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EVALUATION OF MARGINAL ACCURACY & FRACTURE RESISTANCE OF DIFFERENT CAD/CAM FABRICATED MONOLITHIC VONLAYS

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ABSTRACT

Objective: This research aimed to evaluate & compare marginal accuracy & fracture resistance of three different CAD/CAM fabricated monolithic vonlays.

Materials & Methods: A typodont maxillary second premolar was prepared to receive thirty CAD/CAM monolithic vonlays. Three groups of different materials (n=10) were constructed. Group(CD): Zirconia-reinforced lithium silicate (Celtra Duo). Group(VE):Hybrid ceramic(Vita Enamic). Group(BC): Reinforced composite (BRILLIANT Crios). Measurement of vertical marginal gap distance was performed at 16 predetermined points without cementation. Fracture resistance test was conducted for cemented vonlays on their respective epoxy dies.

Results: Difference in vertical marginal gap of the three groups was not statistically significant, while fracture resistance showed a significant difference between the three groups.

Conclusions: The three tested materials offered vonlays with comparable & clinically acceptable marginal gaps. Concerning the fracture resistance, only Brilliant Crios & Celtra Duo vonlays were proven to have acceptable fracture resistance in premolar area, while Vita Enamic is not recommended as a vonlay in the same area.

KEY WORDS: Marginal accuracy, fracture resistance, vonlay, Celtra Duo, Vita Enamic, BRILLIANT Crios.

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INTRODUCTION

Recently, the trend in dentistry has been focused on "minimally invasive concept", which allows preservation of tooth structure whenever possible. This will permit shifting from full veneer restorations to less invasive choices which are currently accessible due to the newly introduced adhesive systems & high strength ceramics that leads to gaining the same effectiveness as full coverage restoration. Vonlay is one of these novel concepts, as it is a hybrid of an onlay with an extended buccal veneer for use in bicuspid region instead of full coverage restorations. (1)

To enhance restorations' durability, it is crucial to obtain restorations with ideal marginal fit for best prognosis, otherwise microleakage, cement dissolution, recurrent caries, plaque deposition, discoloration & consequently restoration failure might result. (2)

Fracture, being the major mechanical complication of ceramic restorations encouraged the introduction of esthetic CAD/CAM highly homogenous materials with exceptional mechanical properties in comparison to laboratory-processed restorations & permitted fabrication of monolithic restorations. CAD/CAM materials are classified according to the presence of special constituents in their microstructure: polycrystalline ceramics, glass-matrix ceramics & resin-matrix ceramics. (3,4)

A unique member of the glass ceramic has been introduced into the market, zirconia-reinforced lithium silicate (ZLS). It contains (10 wt%) zirconia to acquire the favourable properties of both lithium silicate &zirconia ceramics, so accomplishing high mechanical, & esthetic properties, which allow the chairside fabrication of a monolithic posterior all-ceramic restoration. (5)

Eagerness to develop CAD/ CAM esthetic materials, advanced technology succeeded in an integration between ceramics & composites' favourable properties, that led to the production of resilient ceramics in the form of either nanoceramics (resin nanoceramics) as well as hybrid ceramics (Polymer infiltrated ceramics network (PICN). (6-8)

Composite CAD/CAM blocks were presented to improve the indirect composite restorations through favourable loading & distribution of filler, as well as higher degree of conversion. Brilliant Crios is one of these blocks that contains (71 wt %) inorganic filler,(9,10) Furthermore, hybrid ceramics (Vita Enamic) comprises a fine structure feldspathic ceramic network (86 wt%), infiltrated by (14 wt%) polymer.(11)Launching both materials aims to obtain a material greatly mimicking the dentin's modulus of elasticity, facilitating both milling as well as intra-oral repairing. (3)

Due to vast introduction of new products, the practitioner might be exposed to hard decisions while selecting a CAD/CAM material for a specific restorative indication. Taking into consideration that choosing materials for posterior restorations is highly dependent on their mechanical properties.(3) This study targeted to compare & evaluate marginal accuracy & fracture resistance of monolithic vonlays constructed from three different CAD/CAM materials (Zirconia-reinforced lithium silicate, Hybrid ceramic, & Reinforced composite).

The null hypothesis was that there will be no difference in the marginal accuracy & fracture resistance of the three vonlay groups.

MATERIALS AND METHODS

Samples grouping:

In this study (30) monolithic vonlays were fabricated & distributed equally according to the material used into three groups (n:10) as follows:

Group (CD): Zirconia-reinforced lithium silicate (Celtra Duo) (Dentsply Sirona, USA).

Group (VE): Hybrid ceramic (Vita Enamic) (VITA Zahnfabrik, Germany).

Group (BC): Reinforced composite (BRILLIANT Crios) (COLTENE, Switzerland).

Tooth preparation

In the current study, a typodont maxillary second premolar (Frasaco GmbH, Tettnang, Germany) was selected to represent a patient's tooth. It was inserted in an acrylic resin mold & prepared according to the regular dimensions of vonlay preparation guidelines. Functional cusp was occlusally reduced by 2mm, while the non-functional cusp by 1.5 mm. The depth of the occlusal box from cusp tip to pulpal floor was 2 mm & depth from pulpal floor to gingival seat was 1 mm, with 12° angle of divergency (confirmed by the aid of a dental surveyor). The preparation blends with an isthmus about 1/3 the bucco-lingual width following ceramic MOD inlay preparation. A labial extension was performed to end with an 0.5 mm chamfer finish line. Rounding & finishing all margins & line angles was done. [12-15]

Digital Workflow & Monolithic Vonlays Fabrication

Digital Scanning

Digital scanning of the prepared tooth by a 3D dental scanner (Identica hybrid blue scanner, MEDIT T 300, Seoul, Korea) was done. The scan was sent directly to the lab being converted to an STL format.

Designing & Milling of Vonlays

Vonlay design was accomplished using CAD software (Exocad Dental CAD, v.2016, GmbH, Darmstadt, Germany). Fig. (1) having a cement space set at 60 μm [15] & restoration dimensions were illustrated & adjusted on the design window. Data were transported to the computer connected 5-axis milling machine (vhf CAM 5-S1; vhf camfacture AG, Ammerbuch, Germany) following manufacturer instructions of each material.

After milling, vonlays were polished according to their manufacturer instructions (Polishing Set clinical, VITA Zahnfabrik, Germany). Then, they were ultrasonically cleaned (Skymen/OEM/ODM, JP-031, Guangdong, China) using distilled water for 5 minutes.

Marginal gap measurements

Uncemented vonlays were assessed for vertical marginal gap distance between each vonlay & the prepared premolar. [13] A holding jig was used to secure the vonlays on the prepared tooth, then vertical marginal gap was measured. [14]

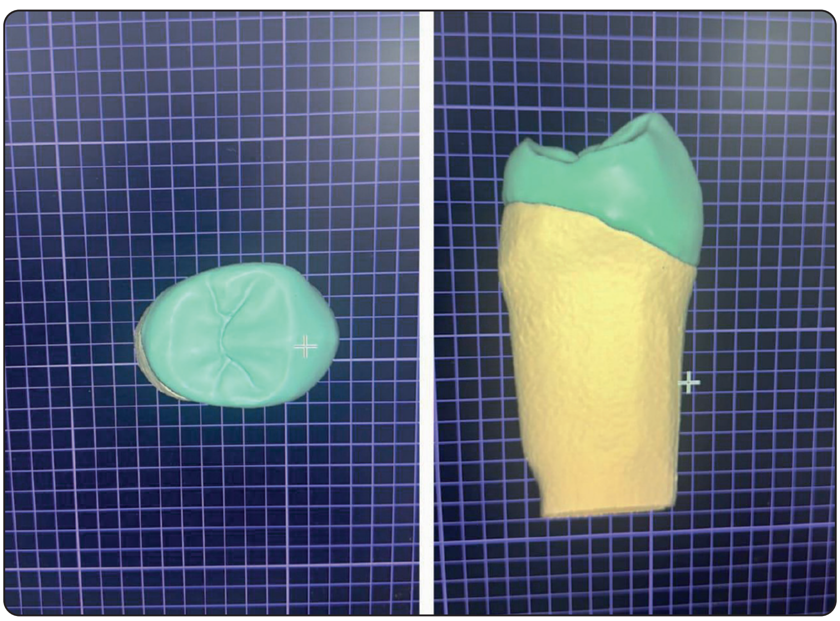

Fig. (1) Digital Designing of Vonlay

A digital microscope with a built-in camera (Scope Capture Digital Microscope, Guangdong, China) was used at 90X magnification. The captured images were transferred to a compatible personal computer equipped with the Image-Tool software (Vertical Image J 1.43U, National Institute of Health, USA) to evaluate the gap width. Morphometric measurements were performed for the taken shots, 16 points per vonlay (4 equidistant points for each surface). Data obtained was collected, tabulated & statistically analyzed.

Duplication of the prepared tooth & construction of epoxy dies

Polyvinyl siloxane addition silicon (Express XT;3M ESPE, USA) was used for duplication of the prepared tooth for construction of 30 epoxy resin dies. The epoxy resin base & catalyst (Kemapoxy 150, CMB International, Egypt) were mixed according to manufacturer instructions. The mix was poured under vibration to eliminate any entrapment of air & then left for curing at room temperature for 24 hours. The epoxy dies were designed with a large base to support & hold each die during cementation while testing fracture resistance testing.

Cementation procedure

The fitting surfaces of groups (CD) & (VE) vonlays were etched according to the manufacturer instructions, with 5% HF gel (VITA Ceramics Etch, Zahnfabrik, Bad Säckingen, Germany), group (CD) for 30 seconds, while group (VE) for 60 seconds, then they were rinsed with water & ultrasonically cleaned for 5 minutes to remove debris & salts. While the fitting surface of (BC) vonlays were sandblasted with 50 μm Al_2O_3 powder, then ultrasonically cleaned for 5 minutes. The fitting surfaces of all groups were then painted with a single coating of silane coupling agent (Bisco, USA) using small brushes, which was left for 60 seconds to react before being air dried with oil-free air spray. Then according to the manufacturer instructions, application of a single coat of a light-cured dental adhesive (All-Bond Universal, Bisco, USA) onto the internal surfaces of vonlays was done. Surfaces were then air-dried & light cured for 10 seconds.

All vonlays were cemented on their respective epoxy dies using self- adhesive resin cements (RelyX Unicem, 3M ESPE, USA), a 2 kg load was used for 5 min to standardize the cement thickness in all samples using custom-made seating device.[15] Then, excess cement was removed using a microbrush. Margins were spot cured for 2-3 seconds/surface using a light curing unit. After 1 hour bench setting, all samples were stored in distilled water at room temperature for 24 hours before fracture testing. [16]

Fracture resistance testing

All samples were individually tested for fracture resistance using a computer-controlled testing machine with 5 kN load cell. An audible crack followed by a sudden drop in resistance level, represented the load of failure. Data were recorded using computer software (Bluehill Lite Software Instron® Instruments).

Statistical Analysis

Statistical analysis was performed with IBM® SPSS® Statistics Version 20 for Windows. For comparing more than two groups in non-related samples. Data was manipulated using one-way ANOVA followed by Tukey post hoc test., with significance at $P \leq 0.05$. Collected data was explored for normality using Kolmogorov-Smirnov & Shapiro-Wilk tests.

RESULTS

Marginal gap distance results:

Marginal gap results showed no statistically significant difference between the three groups at (p=0.194). Group (BC) recorded the highest marginal gap, followed by (VE), then (CD). Table 1, Fig.2

Fracture resistance results:

There was a statistically significant difference between (BC), (VE) & (CD) groups where (p<0.001). Group (BC) recorded the highest fracture resistance, followed by (CD) then (VE). Table 2, Fig. 3

TABLE (1) Descriptive statistics for marginal gap values of tested groups.

Variables	Marginal gap distance (µm)	
	Mean	SD
Brilliant Crios	67.87 [a]	1.71
Vita-Enamic	67.16 [a]	1.51
Celtra Duo	65.65 [a]	2.24
p-value	**0.194ns**	

Same superscript letters refer to non-significance ns; non-significant(p>0.05)

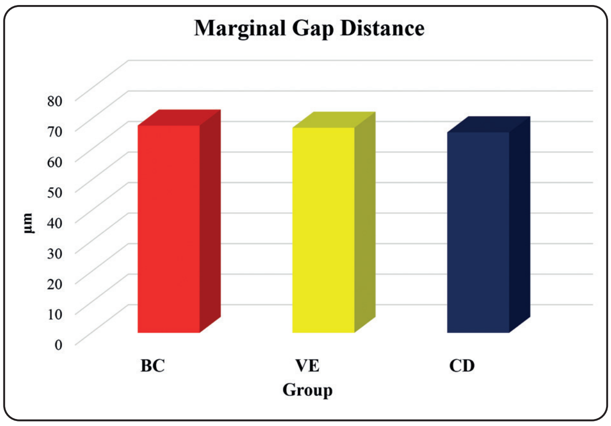

Fig. (2) Bar chart representing marginal gap distance for different groups.

TABLE (2) Descriptive statistics for fracture resistance values of tested groups.

Variables	Fracture resistance (N)	
	Mean	SD
Brilliant Crios	677.48 [a]	3.98
Vita-Enamic	412.11 [c]	9.39
Celtra Duo	614.58 [b]	4.71
p-value	**<0.001***	

Different superscript letters indicate significant difference, *; significant (p<0.05)

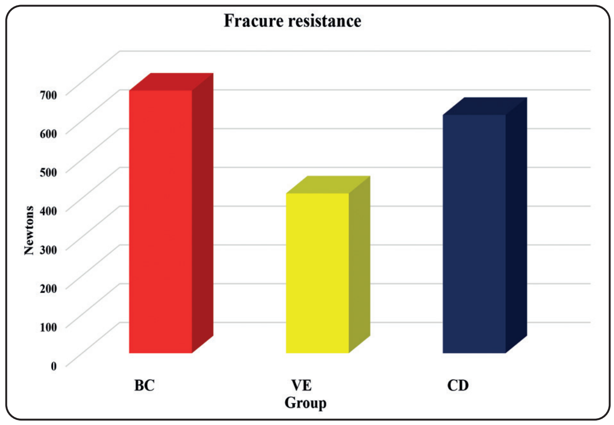

Fig. (3) Bar chart representing fracture resistance for different groups.

DISCUSSION

Vonlay was chosen as an alternative to full coverage restorations as it combines the benefit of onlay associated with that of laminate veneer requiring minimal preparation. [15] Standardized preparation dimensions were guaranteed by duplicating the prepared tooth & the construction of epoxy resin dies. The epoxy used has modulus of elasticity that is near that of tooth structure to mimic the clinical situation. [17,18]

Being fabricated under the most favourable standardized conditions, CAD/CAM blocks have the privilege of being homogenous with optimal mechanical properties. In this study, three materials were used; two ceramic materials with different microstructures; a zirconia-reinforced lithium silicate (Cetlra Duo), hybrid ceramic (Vita Enamic) & composite (BRILLIANT Crios) with moderate filler loading. It is described as a ceramic-like material. [19]

Direct measurement of marginal gap was performed using a digital microscope, as it was presented as the most reliable, commonly used test. [20,21] The marginal gaps of the uncemented vonlays were evaluated on the prepared tooth for standardization & to exclude the effect of cement. [22,23]Results revealed no statistically significant difference, where CD group showed the best marginal adaptation followed by VE then BC. The recorded marginal gap of all groups lies within the clinically acceptable range, as records were below 120µm.[24,25] The current results agree with **Taha et al** (2018).[26]

These results contradict with **El Mekawi** (2020),[27] who recorded that Vita Enamic showed significantly better marginal accuracy than Celtra Duo. Many researchers, [10, 28- 30] claimed that machinable hybrid CAD/CAM materials are more compatible with milling machine & exhibit better marginal quality. This contradiction might be attributed to the effect of milling tools size & condition, as well as the type & microstructure of the materials affecting the performance of a CAD/CAM system in terms of marginal accuracy.[27, 28]

Fracture is the main cause of ceramic failure. The fracture resistance results revealed significant difference between the three examined groups, where the group (BC) showed the highest fracture resistance followed by (CD), then (VE). All the recorded fracture strength results except for (VE) were in the range of the normal biting forces in the premolar area which was proven to be 450N.[31]

These results might be attributed to the difference in chemical composition & microstructure of the three groups as well as their mechanical properties. Dental ceramics' brittleness & stiffness affect their performance & durability by rendering them liable to fail due to crack propagation which might occur during function or milling.[10, 31]

Group (BC) recorded the highest fracture mean value which might be related to its dentine-like modulus of elasticity, allowing dentine-like shock absorption & plastic deformation, transmitting the applied loads to the underlying dentine rather than the vonlays. BRILLIANT Crios has a relatively high fracture toughness as the organic content absorbs the chewing forces.[3] This comes in accordance with **Jassim** & **Majeed** (2018),[6] who also attributed the increase in fracture strength of BRILLIANT Crios has to the creation of a high bond capacity between the adhesive bonding agent, resin cement & reinforced composite due to the similarity in chemical composition. Bonding agent monomers infiltrate the composite polymerized resin matrix resulting in chemical as well as mechanical bonding "interlooping".[32] This is combined with the creation of a monoblock due to the adhesive bonding between the reinforced composite & the tooth by a resin cement.[33] Celtra Duo lacks all these properties. Also, Vita Enamic recorded the lowest fracture resistance compared to the other two groups due to its relatively lower mechanical properties as microcracks are considered common in boundaries of the interconnected hybrid network due to varying ablation rates of polymer & ceramic during milling & finishing process.[34,35] Failure might arise from the polymer as the weakest point in the microstructure.[36] These findings line up with **Bilkhair et al** (2014)[37]**, Sieper et al**(2017),[38] & **Jassim** & **Majeed** (2018)[6]

In the current study, the null hypothesis is partially accepted as the material type did not significantly affect the marginal accuracy of vonlays, but significantly affected their fracture resistance.

CONCLUSIONS

Within the limitations of this study, it was concluded that:

- Vonlays with the 3 tested materials offer comparable & clinically acceptable marginal gaps.
- Concerning the fracture resistance, only BRILLIANT Crios & Celtra Duo vonlays were proven to have acceptable fracture resistance in premolar area, while Vita Enamic is not recommended as a vonlay in the same area.
- The chemical composition, microstructure, as well as mechanical properties should be considered when selecting a material for partial coverage restoration taking into consideration the maximum biting force in the selected area.

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