfaces were light cured for 20 sec per side by wave length 420-480 nm and light intensity 850-1200 w/cm<sup>2</sup>.<sup>(17)</sup>

### Fracture resistance test

All specimens were loaded vertically till fracture in a universal testing machine (Model 3345, Instron, USA). An indenter with 6mm diameter was used to apply compressive load perpendicular to specimens along their long axis with a crosshead speed of 1mm/min till fracture.<sup>(5)</sup> To distribute loads evenly, a 0.5 mm tin foil was positioned between the indenter and the specimen. The load needed for fracture of each specimen was recorded automatically in Newtons (N) using a special software.<sup>(18)</sup>



Fig. (2): Specimens after cementation.

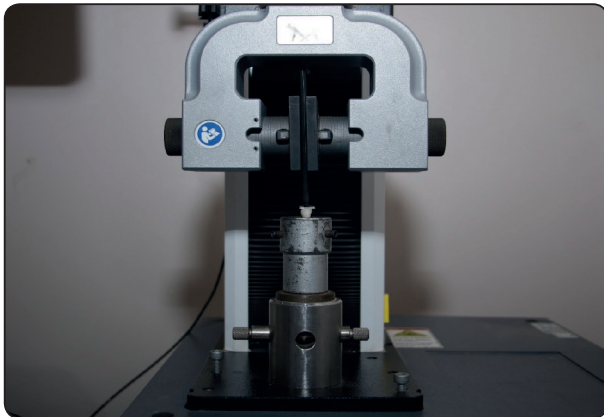


Fig. (3): Specimen within the universal testing machine.

**RESULTS**

Data were collected, tabulated then analyzed using the computer program SPSS (Statistical package for social science) version 26.0.

**Effect of the preparation design on the fracture resistance of occlusal veneers:**

Student’s test (Unpaired) was used for comparing between fracture resistance of occlusal veneers preparation designs within each ceramic material and it was found that regardless of the ceramic material, modified occlusal veneer preparation design showed non-significant difference compared to butt joint preparation design. ( Table 1)

TABLE (1): Student’s test (Unpaired) used for comparing between fracture resistance of occlusal veneers preparation designs within each ceramic material

	Group B	Group M	t	P
Material L	819.65±233.95	803.43±246.06	0.135	0.89
Material H	773.42±152.02	949.68±370.72	-1.244	0.23

Data expressed as mean±SD SD: standard deviation

P: Probability \*: significance p <0.05

Test used: Student’s t-test (Unpaired)

**Effect of ceramic material on the fracture resistance of occlusal veneers**

Student t-test (Unpaired) was used for comparing between fracture resistance of occlusal veneer ceramic materials within each preparation design and it was found that regardless of the preparation design, hybrid ceramic occlusal veneers showed non-significant difference from lithium disilicate occlusal veneers. (Table 2)

TABLE (2): Student t-test (Unpaired) used for comparing between fracture resistance of occlusal veneer ceramic materials within each preparation design

	Material L	Material H	t	P
Group B	819.65±233.95	773.42±152.02	0.45	0.65
Group M	803.43±246.06	949.68±370.72	0.40	0.37

P: Probability \*: Significance < 0.05

According to Two-way ANOVA test that was used for detecting the effect of each variable and the interaction between them, it was found that the preparation design, the ceramic material and the interaction between both of them had a statistically non-significant difference on fracture resistance of occlusal veneers. (Table 3)

TABLE (3): Two-way ANOVA results that represent the effect of different variables on fracture resistance of occlusal veneers

Source of variations	Type III Sum of Squares	df	Mean Square	F	P
Designs	51223.203	1	51223.203	0.743	0.396
Materials	20005.500	1	20005.500	0.290	0.594
Designs * Materials	74092.289	1	74092.289	1.075	0.309

P: Probability \*: significance p <0.05

### Fracture mode

The fractured specimens showed fracture mode within Mode I, II and V, but the majority of fractured specimens were within mode I and II. Most of Lithium disilicate occlusal veneer fractured specimens were within mode (I) whereas most of polymer-infiltrated ceramic network fractured specimens were within mode (II).

The mode of fracture was categorized according to Burke's classification into the following<sup>(2)</sup>:

Mode I: Crack or fracture in the restoration only.

Mode II: Fracture in the restoration involving a small part of tooth structure.

Mode V: Catastrophic fracture of the tooth and the restoration.

### DISCUSSION

The purpose of this in vitro study was to investigate the effect of using two different preparation designs and materials on fracture resistance of occlusal veneer restorations.

It was hypothesized that both the preparation design and the type of material would affect occlusal veneers fracture resistance.

According to the results of our study: preparation design and type of material had non-significant effect on fracture resistance of occlusal veneers, so the hypothesis was rejected.

In our study, natural teeth were chosen over epoxy resin dies because of their strength and bonding ability that represented better clinical situation.<sup>(19)</sup> Digital caliper was used to make sure that all selected teeth had comparable dimensions to eliminate potential differences.<sup>(20)</sup> Then all teeth were stored in saline to preserve them till use as saline protected them from drying out and becoming brittle.<sup>(16)</sup>

Lithium disilicate (IPS e.max CAD) was chosen in our study because of its superior mechanical

properties, good bonding characteristics, long-term clinical acceptability and favorable esthetics.<sup>(20)</sup>

Polymer-infiltrated ceramic network (Vita Enamic) was chosen in our study as it was a material that combined the advantages of ceramics and resins, so it was an easily milled and repaired material with high damage tolerance.<sup>(14)</sup>

The decision of using the two preparation designs (butt joint and modified occlusal veneer design) was to investigate the effect of increasing the surface area of adhesion and marginal preparation on the fracture resistance of occlusal veneers.

For standardization of teeth preparation, heavy body index and depth grooves were used as a guide during occlusal reduction and a dental surveyor was used to standardize the circumferential finish line preparation.<sup>(17)</sup>

For standardization of occlusal veneer restorations, CAD/CAM technology was used to standardize the thickness and the anatomy of the restorations and to avoid laboratory errors.<sup>(21)</sup>

Adhesive resin cement was chosen in our study as it was found that all ceramic restorations cemented using adhesive resin cements had greater fracture resistance than those cemented using traditional cements.<sup>(22)</sup>

Moreover, in our study we used total etch technique because it was reported that the use of total-etch technique enhanced the bond strength up to 28 MPa within enamel and 13-20 MPa within dentin that lead to improving the fracture resistance.<sup>(23, 24)</sup>

Fracture resistance test was chosen in our study as it played a crucial role in determining the longevity of the restorations.<sup>(21)</sup>

Regarding the effect of the preparation design on fracture resistance of occlusal veneers in our study, the type of the preparation design had non-significant effect and that might be because the point of

loading during fracture resistance test was centralized on specimens away from the finish line.<sup>(25)</sup>

Our results agreed with Abdelhameed et al. (2018)<sup>(5)</sup> and Emam Z and Aleem N. (2020)<sup>(7)</sup> who found that there was no effect of the preparation design on occlusal veneers fracture resistance .

Regarding the effect of the materials on fracture resistance of occlusal veneers in our study, it was non-significant. This could be attributed to that polymer-infiltrated ceramic network had higher bond strength to resin-based adhesive materials than lithium disilicate, so its bond strength increased its resistance to fracture and compensated for its lower flexural strength.<sup>(26, 27)</sup>

These results agreed with Al-Akhali et al. (2018)<sup>(28)</sup>, Ioannidis et al. (2019)<sup>(3)</sup> Gurpınar et al. (2020)<sup>(29)</sup> and Zamzam et al. (2021)<sup>(30)</sup> who found that lithium disilicate occlusal veneers had non-significantly different fracture resistance from polymer-infiltrated ceramic network occlusal veneers.

On contrast, our results disagreed with Al-Akhali et al. (2017)<sup>(18)</sup> ,Andrade et al. (2018)<sup>(31)</sup>, Rabeae et al. (2020)<sup>(32)</sup> and Albelasy et al. (2021)<sup>(33)</sup> who found that lithium disilicate occlusal veneers showed significantly higher fracture resistance than those made of polymer-infiltrated ceramic network and this could be attributed to that lithium disilicate had higher mechanical properties than polymer-infiltrated ceramic network.<sup>(27)</sup>

Also, the results of our study disagreed with Maeder et al. (2019)<sup>(34)</sup> and Emam Z and Aleem N. (2020)<sup>(7)</sup> who found that polymer-infiltrated ceramic network occlusal veneers had significantly higher fracture resistance than lithium disilicate occlusal veneers and this could be attributed to that they subjected the specimens to cyclic fatigue loading as polymer-infiltrated ceramic network demonstrated more favourable resistance to fatigue due to the presence of polymers in its microstructure that enhanced its resistance to crack propagation.<sup>(35)</sup>

The limitation of this study was that it was a laboratory study which lacked simulating the oral environmental conditions through thermocycling and cyclic loading.

## CONCLUSIONS

- 1- Lithium disilicate and polymer-infiltrated ceramic network occlusal veneers had comparable fracture resistance that exceeded the reported range of human masticatory forces, so they can be used as a conservative alternative to full coverage crowns for treatment of severely worn dentition.
- 2- There were no effect of the preparation designs and the material types on fracture resistance of occlusal veneers.
- 3- Fracture mode of the specimens proved that polymer-infiltrated ceramic network had greater bond strength to resin-based adhesive materials than lithium disilicate.

## Recommendations

- 1- Further investigations should be conducted including different ceramic materials and new preparation designs.
- 2- The use of artificial chewing simulator to simulate clinical condition effects on fracture resistance of occlusal veneers.
- 3- In vivo studies should be done to evaluate occlusal veneers as the assessment of their clinical performance would be the best judgment for their success and longevity.

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