Original Article

Fracture Resistance Of Cad/Cam Occlusal Veneers Constructed From Glass And Hybrid Ceramics With Two Preparation Designs “An In -Vitro Study”

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DOI: 10.47750/pnr.2023.14.02.50

Abstract

Statement of Problem. The information regarding the influence of the type of ceramic material and the preparation design on the fracture resistance of occlusal veneers for treatment of patients with severe wear is still insufficient

Purpose. Purpose of the study was to analyze the fracture resistance and the failure mode of lithium disilicate and hybrid ceramic materials with various preparation designs to be used as bonded occlusal veneers.

Material and Methods.

Two mandibular first molars of a typodont were used for the master preparations; one for the conventional planar design and the second for the modified design, the preparations were duplicated into twenty epoxy resin dies over which the occlusal veneers were adhesively cemented. Each group of epoxy resin dies was subdivided randomly into two equal subgroups according to the ceramic material to be tested; lithium disilicate "Rosetta " and the hybrid ceramic "VITA ENAMIC". Then the fracture resistance and failure mode of occlusal veneers were evaluated.

Results:

The results showed that the type of ceramic material and the preparation design had no statistically significant effect on the fracture resistance of occlusal veneers.

Conclusions: All the tested CAD/CAM materials showed fracture loads above the recommended minimum fracture strength for posterior restorations with different preparation designs.

Keywords: Occlusal veneer preparation designs, Planar preparation, Circumferential Preparation, Intracoroanal extension preparation, Fatigue resistance, 3D Finite Element Analysis.

Introduction:

Occlusal tooth structure loss is caused by a variety of factors, including parafunctional habits, bruxism, caries, gastric acid erosion, diet, and traumatic injuries. The treatment of such problems is difficult because undamaged hard dental tissues must be removed in order for conventional restorative materials to be accepted**.** [1]

The usual therapy for this severely worn dentition included many full-coverage restorations, elective tooth devitalization, and crown lengthening. However, in the interest of limiting the number of adjunctive procedures required for dental reconstruction, the trend toward conservatism in tooth preparation and restoration design is strongly re-emerging**.** [2]Therefore, a less invasive non-retentive preparation design should be possible when adhesive luting techniques are used**.** [3]

As a result, novel approaches for providing minimally invasive biomimetic dentistry, such as indirect composite restoration, occlusal veneers, or partial crowns to rebuild erosive defects, have been developed. [(1)]

The strongest glass-ceramic has long been thought to be lithium disilicate ceramic. Because it is made up of a high number of interconnecting, needle-like lithium disilicate crystals in a glass matrix, this type of ceramic offers greater mechanical qualities than other glass-based ceramics**.**[4]

In the dental clinic, there was only one manufacturer of lithium disilicate ceramic blocks for CAD/CAM restoration (IvoclarVivadent, Schaan, Liechtenstein). Another lithium disilicate ceramic block was recently released (Rosetta SM, Hass, Gangneung, Korea**).** [(5)]

VITA ENAMIC is a commercial hybrid ceramic with a dual-network structure that consists of a fine-structure feldspar ceramic network (86%byweight) that is reinforced by a methacrylate polymer network, with both networks fully integrated. [(6)]

Fractures of ceramic are mentioned in the literature as the most frequent reason of failure of all ceramic restorations. [(7,8)]

Materials and Methods:

Two mandibular first molars of a Typodont model (NISSIN Dental Model, Kyoto Japan) were chosen to perform the master preparations; one for the conventional planar occlusal veneer design, and the second for the modified occlusal veneer design.

A standard set of diamond rotary instruments (Komet dental. Gebr. BrasselerGmbH&Co.KG) suitable for different ceramic preparations was for both the conventional and the modified occlusal veneer preparations. For Conventional Planar design(Group I) a1mm reduction from cusps and central fossa was done then the occlusal surface was prepared following the anatomy and reduced by 1.5 mm at the cusp tip and 1 mm at the fossa without opening the proximal contact. **Figure (1)** An addition silicone putty index (elite HD +, Zhermack) was used to check the uniformity and the amount of reduction. For Modified Occlusal Veneer Design a one mm circumferential finish line was prepared. Preparation of the occlusal surface was carried out as in the conventional design (Group I), then tapered round end was used to prepare the axial walls to 1.5 mm height to create 1 mm circumferential chamfer finish line. **Figure (2)** The thickness of the finish line was confirmed by using graduated periodontal probe and the addition silicone index was used to confirm the occlusal reduction. and the two types of preparation were done by a single operator Finishing and smoothening of two types of preparations were executed using extra fine grit diamond stone, 3M Sof-Lex polishing spiral wheels (3M, USA) and eve Diacomp plus occluflex (EVE, Germany). Each Typodont tooth was duplicated to form 20 replicas fabricated from Epoxy resin material (10 dies for each design) using silicon molds that were made from duplicating addition silicon material. **Figure (3)** Each group was randomly subdivided into two equal subdivisions, five per each, according to the ceramic material to be tested.

Figure (1): The Conventional Preparation Design

Figure (2): The Modified preparation Design.

A) Conventional Design **B) Modified Design**

Figure (3): Epoxy resin models

Optical impressions of the two different occlusal veneer preparations on the typodont teeth and the arch were scanned as well using CEREC Prime scan then the captured picture was saved in the preparation catalogue of the software. For the purpose of standardization, the restoration parameters were fixed for all the restorations of two tested groups n = 20 with the radial spacer thickness set at 30 µm, the minimal radial thickness occlusal at 1000 µm. After adjusting all the preparation parameters of the two tested occlusal veneer designs, the selected ceramic blocks were then ready to start the milling process by the MCXL milling machine.

The selected ceramic blocks were inserted into the spindle of the milling chamber of the CEREC (MC XL) milling machine**.** After milling was completed, the ten ceramic veneers of each group were tried for their initial fitting on the original preparations in typodont teeth and on their corresponding epoxy resin dies using a magnifying lens and good lighting condition before crystallization/glaze firing of Rosetta®SM and finishing and polishing of VITA ENAMIC® veneers following the manufacturer's instructions.

The (Rosetta®SM) occlusal veneers were fired at the recommended firing parameters for the crystallization/glazing program in Programat P510 furnace (Ivoclar-Vivadent, Schaan, Liechtenstein). While, the (VITA ENAMIC®) veneers were finished and polished using the special kit supplied by the manufacturer. The occlusal veneers were pre-polished with the pink polishers using 8,000 RPM with light pressure, and high-gloss polish was accomplished with the grey polishers using 5,000 RPM with light pressure.

The adhesive bonding of the two types of tested ceramics was undertaken following the instruction manual of each one. The only difference was that the internal surface of Rosetta®SM occlusal veneers was etched with Bisco's Porcelain Etch (9% HF acid ceramic etching gel) for 20 seconds, while the internal surface of VITA ENAMIC® occlusal veneers was etched for 60 seconds the all restorations rinsed with water and dried with oil-free, moisture-free air. The intaglio surface of the twenty veneers were then salinized using BISCO's porcelain primer for 60s and air dried for 5 seconds.

All the occlusal veneers were then bonded to their corresponding epoxy dies using self-adhesive dual cure resin cement (The Duo-Link Universal TM adhesive resin) following the manufacturer's instructions, while being seated under constant load of 3Kg for 20 seconds using a customized cementing device. The adhesively bonded samples were then exposed to thermocycling program consisted of 5000 thermal cycles (5°C and 55°C in water) with a dwell time of 25 seconds in a computer-controlled thermocycler (Robota automated thermal cycle; BILGE, Turkey). All samples were individually and vertically mounted in the lower fixed compartment of computer-controlled materials testing machine (Model 3345; Instron Industrial products, Norwwod, MA, USA) with a load cell of 5 KN and data were recorded using computer software (Instron (R) Bluehill Lite Software). The maximum load to fracture for each sample was automatically recorded in Newton (N) using computer software. Results were recorded, tabulated and statistically analyzed. All the fractured specimens were inspected visually and under magnification to characterize the mode of failure of each specimen.

Results:

Statistical analysis was performed with SPSS 20®1, Graph Pad Prism®1, and Microsoft Excel 20163. All data were explored for normality by using Shapiro Wilk Normality test and presented as means and standard deviation (SD) values. In quantitative data comparison between more than 4 different groups (quantitative data) was performed by using One-Way ANOVA test followed by Tukey`s Post Hoc test for multiple comparisons. Comparison between 2 groups was performed by using independent t- test. The significance level was set at $P \leq 0.05$.

Also, comparison between all groups was performed by using One Way ANOVA test which revealed insignificant difference between them as $P > 0.05$as presented in Figure (4)

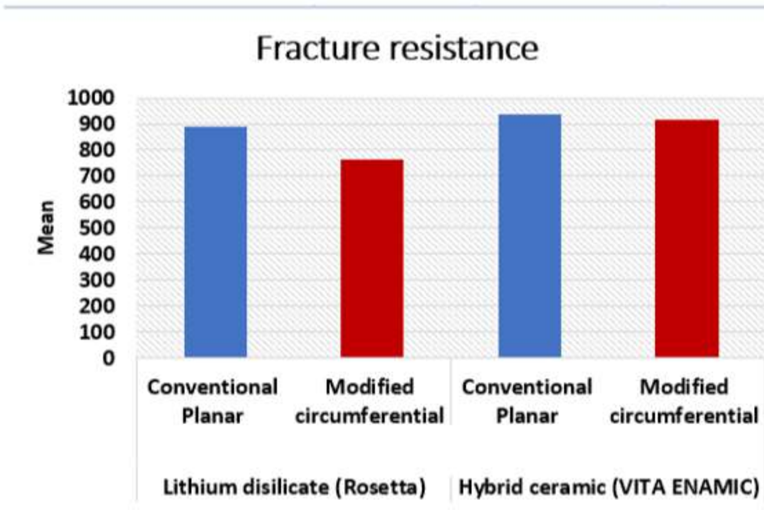

Figure (4) ;Fracture resistance of the two tested materials in the two preparation designs

Effect of ceramic type on fracture resistance regardless of preparation design . Fig (5):

Regardless of design, Vita Enamic (hyprid ceramic) showed statistically insignificant higher mean fracture resistance than Rosetta®SM (Glass ceramic).

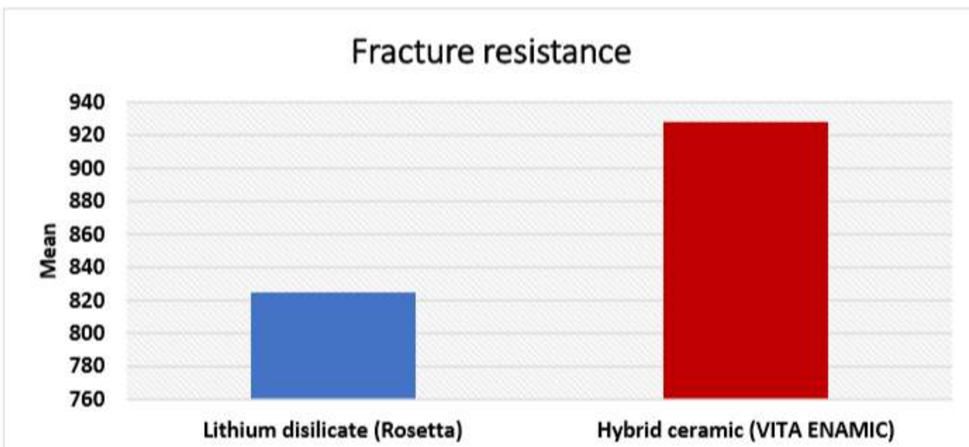

Figure (5): Fracture resistance of Lithium disilicate (Rosetta) and Hybrid ceramic (VITA ENAMIC) (Sub group A, and Sub group B)

Effect of different preparation design on fracture resistance regardless of ceramic type , Fig (6):

Regardless of ceramic type, Vita Enamic (hyprid ceramic) showed statistically insignificant higher mean fracture resistance than Rosetta®SM (Glass ceramic).

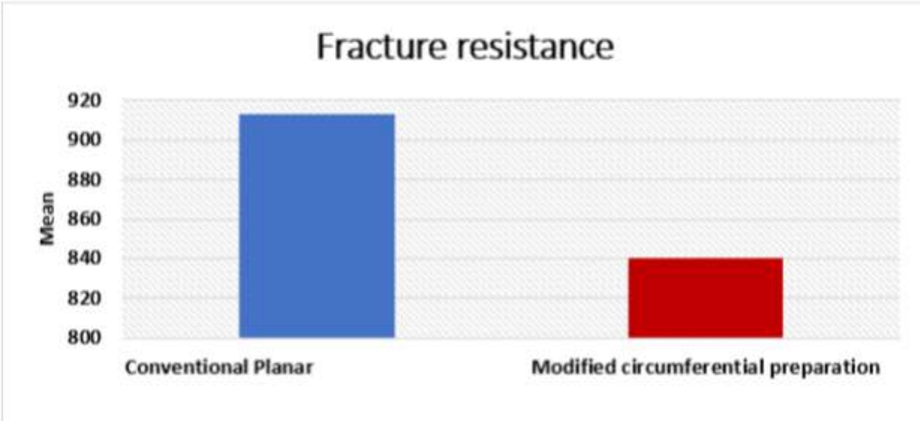

Figure (6): Fracture resistance of the two preparation designs; Conventional planar and Modified Design (Group I, and Group II)

Failure Mode Analysis

After fracture resistance test, all specimens in the tested groups were viewed using a USB digital-microscope (U500x Digital Microscope), magnification X35, and the images were captured and transferred to a computer equipped with the Image-tool software17 to determine the failure mode of each specimen to be categorized according to the extent of the propagated cracks and fractures. The samples were classified in to three modes as observed by Digital microscope and the Scanning Electron Microscope where Mode I represents the mild failure pattern, ceramic failure with intact epoxy resin die(repairable), and Type II represents the moderate failure pattern,fracture of occlusal veneer with coronal portion of the die without extension to the cervical line of die(repairable), and Mode III showing a catastrophic failure of occlusal veneer and epoxy resin die. Figure (7), Figure (8)

The comparison between different groups regarding mode of failure showed that 100% of specimens made from (VITA ENAMIC) in both designs showed a repairable mode of failure (Mode 1), while 40% of specimens made of (Rosetta) with a conventional design and 17% of specimens with a modified design showed a repairable mode of failure (Mode 1). 40% of specimens made from (Rosetta) with a conventional design and 50% of specimens with a modified design showed a repairable mode of failure (Mode 2), and 20% of specimens made from (Rosetta) with a conventional design and 33%of specimens made from (Rosetta) with a modified design showed catastrophic failure (Mode 3).

Figure (7): Descriptive digital microscopic images showing the three detected different failure patterns :(A) Mode I, (B) Mode II and (C) Mode III.

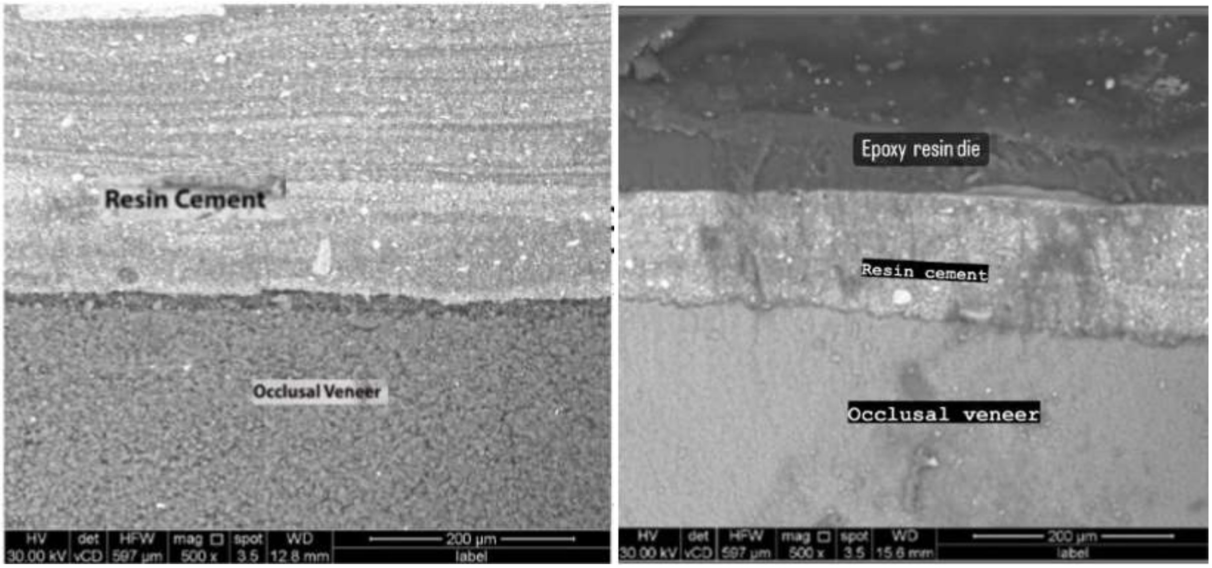

Figure (8): SEM images (500X) showing different failure patterns left Mode I or Mode II (repairable), right Mode III (non-repairable failure)

DISCUSSION

There are a lot of problems with treating patients with advanced wear, such as the need to remove more healthy tooth structure to fix worn teeth and the possibility of wear compensation by tooth eruption to maintain the vertical dimension, where the amount of reduction required varies widely for different restorations, which has suggested the development of a restorative treatment concept that is minimally invasive. [9,10]

Conventional full crowns can be made in cases of worn dentition. However, in order to achieve a functional and aesthetic restoration, full-coverage crowns typically necessitate the removal of additional tooth structure. [9,11]

Occlusal veneers are thin overlay restorations with a non-retentive design. As a conservative way to treat occlusal abrasion or erosion, they are becoming more and more popular right now. [8,10]

Two preparation designs were selected in the present investigation namely; a conventional design where only the occlusal surface was included in the preparation; and a modified design, where an occlusal preparation of one mm depth was carried on together with 1mm marginal chamfer finish line. [12,13]

Planar occlusal veneer preparation was selected because it is less invasive treatment option for severely worn teeth as confirmed in studies. [14] However, it was believed that finish line allows positive seat and provides more support than the conventional planar design. [2]

Furthermore, the diameter of cutting tools of the CAD CAM milling devices requires at least 0.3 mm thickness of the restoration margin for accurate milling, a condition which may be difficult in the conventional planar design. [15]

CAD/CAM technology was chosen because of its ability to control the thickness and anatomy of restorations during the fabrication process, as well as its high aesthetic qualities. It also allowed for the standardization of the interior fit of the restorations as well as the mechanical qualities of the restorative materials. [16]

Two materials were chosen to conduct this study, including lithium disilicate glass ceramic and hybrid ceramic materials. lithium disilicate glass ceramic material can be successfully employed for posterior occlusal veneers in severe worn-out dentition cases, as it offers many advantages, like high fracture resistance allowing minimum restoration thickness (1–1.5 mm), low abrasive potential, high bond strength and excellent biocompatibility (Le Fu et al., 2020). VITA ENAMIC was chosen since this innovative hybrid material ensures a unique balance between strength and elasticity and has a high rate of masticatory force absorption. It also has very good milling properties and reduces tool wear. [6]

Fracture resistance was chosen in this study as it is among the critical factors that determine the success and longevity of a restoration. [17]

Several factors influence the fracture resistance of all-ceramic restorations, including the ceramic material's microstructure and fatigue, fabrication technique, final preparation design, thickness of all ceramic restorations, and luting method. [18,19]

In order to simulate the clinical conditions to which the restorations will be subjected, thermal cycling was carried out; a 5000-cycle programmed from 5°C to 55°C, which represents one year of clinical service, as mentioned in the recommended literature. [20 ,21]

In the current research, a typodont tooth resembling mandibular first molar was used as it represents the most common tooth in the dental arch restored with posterior occlusal veneer. Selection of artificial acrylic tooth was done to overcome any variations in natural teeth which might affect the design and thickness of the restoration. [23]

As the fracture resistance of all-ceramic restorations depends on the modulus of elasticity of the chosen abutment material [22], epoxy resin dies were suggested to be used as a die material for this purpose as they react elastically as natural dentin does. Therefore, they were chosen in the present investigation. [24,2]

For the purpose of standardization in this research, an effort was made to standardize preparations with the use of depth cutters diamond stones, and putty index before preparation, and the preparation was done by a single operator.

The CEREC Prime scan was used in the current study because it is the latest version of the CEREC scanners. It creates digital 3D images that are sharper and more detailed. It is also faster, more accurate, and easier to use, it is easy to achieve a full arch scan in under 45 seconds. [26]

The MXCL (4 axis) (CEREC MC XL, Sirona) was used in this study, which enables high speed, precision, large milling volume and outstanding versatility, so this expands the available range of clinical indications, including occlusal veneers. Additionally, it is a chair side milling unit and the occlusal veneer is one of the most common chair side restorations, so as to stimulate the clinical scenarios. [26]

During the design phase of occlusal veneers, the radial spacer was set at 30 µm, in agreement with **Farag et al** [17] who compared the fracture resistance of ceramic veneers with digital die spacer settings at 30 µm, 90 µm, and 150 µm and they found that the fracture resistance decreased as cement thickness increased, but there was no significant difference.

Force recorder found that the biting forces in the molar region ranged between 597 N to 847 N for young women and men respectively. [25]

In the present research, the mean fracture loads for the two occlusal veneer designs and the two ceramic materials were beyond the range of realistic occlusal forces in the posterior region. So, it's safe to say that all of the samples that were tested can handle the maximum intraoral posterior masticatory forces. The null hypothesis of the present investigation, namely, that there would be no difference in fracture resistance between the two designs or ceric materials tested, was accepted according to the statistical analysis of the obtained data, which revealed that there was no significant difference in fracture resistance between the two tested occlusal veneer designs as well as the two tested ceramic materials.

Regarding the effect of ceramic material, the occlusal veneer made from VITA ENAMIC showed higher mean fracture resistance (928.25 ± 129.64) compared to Rosetta (825.14 ± 220.43), but no statistically significant difference was found between them.

This can be explained by the synergistic behavior achieved between the polymer matrix of VITA ENAMIC, the adhesive system and resin cement used to have high resemblance in compositions, leading to superb bonding capacity to the underlying substrate, and is finally reflected by increased fracture resistance values. [23]

These results were also in agreement with **Abou Bakr et al[24]** who compared the fracture resistance of occlusal veneers made from Lava Ultimate restorative and IPS e.max CAD and found comparable results between them .Also, these findings were in agreement with a study in which the fracture resistance of occlusal veneers made from lithium di-silicate glass ceramics, hybrid all ceramic material, and nano ceramic reinforced resin composite were compared, and their results were as follows: Nano ceramic reinforced resin composite had the highest mean fracture resistance, hybrid ceramic showed a lower mean value, and lithium disilicate showed the lowest mean fracture resistance.[1,28]

On the other hand, the current results are in disagreement with those of a study that investigated the mechanical properties and fatigue behavior of some contemporary used dental ceramics, which found that the maximum load at fracture of hybrid ceramic material was significantly lower than that of lithium di-silicate. [19]

Regarding the effect of preparation design in the present investigation, the conventional planar preparation without finish line was (912.96 ± 203.48), while in the modified circumferential preparation with 1 mm chamfer finish line was (840.42 ± 164.51) but there was no statistically significant difference between them, which means that there was no effect of the preparation design on fracture resistance of the two used materials.

These results were in agreement with those of another study that employed two preparation designs and evaluated their effects on fatigue resistance of lithium disilicate glass ceramic and found that preparation designs had no significant effect on the tested mechanical property.

Also, these findings are in agreement with a study that investigated the effect of two different preparation designs on marginal fit and fracture resistance of CAD/CAM fabricated occlusal veneers. Whereas preparation design had no statistically significant effect on mean fracture resistance regardless of the material used. [1]

On the other hand, these findings disagree with **(Halim)[2]** study that compared the fracture resistance and failure mode of a newly proposed occlusal veneer design constructed of zirconia reinforced lithium silicate and hybrid ceramic materials with the conventional design restored with the same tested materials. Regarding the effect of the occlusal veneer designs, the modified design showed a higher mean statistically significant fracture resistance value than the conventional design. [8]

Regarding the mode of failure, the comparison between different groups demonstrated that 100% of specimens made from hybrid ceramic (VITA ENAMIC) in both groups (Group 1 and Group II) showed a repairable mode of failure (Mode 1).These findings could be attributed to low modulus of elasticity of hybrid ceramic (VITA ENAMIC) and higher resiliency with more load absorption during the process of loading and the presence of polymers in the microstructure of hybrid ceramics which made them more resistant to crack propagation than their conventional ceramic counterparts.[27,1]

This study has some limitations. The fracture load applied to the restoration during testing was vertical and static which does not imitate clinical loading situations having vertical and lateral components due to the limitations of the loading device. Also, resin dies were used instead of natural teeth for the purpose of standardization. However, they are not identical to dentine in terms of microstructure, bonding mechanism, and mechanical strength. Finally, clinical research is needed to determine the impact of more complex oral environmental conditions on the mechanical properties of different ceramic restorations, despite the difficulty of standardization and controlling the variables.

Conclusions

Both the conventional and modified occlusal veneer designs presented fracture resistance mean values with the two tested materials (VITA ENAMIC &Rosetta®SM) that exceed the range of clinical acceptability. 2- Regarding the effect of preparation design in the present investigation, the conventional planar preparation without finish line was superior to modified circumferential preparation with 1 mm chamfer finish line but there was no statistically significant difference between the mean fracture resistances of the two preparation designs 3- CAD/CAM hybrid ceramic (VITA ENAMIC) occlusal veneers were superior to lithium disilicate (Rosetta®SM) in terms of fracture resistance, but there was no statistically significant difference. 4- Hybrid ceramic (VITA ENAMIC) occlusal veneer can be the first choice in cases with increased occlusal stresses as it showed a more favorable failure mode than lithium disilicate (Rosetta).

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