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MARGINAL ADAPTATION AND FRACTURE RESISTANCE OF VONLAYS RESTORING PREMOLARS USING DIFFERENT CERAMIC MATERIALS: AN IN-VITRO STUDY

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ABSTRACT

Purpose: To evaluate and compare marginal adaptation and fracture resistance of vonlays restoring premolars of three different ceramics.

Materials and methods: 30 3D printed resin dies of natural premolar no. 14 prepared for vonlay restoration. Three groups (n = 10) of vonlays were categorized according to ceramic material. Group I: Zirconia. Group II: Glass ceramic. Group III: Nanohybrid ceramic. Vertical marginal adaptation was measured on the natural premolar tooth without cementation using a digital microscope (90X). Then, it was measured after adhesion of vonlays over their respective dies. Vonlays were subjected to thermomechanical fatigue for aging. Universal testing machine used for measurement of the fracture resistance. Failure mode was examined visually and microscopically. Statistical analysis was done using One- way ANOVA, LSD, and Fisher's Exact test.

Results: No statistical significance recorded in the marginal gaps of the three groups. Notable variation in fracture resistance recorded among the three groups: zirconia had the highest mean value, followed by glass ceramics, then nanohybrid ceramic. Visual inspection of the failed sections revealed that, there were 80% class II fracture mode in group I, 70% class IV in group II, and 80% class IV in group III. Stereomicroscope images of all specimens showed mixed adhesive cohesive fracture mode.

Conclusion: The three tested materials offered clinically acceptable marginal gaps. Fracture resistance of vonlays shown to be significantly variant between tested materials, it was exceeded the limit of chewing force in the premolars. Vonlays offers a reliable and cautious restoration in the premolars.

KEYWORDS: Zircon, emax press, Grandio, Fracture resistance, marginal adaptation, vonlay

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INTRODUCTION

Recently, 'minimally invasive dentistry' considered the trend, because of advances in adhesive approach and equally effective strength with more invasive restorations. Furthermore, minimally invasive restorations achieve preservation of the tooth structure in comparison with full coverage restorations. (1)

Vonlay is one of the newly introduced conservative fixed restorations combine between veneer and onlay preparations. Vonlays can be used as a substitute for complete coverage fixed restorations in posterior region. (2)

Recent advancements in treatment techniques and the usage of sophisticated ceramics have been made possible by CAD/CAM. With CAD/CAM technology, milled restorations have a more homogeneous structure, higher accuracy, and shorter production times. (3)

Because of increased cement film display, unacceptably or poor marginal fits (wider than 120 μm) can worsen the restoration prognosis, (4) resulting in several complications; including discoloration, luting agent dissolution, decay, microleakage and plaque accumulation (5) so it is very important to fabricate restorations with optimum marginal fit to enhance restoration longevity. (6)

Fracture, being the major mechanical complication of ceramic restorations encouraged the introduction of esthetic CAD/CAM homogenous materials with exceptional mechanical properties in comparison to processing of restoration manually & permitted fabrication of monolithic restorations. (6,7)

All ceramics have a natural look compared to natural dentition due to absence of metal coping. Also, they have acceptable mechanical properties and wear resistance which serve to enable them to withstand occlusal forces and apply low abrasiveness on the opposed teeth. (8)

Bilayered and monolithic construction techniques were the two types of ceramic construction. Bilayered ceramics exhibit a poor link between the veneer and framework due to differences in the coefficient of thermal expansion and stress distribution. They are thus noting a significant rate of veneer delamination and chipping from the inner core. Monolithic ceramics were presented to overcome these previous problems of bilayered ceramics. Also, it eliminates residual stresses and lead to easier fabrication of restoration. (9)

CAD/CAM ceramics are classified according to the presence of special constituents in their microstructure: polycrystalline ceramics, glass-matrix ceramics and resin-matrix ceramics.

Yttria stabilized zirconia (YTZ) was investigated as a potential material for high strength restorations. The structure of YTZ is a polycrystalline ceramic with a finely grained crystalline structure that offers excellent strength and fracture toughness while exhibiting a low degree of translucency. While monolithic zirconia's microstructure has been suitable to improve their translucency. (10)

One of the ceramic materials which have excellent esthetic properties and acceptable compressive strength 448 MPa (±68 MPa) as a single restoration is lithium disilicate glass-ceramics.(11) Glass ceramics have different techniques for fabrication, such as CAD-CAM and heat pressing. Heat pressing became an effective technique for fabrication of glass ceramic restoration with excellent marginal fit, high flexural strength and decreased porosity. (12)

Ceramic materials expressed to be rigid and may cause excessive wear of the opposing dentition. Contrary, composite materials exhibited low abrasive effect combined with low mechanical and wear resistance properties. (13)

Polymer- based resin materials was developed to gain strength and color stability of dental ceramics and low abrasion of composite which is hybrid dental ceramics. (14)

Nanoceramics are composed of 76% ceramics and 24% resin materials. Nano-particles are sized between 0.6 and 1 μm and they embedded in resin matrix that enhances the material abrasion and fracture resistance. [15,16]

There were a few researches have been investigated marginal adaptation and the fracture resistance of polycrystalline, lithium disilicate and nanohybrid ceramics vonlays restoring premolars. So, this study targeted to evaluate and compare the marginal adaptation and fracture resistance of vonlays restoring premolars constructed from three different ceramic materials (zirconia, lithium disilicate and nanohybrid ceramics)

The null hypothesis of this study was that there was no difference in the marginal adaptation and the fracture resistance of the three vonlay groups.

MATERIALS AND METHODS

Ethical approval

The research gained approval from the Research Ethics Committee of the Faculty of Dentistry at Tanta University, with the reference number R-BIO-9-23-3060. The design and techniques of the current study were conducted in accordance with the research criteria established by the Research Ethics Committee of the Faculty of Dentistry at Tanta University.

Sample collection

A healthy, non-caries human first premolar (number 14), recently extracted for orthodontic procedures, was acquired from the maxillofacial surgery clinic at Tanta University's Faculty of Dentistry. The patient was informed of the goal of the study and gave consent to have his extracted tooth used in it, in accordance with the research ethics committee's standards on human research issued by Tanta University's Faculty of Dentistry.

Using a hand scaler, all soft deposits and calculus were eliminated from the tooth. With the aid of low-speed hand piece and pumice slurry and water, the tooth was completely cleaned and polished before being thoroughly rinsed with tap water. After that, the tooth was closely checked under a magnifying glass, to be free from caries on any surface, hypoplasia, evident cracks, or white spot lesions. The chosen tooth was kept in distilled water until needed and cleaned in a 0.5% chloramine T solution. The study was designed to prepare the tooth for vonlay restoration, then replicated into 30 3D printed resin dies for standardization of all specimens. [17]

Tooth preparation

In the current study, the selected tooth was embedded in an acrylic resin block so that the root is covered with 0.3mm layer of a molted dental wax material for simulation of periodontal ligament. It was embedded in a self-cure acrylic resin block up to 2 mm below the cement-enamel junction. It was prepared according to the regular dimensions of vonlay preparation guidelines. [18].

Vonlay preparation guidelines were as follow:

- Occlusal reduction (1.5 mm) for non-functional cusp and (2 mm) for functional cusp, using a tapered flat end diamond stone (TF-12, Mani, Germany).
- Using TF-12, the occlusal box was prepared to be 2 mm deep from the cusp tip to the pulpal floor and 1 mm deep from the pulpal floor to the gingival seat.
- 1 mm functional cusp ledge with tapered round end diamond stone (TR-13, Mani, Germany).
- Using a tapered round end diamond stone (TR-12), the preparation is extended to the labial surface and ends with a chamfer finish line (0.5mm).
- The margins and line angles were all finalized and rounded. [19] (Fig.1)

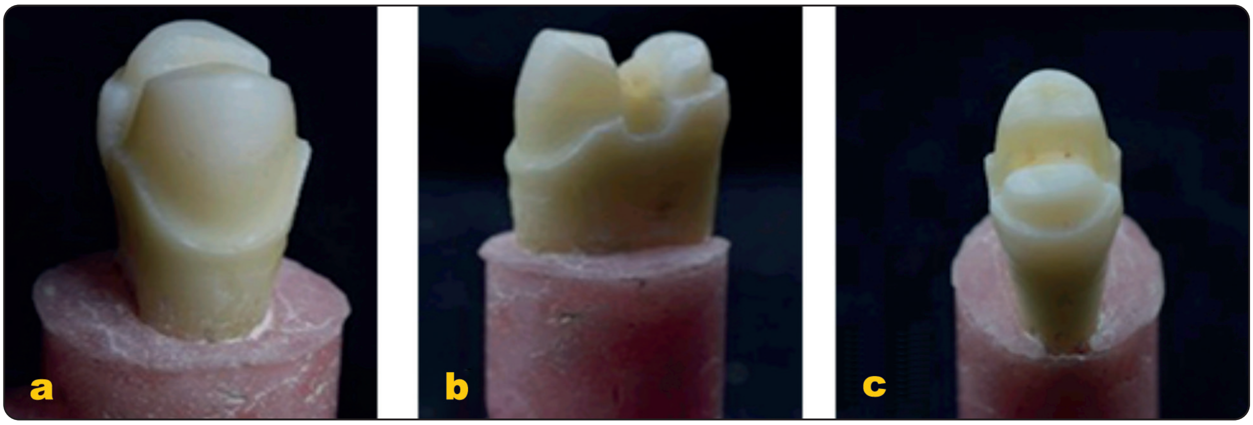

Fig. (1) a) Facial view, b) Proximal view. and c) Occlusal view of vonlay preparation

3D printed resin dies fabrication

Scanning of the prepared premolar (tooth number 14) was done using extraoral scanner (DOF freedom HD Scanner, South Korea). A STL file was generated and saved, followed by the creation of an 18 mm die stand designed to facilitate the printing of the dies without compromising the preparation margin. The STL file was exported to dental CAD software (Exocad Dental CAD, Exocad, Darmstadt, Germany) which control the setting of 3D Dental Model Printer (phrozen 3d printer, China) to produce identical 30 3D printed resin dies. [20]

Specimens grouping

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

Group I: Polycrystalline ceramic (zirconia, SHT Pre-shaded zirconia blank, XTCERA, Shenzhen, Guangdong, China) vonlays.

Group II: Glass ceramics (IPS E.max press) vonlays.

Group III: Nano hybrid ceramic CAD/CAM composite block (Grandio Disc, VOCO GmbH, Germany) vonlays.

Digital Workflow & Vonlays Fabrication

Designing & Milling of Vonlays

Designing of the vonlays for both zircon and Grandio

For group I (zircon), the vonlay was designed to be oversized by 2mm in all directions to avoid the effect of polymerization shrinkage after sintering process. For groups III (Grandio), the 3D virtual model displayed on the design window was trimmed then used to design the vonlays with the help of the dental CAD software (Exocad Dental CAD, Exocad) (**Fig. 2**) given tools in view and design window. Preparation margins was then drawn on the 3D virtual model as a closed green line to detect the marginal line by series of clicking around margin of the preparation. It was selected as 0.8 mm for the cement material application. Cements space was selected on all the surface of the preparation leaving 1 mm at the margins. After that, the insertion direction was defined which is the direction of restoration placement on the virtual model and should be adjusted with the mesial, distal, buccal, and lingual aspects of the model. Then, the virtual restoration was built by margin trimming according to the selected shape. [2]

Milling of zircon and Grandio vonlays

After the designing process, the milling preview window was activated (icam v5 smart) to start the

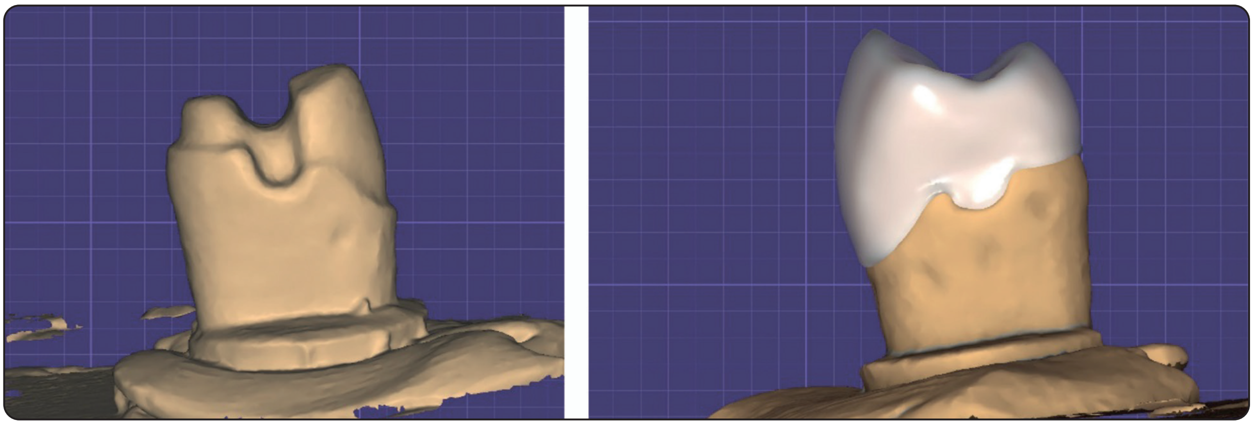

Fig. (2) Scanning of vonlay preparation and designing of restoration

milling process using CAM machine (imes-icore 350i milling machine).

For group I, the zircon blank was fixed successively in the spindle of the 5-axis milling machine (Redon hybrid, the dental experience, İstanbul, TURKEY) and tightened, together with the blank holder. Vonlay restorations was sintered in 6 phases as follow (phase 1 at 20-900ºC for 1.5 hours, phase 2 at 900ºC for 0.5 hours, phase 3 at 900-1530ºC for 3 hours, phase 4 at 1530ºC for 2 hours, phase 5 at 1530-800ºC for 1 hour and finally phase 6 in which temperature was 800ºC and the restorations left for natural cooling till 100ºC). Regarding group III, the Grandio disc was fixed successively in the spindle of the milling machine and tightened, together with the block holder. Then the excess material at the site of connection with blanks was removed using slow speed diamond disk. Then the restorations of each group were checked over corresponding master dies to check for accuracy. [20]

Fabrication of IPS e-max press vonlays using heat pressing technique

For group II, IPS e-max press vonlays were fabricated using heat pressed technique. The restorations are waxed, sprued, invested, and pressed in a manner somewhat similar to that in the lost wax technique. The investment was heated at 800ºC to eliminate the wax pattern. Then the ceramic ingot of the appropriate shade was inserted and refractory plunger in the investment ring and place the refractory cast in the special pressing furnace. After heating to 920ºC, the softened ceramic was pressed into the mold under vacuum. After pressing, the restoration recovered from the investment by airborne-particle abrasion and the sprue was sectioned and checked on the corresponding die. Finishing was done by layering technique with a glass containing some dispersed fluorapatite crystals. Polyvinyl siloxane index of the vonlay created from milling of the zircon vonlay was used for standardization of IPS e-max press restorations. [21]

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. [2]

Marginal gap measurements

Uncemented vonlays were assessed for vertical marginal gap distance between each vonlay & the prepared premolar. A stabilization device was utilized to hold the veneers in place on the tooth, after which the distance between the veneers and the adjacent tooth was measured. [22]

A digital microscope, which also had a built-in camera (Scope Capture Digital Microscope, Guangdong, China) was employed at a magnification of 90X. The images taken were then transferred to a device that was compatible with a personal computer and had the Image-Tool software installed (Vertical Image J 1.43U, National Institute of Health, USA) for the purpose of assessing the gap width. Measurements of the gap width were made on the images taken, with 12 points per veneer (3 points were placed at equal distances on each side of the veneer). (23)

Vonlay cementation procedures

Surface treatment of the restoration

The intaglio surface of zirconia vonlays (Group I) was treated with silica coating of the fitting surface of each restoration. On the other hand, the intaglio surface of E-max press vonlays (Group II) was treated with application of hydrofluoric acid 9.5% (BISCO-USA) on the fitting surface of each restoration for 30 sec then washed and air dried. Finally, silane coupling agent (BISCO-USA) was applied as two layers to the fitting surface of all restorations via mini brushes for 1 min then completely dried with air spray. (24,25)

For group III, the intaglio surface of Grandio vonlays was treated with air abrasion with (25–50 μm) aluminum oxide particles applied perpendicular to the surface using microblaster. Each surface was exposed to 10 s and pressure was set at 1.5–2 bar, the distance between the surface of the vonlays and the nozzle of the microblaster was set for 10 mm. (24)

Surface treatment of 3D printed resin dies

It was done using phosphoric acid etch 37% (IvoclarVivadent, Schaann, Liechtenstein) for 10 sec, then rinsed with air-water spray for 30 sec. Final step was done by applying a thin layer of the bond (All bond universal, Bisco, USA) to the die using mini brushes.

Specially designed cementing device was used, each vonlay was seated to its congruent die and a 5 kg load (50 N) was applied to the occlusal surface of each restoration. Then automix dual-cured cement (Duo-Link universal, Bisco, USA) was applied to the fitting surface of the vonlay and inserted into cavity of corresponding die by finger pressure for 2 min then a custom-made seating device with a 3 kg load was used for 5 min to standardize the cement thickness in all specimens. Cement was chemically cured, then the excess was removed using sharp probe. (26)

Thermo-mechanical fatigue

A four-station multimodal robotic chewing simulator, equipped with a thermo-cyclic protocol and servo- motor (ACH-09075DC-T, AD-TECH TECHNOLOGY CO., LTD., GERMANY), was created and utilized for the purpose of simulating thermo-mechanical aging in this research. Four chambers in this simulator are modeled to replicate both horizontal and vertical movements under thermodynamic circumstances. Each chamber has a lower section made of a Teflon housing that holds the samples, and an upper Jacob's chuck that holds a stylus antagonist made of hardened steel that is screw-secured. During thermal aging, a weight of 5 kg, or 49 N of chewing force, was applied to the samples, ranging from 5° C to 55° C. The simulation of thermo-mechanical aging was conducted over a period of 6 months, with 75,000 cycles applied to each specimen. (26)

Fracture resistance testing procedure

A computer-controlled materials universal testing equipment (Model 3345; Instron Industrial Products, Norwood, MA, USA) with a 5 KN loadcell was used to hold each sample separately. Computer software (Instron® Bluehill Lite Software) was used to acquire data. Screws were tightened to secure the specimens to the testing machine's lower fixed compartment. A metallic rod with a spherical tip (5 mm diameter) was used to apply load occlusally to the restorations at their cuspal inclinations during compressive fracture testing **(Fig. 3)**. This rod moved at a cross- head speed of 1 mm/min and was attached to the testing machine's upper movable compartment. An abrupt decline in the load resistance measurement recorded by the software, accompanied by an audible crack, indicated the fracture resistance of the load at which the material failure occurred. Newtons were used to record the load needed to fracture. (27)

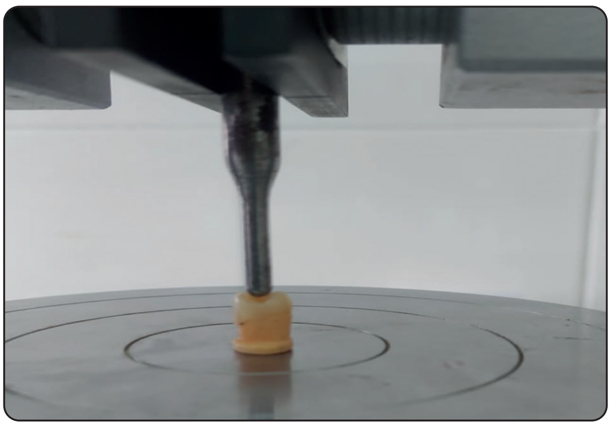

Fig. (3) Fracture resistance testing of vonlays on corresponding 3D printed die

Mode of failure examination

Visual examination

Examination of failure mode upon conducting fracture testing, the mode of failure underwent a visual examination and was categorized based on Burke's classification (1995) in the following order: (2)

Class I: Crown fracture or crack with minimal severity

Class II: The loss of less than half of the crown

Class III: Half of the crown was lost or displaced due to a crown fracture through the midline.

Class IV: The crown lost over half of its material

Class V: Serious crown or tooth fractures.

Stereomicroscopic Examination

Surface images were taken using stereomicroscope (Olympus model no. SZ11, Japan) with magnification of 30X. Three categories of failure modes were identified: cohesive, adhesive, and mixed adhesive cohesive. (28)

Statistical Analysis

For statistical analysis, IBM® SPSS® Statistics Version 20 for Windows was used. NY / Armonk: IBM Corp. By analyzing the distribution of the data and performing normality tests (Kolmogorov-Smirnov and Shapiro-Wilk tests), numerical data was screened for normality. The results on fracture resistance and marginal gaps had a normal, or parametric, distribution. The information was displayed as mean, standard deviation (SD), and mean values' 95% Confidence Interval (95% CI). One-way ANOVA was used to manipulate the data, and it was followed by an LSD test with significance set at $P \leq 0.05$. Frequencies and percentages representing the qualitative failure mode were shown. The two groups were compared using Fisher's Exact test. $P<0.05$ was set as the significant level.

RESULTS

Marginal gap distance results

Marginal gap results showed no statistically significant difference between the three groups at (p=0.254). Group (III) recorded the highest marginal gap, followed by group (II), then group (I). (Table 1)

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

Variables	Marginal gap distance (µm)	
	Mean	±SD
Group I (Zirconia)	85.54	1.36
Group II (IPS e-max press)	86.36	1.89
Group III (Grandio)	87.69	2.12
p-value	0.254 ns	

ns : non-significant

TABLE (2) Descriptive data of the tested groups' fracture resistance expressed in N

Groups	NO	Mean	±SD	Test of significance
Group I (Zirconia)	10	1776.711	168.92	F=105.6
Group II (IPS e-max press)	10	906.411	86.62	P<0.001*
Group III (Grandio)	10	609.8237	75.35	

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

Fracture resistance results:

The fracture resistance values in (N) for the three groups are presented in (Table 2), showing the mean and standard deviation. Among the groups, zirconia vonlay (Group I) had the highest mean fracture resistance value of 1776.711±168.92 N, followed by lithium disilicate vonlays (Group II) with a mean value of 906.411±86.62 N. On the other hand, nanohybrid ceramic vonlays (Group III) had the lowest mean fracture resistance value of 609.8237± 75.35 N. A one-way ANOVA test was conducted to compare the significance between the tested groups, revealing a highly significant difference ($p<0.001$). Table 3 displays statistically significant differences ($p<0.01$) between each pair of groups based on additional comparisons using the LSD test.

Failure mode results

Visual examination

In Group I, the analysis of failed zirconia vonlays revealed various types of fractures. Class II fractures, in which less than half of the restoration was broken, and the remaining portion was still attached to the 3D printed resin die, were seen in seven specimens. Class IV fractures were seen in two specimens, where the complete restoration broke into four pieces and was dislodged from the die. In the last specimen, the die was broken vertically into two segments, and the entire repair was displaced and fragmented into minute fragments, exhibiting a Class V fracture.

Moving on to Group II, the failed IPS e.max press vonlays exhibited different types of fractures as well. Three specimens had Class V fractures, which were defined as the restoration being totally displaced and breaking into four pieces, along with the breaking of the lingual cusp of the 3D printed resin die. In two specimens, there were Class IV fractures, meaning that portion of the restoration had split into two pieces, while the proximal section was still adhered to the die. Five specimens also had Class IV fractures, which meant the whole restoration falling apart and shattering into two sections and four microscopic fragments.

Lastly, in Group III, the failed Grandio vonlays also presented various types of fractures. Class IV fractures, in which the entire restoration was shifted and broken into two portions and three microscopic fragments, were seen in six specimens. Class IV fractures were seen in two specimens, one where the restoration's proximal portion was still held to the die and the other section was broken into two pieces. Finally, two specimens showed Class V fractures, in which the die was broken vertically into two segments and the entire restoration had moved and shattered into small chunks.

Stereomicroscopic examination

As seen in figure (4 a), the fractography revealed that surface cracks were the primary source of fractures in groups II and III. However, as seen in figure (4 b), group I displayed radial fissures, or internal surface cracks attributed to cementation. Also, specimens of all tested groups showed mixed adhesive cohesive failure mode.

TABLE (3). LSD test for comparison of fracture resistance between tested groups

Groups	(J) factor	Mean Difference (I-J)	Standard Error	Sig.
Group I	Group II	-312.3698*	90.632	0.000 (HS)
	Group III	716.9526*	90.632	0.000 (HS)
Group II	Group III	1369.3487*	90.632	0.000 (HS)

**** The mean difference is significant at the 0.05 level*** ***HS: Highly Significant***

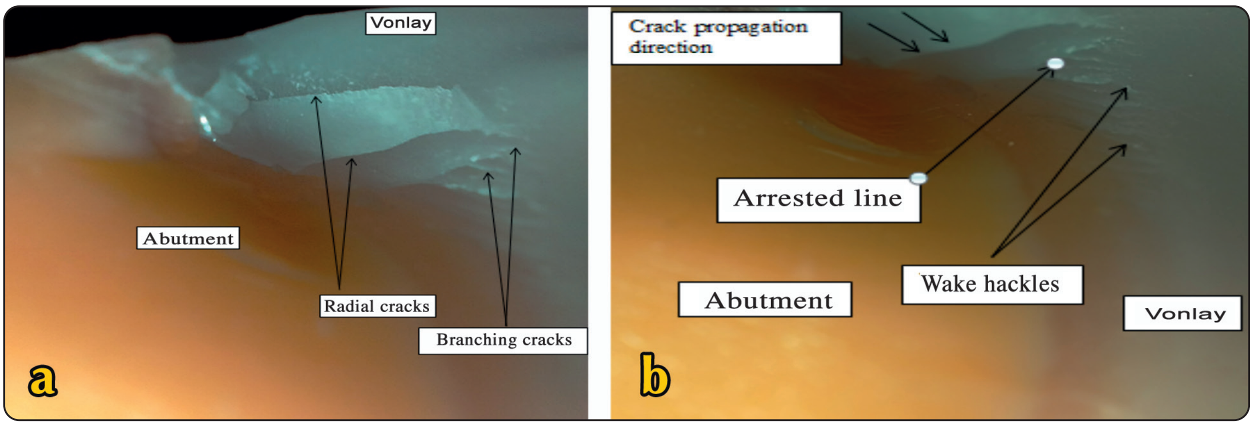

Fig. (4) Failure mode of a. IPS e-max press, b. Zirconia

DISCUSSION

This in vitro study aimed to assess and contrast the marginal adaption and fracture resistance of vonlays restoring premolars constructed from three different ceramic materials (zirconia, lithium disilicate and nanohybrid ceramics).

Typically, if a posterior tooth required a restoration, the ideal plan of treatment was thought to be a full coverage crown. Although, the issue with full coverage restorations, which involves a greater amount of sound tooth structure reduction, which can result in pulp involvement in some cases, has caused a shift toward the newly adopted minimally invasive dentistry, this means that the patient's tooth is restored with the least amount of tooth reduction possible. [29]

To achieve the goal of conservative reduction which entails not much tooth reduction and to increase mechanical resistance and retention forms, partial coverage restorations have been adopted by the dental community. [30]

A combined restoration known as "vonlay" is a recently introduced approach. It is a monolithic ceramic restoration that combines a complete onlay with an additional buccal veneer surface. 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. [2]

The adhesive concept has been used for indirect restorative procedures as partial coverage indirect restorations have a reduced surface area of bonding. It ensures a strong and long-lasting adhesion between the restoration and the dental structure, while also improving marginal integrity and restoration strength [31]

Resulting from their improved translucency, ceramic restorations are nowadays commonly used. They also resemble natural teeth as they have beneficial qualities, like their mechanical and physical characteristics; great periodontal tissues biocompatibility; lowered plaque formation when compared to metal ceramic. [32]

Intraoral imaging and manufacturing technology revolution and advances, lead to increase in the use of computer-aided design and manufacturing (CAD/CAM) materials in dentistry both lab side and chairside. This technique used to prepare indirect restorations from ceramic and composite blocks. [33]

CAD/CAM technology was used in this study to promote the idea of standardization in the manufacturing of all specimens, as it simplifies the design of fabricated restorations and milling procedures. [34]. In this study, three materials were used: polycrystalline ceramic (zirconia), lithium disilicate (IP emax press) and nanohybrid ceramic (Grandio Disc, VOCO).

YTZ overcomes low tensile strength of previous types of ceramics. Beside the YTZ good tissue tolerance and acceptable esthetic, it also possesses a transformational toughening characteristic that provides exceptional fracture toughness and flexural strength. [35]

Lithium disilicate glass-ceramics have been introduced in recent years to offer excellent aesthetics, high translucency, and optical properties for both anterior and posterior single restorations. Because of its long-term success and stability, the IPS Emax press was chosen for this study. Furthermore, because it is an etchable ceramic, it has excellent bonding qualities due to its composition that contains scattered crystals in a glassy matrix that is partially dissolved during the etching process, resulting in a surface roughness that improve bonding. [36]

Eagerness to develop CAD/ CAM esthetic materials, advanced technology succeeded in an integration between ceramics & composites' favorable properties, that led to the production of resilient ceramics in the form of nano hybrid ceramics. In this study, Grandio nano hybrid ceramic was selected. [37,38]

Natural teeth have a wide range of dimensions that could affect the restoration dimensions fabricated. Therefore, based on the inclusion criterion, The maxillary premolar was chosen as the single master die due to their unique anatomy together with special morphology that is more susceptible to fracture under occlusal loads and cusp deflection. [39]

It was prepared according to guidelines for ceramic vonlay preparation, with a functional cusp occlusal reduction of 2 mm and a non-functional cusp occlusal reduction of 1.5 mm, while keeping the inclination of the cusps to preserve the prepared tooth's occlusal morphology, which is essential for resistance form. The depth of the occlusal box was 2.0 mm, and a divergence angle of 12° was formed in direction of the occlusal surface to create diverging walls toward the occlusal surface, which aids in the creation of the restoration path of insertion. [40]

Proximal boxes were prepared with a third of the buccolingual width isthmus and 1.0 mm in depth from the gingival margin, where these boxes improve the restoration resistance form. [41]

Then, as a veneer preparation, the labial surface was also included in the preparation with a chamfer finish line "0.5 mm". Finally, the margins and line angles were polished and rounded to eliminate any stress concentration areas under the restoration. A chamfer finish line design was selected as the chamfer marginal design creates a round angle between the gingival and axial seats, the crown can be seated more accurately than with a 90° shoulder finish line. Shoulder marginal design results in an incomplete crown seat and a larger vertical marginal gap. Also, as noted by Al-Zubaidi Z A K and Al-Shamma A M W, 2015, it could be owing to the precision of digital scanner detection being affected by variances in preparation depth, which could be easily observed in deep chamfer marginal design. [42]

Standardized preparation dimensions were guaranteed by duplicating the prepared tooth & the construction of 3D printed resin dies. To replicate the clinical scenario, these dies have an elasticity modulus that is like that of tooth structure. (42) In this study, shrink-free 3D printed resin material was utilized to make resin dies, which were then used as a substitute for natural teeth to allow for the construction of identical restorations, which is critical for a realistic comparison of different groups. (43)

3D printed resin dies were employed in this investigation because they had greater dimensional accuracy, surface detail reproduction, transverse strength, and abrasion resistance than other materials. The modulus of elasticity of 3D printed resin is like that of dentin (12.9 GPa). There's also the ability to bond with luting agents like dentin.(44)

Scanning of the manufactured 3D printed resin dies was performed with an extraoral 3D dental scanner, after spraying the dies with Sironaoptispray to obtain an evenly reflecting surface, increasing the precision of the scan. The software was used to design the vonlay restoration, which resulted in restorations with dimensions that mimicked those of a natural premolar tooth, with a material occlusal thickness of 2 mm, ensuring the highest material strength according to manufacturer instructions.(45)

Cement space parameters were found to have a statistically significant impact on the marginal fit of CAD/CAM restorations. The die spacer parameter was set to 80 microns in this study. (46)

Redon hybrid milling machine (İstanbul, TURKEY), which provides a high level of accuracy, was used to mill the restorations. A study by Goujat et al., 2019 confirmed this, claiming that the axial internal and marginal fit produced by a 5-axis milling machine is superior to that of a 3-axis milling machine. (47)

Marginal adaptation of fixed restoration is very important, to assess the smallest number of gap measurements on margins of single restoration to have relevant gap analysis. A variety of methods have been employed to assess the marginal adaptation, such as radiograph microtomography, profilometry, light-bodied impression replication, cross-sectional views, direct microscope, and laser videography. These methods have allowed for the observation of both 2D and 3D images of the area between the restoration and the tooth/model die. (48,49).

In this study direct measurement of marginal gap was performed using a digital microscope, as it was presented as the most reliable, commonly used test. (50,51) The marginal gaps of the uncemented vonlays were evaluated on the prepared tooth for standardization & to exclude the effect of cement. (52,53). Results revealed no statistically significant difference, where groupI (Zirconia) showed the best marginal adaptation followed by group II (IPS e.max press) then group III (Grandio). The tested groups recorded marginal gaps fall within the range that is considered clinically acceptable, as records were below 120µm. (54,55).

The current results supported with **Taha et al, 2018**(56), who found that the difference between values of marginal gap of the tested materials which included lithium disilicate and zirconia reinforced lithium silicate endocrown restorations was statistically insignificant.

These results contradict with **El Mekawi, 2020,** (57) who recorded that Vita Enamic showed significantly better marginal accuracy than Celtra Duo. Many researchers, (58-61) claimed that materials with machinable hybrid CAD/CAM demonstrate superior marginal quality and are more compatible with milling machines. This contradiction might be attributed to the effect of milling tools size & condition, as well as the type & microstructure of the materials affecting CAD/CAM system performance in terms of marginal accuracy. (57, 59)

Thermomechanical fatigue was done to all specimens before fracture testing, to simulate the oral environment. In vitro investigations have shown that it can replicate an intimate simulation of the oral environment. (62)

Fracture resistance results revealed significant difference between the three examined groups, where the group I (zirconia) showed the highest fracture resistance followed by group II (IPS emax press), then group III (Gandio). The average fracture resistance of all groups' vonlays exceeded the maximal biting force in the premolar area (450N), despite the statistically significant differences in fracture resistance across the groups in this study. [63]

One explanation for the observed outcome is that the teeth were properly prepared to meet the specifications of the different materials utilized in this study, guaranteeing that there was enough material volume to bear the applied stress. However, this can be explained by using an adhesive cementation technique and applying the necessary surface treatment to each material in accordance with the manufacturer's recommendations. However, differences in mechanical characteristics, chemical structure, and microstructure are typically responsible for the notable fracture resistance variances between the groups of materials. 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.[58,63]

Fracture resistance demonstrated the highest mean value (1776.711± 168.92 N) when Zirconia vonlays (Group I) were compared to other vonlay materials. Zirconia's outstanding mechanical characteristics, including its high fracture toughness (7 MPa m1/2) and flexural strength (> 900 MPa), may be the cause of this. Zirconia's unique characteristics stem from its polycrystalline structure, in which atoms are firmly arranged into uniform crystalline arrays. This structure makes it more difficult for cracks to spread than the less dense and uneven network present in glasses. As a result, compared to ceramics made of glass, polycrystalline ceramics are typically stronger and more durable. [64,65]

Furthermore, the reason behind this phenomenon may be attributed to the transformation toughening mechanism, where a stress field located at the tip of a crack in motion initiates the conversion of tetragonal particles within to the monoclinic structure. This alteration in crystal phase results in a concentrated increase in volume, generating a compressive stress on the crack as it grows, ultimately halting its advancement. This mechanism is widely recognized as a key factor in the exceptional strength of zirconia, enabling it to withstand chipping and fracturing during use. [66]

The preceding findings align with research conducted by Preis et al. 67, Al-Joboury and Zakaria 68, Aboushelib and Elsafi 69, Zhang et al. 70, and Gungor and Nemli 71. These studies examined the fracture strength of all-ceramic crowns made of zirconia and various other materials, concluding that the zirconia-made crowns had the highest mean fracture resistance value.

The fracture resistance of vonlays made from glass ceramic materials (IPS e.max press) was found to be lower compared to zirconia vonlays. This difference was statistically significant and may be attributed to the glass ceramic materials having lower mechanical properties such as flexural strength, elastic moduli, and fracture toughness when compared to zirconia. However, this finding contradicts the results of Sieper et al. 45 and Gungor and Nemli 71, who found that crowns made from lithium disilicate had higher fracture strength than zirconia crowns when testing various all-ceramic materials.

In this study, the vonlays made from Grandio (group III) exhibited the lowest fracture resistance mean value (609.8237± 75.35 N). The outcome might be explained by the material's comparatively low mechanical characteristics, which include low fracture toughness (1.5 MPa m1/2) and low flexural strength (150–160 MPa). [72]

Additionally, the nano hybrid composition of Grandio, which is made up of networks of interconnecting ceramic and polymer, may also be involved. When grinding and polishing, this mixture results in different rates of removal for ceramic and polymer, potentially causing microcracks at the network boundaries. These microcracks are believed to contribute to the reduction in the material's mechanical properties. [73]

Additionally, failure in a nano hybrid material may originate from any vulnerable area within the microstructure, such as the polymer within polymer infiltrated ceramic. [74].

The outcome is consistent with the research of Bilkhair [75], which examined the fracture resistance of hybrid dental ceramic monolithic crowns vs lithium disilicate and feldspathic ceramic crowns. The results of the study showed that lithium disilicate crowns had a higher fracture resistance than crowns made of hybrid ceramics. The results are consistent with the study conducted by Sieper et al. 45, which examined the ability of hybrid dental ceramic, lithium disilicate, and zirconia-reinforced lithium silicate to withstand fractures in all-ceramic crowns. According to their research, hybrid dental ceramic-made all-ceramic crowns had the lowest fracture strengths. Upon visual inspection of the failed restoration components and analysis of stereomicroscope images, it was observed that within group I (Zircon), 8 specimens displayed class II fracture mode, 2 specimens displayed class IV, and 1 specimen displayed class V. For group II (IPS e.max press), 7 specimens exhibited class IV fracture mode, while 3 specimens exhibited class V. Eight specimens in group III (Grandio) exhibited class IV fracture mode, whereas two specimens showed class V fracture mode. A Class II fracture mode occurs when part of the crown breaks but the remainder of it is still attached to the tooth. Notably, 80% of Zircon vonlays demonstrated class II fracture mode based on Burke's classification, indicating a greater bonding compared to IPS e.max press and Grandio samples. The stereomicroscope images, which revealed that specimens in groups II and III failed adhesive-cohesively with tiny patches of cement on the surface of the failed restoration, further corroborated this conclusion. Conversly, specimens in group I failed adhesive-cohesively, with thick cement patches sticking to the cracked Zircon pieces' whole surface. These findings align with research of Elsayed, et al., 2020. [2]

The current study partially accepts the null hypothesis, indicating that the type of material had no significant impact on the marginal accuracy of vonlays. However, it did have a significant effect on their fracture resistance.

It is important to note that this in vitro study has certain limitations in terms of replicating real clinical conditions, such as the absence of periodontal ligament (PDL) simulation and oral environment representation. Additionally, the fracture resistance test was conducted on 3D printed resin dies rather than natural teeth, potentially lacking the full simulation of the clinical situation.

CONCLUSION

Within the parameters of this study, the following conclusions were drawn:

1. The study found that Vonlays made with the 3 tested materials demonstrated similar and clinically acceptable marginal gaps, making them safe for use on premolars.
2. The microstructure and chemical structure of the material utilized in the manufacture of monolithic CAD/CAM vonlays had a major impact on their fracture resistance.
3. Vonlays made from the materials tested in the study showed fracture resistance exceeding the limit of chewing force in the premolar region, indicating acceptable fracture resistance.
4. Preparation of Vonlays was shown to offer a reliable and conservative partial coverage restoration for premolars.

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