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INFLUENCE OF DIFFERENT VONLAY PREPARATION DESIGNS ON FRACTURE RESISTANCE

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ABSTRACT

Objectives: This research aimed to evaluate the influence of different vonlay preparation designs on fracture resistance in comparison with full coverage ceramic crown (as a control group)

Methods: Thirty fresh extracted upper four teeth were collected from the orthodontic clinic in Minia and Nahda university. Teeth were divided according to the design of vonlay preparation into three groups. In Group (A); the control group the teeth were prepared to receive full coverage lithium-disilicate crowns (n=10), Group (B); teeth were prepared to receive bonded partial restoration (vonlay) involving functional cusp (n=10), and Group (C); teeth were prepared to receive bonded partial restoration (vonlay) without involving functional cusp (n=10). Then, by using a universal testing machine, samples were loaded along the long axis of the teeth until they fractured, and the maximum breaking load was recorded, as well as fracture patterns were noted. All samples were exposed to thermo-mechanical aging before testing.

Results: preparation design of vonlay influences the fracture resistance of restoration.

INTRODUCTION

The recent treatment modality in dental practice is focused on the least invasive method, with undamaged tooth structures being preserved to the greatest degree. In addition, aesthetic dentistry has become an important phasis of dental practice. Restorative dental materials are now commonly used not only to restore damaged dental tissue but also to improve the shape and color of the teeth. [1]. New dental restoration, adhesive systems, and methods of fabrication have been introduced, and computer-aided manufacturing (CAM) technology can generate a more uniform dental restoration. In addition, CAD/CAM technology enables the replication of tooth anatomy and texture. [2]. Ceramic crown fracture resistance is influenced by tooth preparation and restoration design. The

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fracture strength of ceramic veneers can be affected by different tooth preparation designs, as well as one design of tooth preparation being superior to another. [3].

MATERIALS AND METHODS

Methods

I-Tooth selection and mold construction:

Freshly extracted sound, crack and caries-free upper premolars were collected from orthodontic out clinics; teeth with approximate dimensional similarity (mesiodistal diameter 8.5mm & buccolingual diameter 7 mm of the crown) were selected.

Periodontal ligament space achievements were done, and the teeth were immersed in molten paraffin wax up to 2.0 mm below the cementoenamel junction to obtain a thin layer of wax over the root of the teeth. Epoxy resin was mixed according to the manufacturer's instructions. Then the mixed epoxy was poured into a split cylindrical capper mold and ring; the root of each tooth was embedded in epoxy resin 2 mm below the cementoenamel junction and ensured covering the furcation area to mimic the position of the root in the bone. The modulus of elasticity of epoxy resin (12 GPa) was chosen to be close to that of human bone (18 GPa) [4]. The top of the copper mold was placed 3mm below the cementoenamel junction of the embedded tooth. the excess epoxy resin was removed with a metal carver before setting. After the complete set of epoxy resin, the split copper mold and ring were disassembled, and each epoxy block was removed. Then the tooth was pulled from its block and heated in warm water for 2 sec to remove the wax from the root surface and epoxy resin blocks 'epoxy resin sockets. For periodontal ligament simulation, a light viscosity addition silicone impression material was mixed by auto mixing tip according to the manufacturer's instruction and injected into the epoxy resin mold sockets. Then the teeth were repositioned into their respective sockets.

II-Tooth Preparation to Receive Different Restorations:

Prior to tooth preparation, extraoral scanning is done using (Medit i710) and a putty index of addition silicone material to analyze the preparation.

Tooth preparation to receive full coverage crown restoration.

All crown received samples (n=10) were prepared according to the regular dimension of all ceramic crown restoration preparation guidelines. The resultant prepared teeth had the following criteria: with 1mm deep chamfer finish line, 0.5 mm occlusal to the cementoenamel junction, 5mm occlusal-axial height, and 2mm occlusal reduction and 6-degree axial wall conversions. All these were done using a tapered stone with a rounded end. The occlusal preparation was performed following the anatomical contour [5].

Tooth preparation to receive vonlay restoration involving functional cusp

All vonlay received samples (n=10) was prepared according to the regular dimension of all ceramic vonlay restoration preparation guideline [6] with an occlusal box with ½ of the buccal-lingual distance and a depth of 2mm, 2mm butt joint occlusal reduction of the functional cuspid all these done using 271 carbide bur. The preparation design for a buccal veneer preparation was additionally extended to the labial surface with a chamfer reduction of 0.5 mm by preparing three 0.4 mm depth marks on the labial surface with the 834-diamond stone. Reduce the facial surface with the conical 852 diamond instrument. After the reduction of the facial surface, the proximal and occlusal surface all of the angels and the gingival margin will be rounded and finished using the fine grit Diamond 852F to create a perfectly smooth surface Jota Arkansas stone 649 is used.

Tooth preparation to receive vonlay restoration without involving functional cusp.

As the previous vonlay received sample preparation but without involving functional cusp (keeping palatal cusp intact).

III- Digital Optical Impression:

All the prepared teeth were digitalized by optical extraoral scanning using medit i710**.** The prepared tooth was sprayed with optical spray to enhance the quality of the digital impression. The precision of the scan ensures a complete digital model of the tooth has been created without any defects.

IV-Computer Aided Restoration Designing.

Designing of all restorations was done by Sirona in-lab 20.1 CAD software. The margin of all restorations was identified and drawn then the path of insertion was determined in the best position for insertion of restoration. The restoration parameter was adjusted by 60 micrometers for cement space, 800 micrometers for axial wall thickness of restoration and 2mm for the occlusal thickness of restoration, and 0.5 mm margin thickness. The dimension of the restoration was designed to adjust the anatomy, fissure depth, cusp heights, buccolingual, mesiodistal dimensions, and thickness of restoration.

V-Computer Aided Milling of the Restoration.

Milling of restorations was done using CEREC MCXL chairside milling machine using Ivoclar E-max CAD blocks.

-30 E-max CAD blocks with size C14 shade A2 HT were used to mill samples

Each block was tightened into the block holder part in the milling machine. Wet milling procedures were done that talk approximately 15 min per milling cycle.

VI-Crystallization & glaze.

All restorations were crystallized and glazed by using a CEREC speed fire furnace that talks approximately 30 min per firing cycle.

VII- Bonding Procedures.

Surface Treatment:

The surface treatment of all restorations was done according to manufacture instructions (same for all groups of restorations)

A- Applying hydrofluoric acid 9.5% on the fitting surface of each restoration for 30 sec then rinsed with air-water spray for 30 sec.

B- Complete drying of restoration using air spray

C- Applying a single layer of silane coupling agent to the fitting surface of all restorations using mini brushes for 1 min then completely drying the restorations with air spray.

D- Surface treatment of tooth structure:

- By using phosphoric acid etch 37% for 10 sec on dentin and 15 sec on enamel then rinsed with air-water spray for 30 sec.
- Applying a thin layer of the bond to the tooth by using mini brushes.

Cementation of Restorations:

a dual cure self-adhesive resin cement (totalcem, itina) was used by auto mixing tip according to the manufactures recommendations and applied to the fitting surface of restorations.

Using specifically constructed cementation equipment, each restoration was seated to its corresponding tooth and a load of 5 kg (50 N) was applied to the occlusal surface of each restoration.

Thermocycling:

1200 cycles were done, which equals three months. The automated thermocycling machine performed thermal cycles in distilled water with temperature extremes of 5°C and 55°C (transit time: 30 seconds, pause duration: 13 seconds). [7]

Testing Procedures.

Fracture resistance testing procedure:

After thermocycling, all samples were mounted individually on a universal testing machine (Model 3345; Instron Industrial Products, Norwood, MA, USA) with loadcell 5KN, and data were recorded and calculated by Instron® Bluehill Lite Software.

Screws were tightened to attach samples to the lowest fixed part of the testing equipment. A compressive mode of the load was applied occlusally with a metallic rod with a spherical tip (5.8 mm diameter) that touched the occlusal surface of the restorations at their cuspal inclinations during the fracture test. It is coupled to the testing machine's upper moveable compartment and moves at a crosshead speed of 1mm/min.

To promote proper stress distribution and reduce the transmission of local force peaks, a tin foil sheet was inserted between the occlusal surface and the metallic rod. An audible crack followed by a dramatic drop in the load resistance level recorded by the program indicated the load at which the material failure occurred. The amount of force required to fracture was measured in Newtons.

Fracture pattern analysis was performed using a scanning microscope to determine the mode of failure of deboned all samples.

The samples were categorized according to fracture patterns into the following descriptions:

- Type I: No fracture patterns (favorable failure)
- Type II: Fracture within restoration without tooth fracture (favorable failure)
- Type III: Fracture within restoration and tooth (non-favorable failure)
- Type IV: Fracture within the restoration, crown, and root (non-favorable failure)

All data was gathered, collated, and statistically examined.

RESULTS

Results of fracture resistance of lithium disilicate restoration samples were determined by calculations of the mean values and standard deviation. One-way analyses of variance (ANOVA) were performed followed by a **post hoc LSD test** between every two groups for comparison. For parametric (normally distributed) quantitative data, descriptive statistics were calculated using the mean, standard deviation (SD), and minimum and maximum range values.

Regarding the assessment of fracture resistance of samples, one-way analyses of variance (ANOVA) were performed for the three groups of subgroups P2. Results showed that the highest fracture resistance mean values (1015.7 N) were recorded in the group (A) which constitutes samples with full coverage crown restorations followed by group (B) which constitutes samples with vonlay restorations involving functional cusp (745.5 N) and the lowest fracture resistance mean values (570.9 N) were recorded in the group (C) that constitutes samples with vonlay restorations without involving functional cusp as shown in table (1).

- One Way ANOVA test for comparison of quantitative data between the three groups followed by post hoc LSD analysis between each two groups
- Superscripts with different small letters refer to the significant difference between each two groups
- Significant level at P value < 0.05

As regarding fracture resistance, there was significant difference between the tested three groups as group A showed significant increase compared with group A and B, and group B showed significant increase compared with group C. **Figure (1)**

TABLE (1): Fracture resistance between the three groups

		A	B	C	
		N=10	N=10	N=10	P value
Fracture resistance	*Range*	(974.2-1077) [a]	(619.8-866.5) [b]	(465.7-692.4) [c]	*<0.001**
	Mean ± SD	1015.7±38.9	745.5±96.5	570.9±87.2	

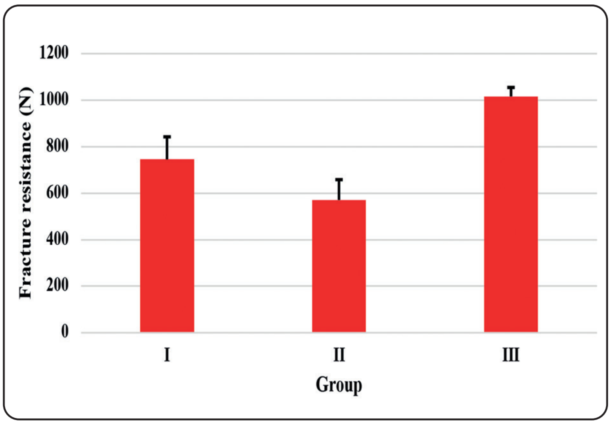

Fig. (1) : Histogram Of fracture resistance Between the Three Groups

- Failure Pattern Analysis:

Fracture pattern analysis was performed using a scanning microscope to determine the mode of failure of deboned all samples.

The samples were categorized according to fracture patterns into the following descriptions:

- Type I: No fracture patterns (favorable failure)
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- Type III: Fracture within restoration and tooth (non-favorable failure)
- Type IV: Fracture within the restoration, crown, and root (non-favorable failure)

Regarding the assessment of the failure pattern of samples we found 80% of samples were fractured in type II fracture (Fracture within restoration without tooth fracture), 10% of samples were fractured in type III (Fracture within restoration and tooth), 6% of samples were fractured within restoration and crown and root (type IV) and 4% of samples were excluded from the study due to its abnormal fracture behavior.

DISCUSSION

A conservative approach to dentistry has been made possible because of technological advancements. Indirect dentistry is being approached in a minimally invasive way. [8].

In addition, Lithium disilicate ceramics have been introduced to obtain proper aesthetic results, especially in laminate veneer and indirect restorations in addition to proper bonding to the tooth structure and superior mechanical properties.

Restoration fracture is influenced by a mixture of factors including the mechanical properties of the material, as well as the preparation geometry and restoration design. [9].

Advance CAD/CAM systems and new ceramic materials increase the accuracy and produce a more homogenous restoration that helps in developing new treatment techniques [10].

According to ***Estevan LF, et al (2017)***[11], a natural tooth with similar dimensions was chosen for all samples fabrication to improve standardization and simulate clinical conditions. By using natural teeth, the researcher can perform a variety of bonding procedures, which have a significant impact on the behavior of the materials being studied.

Addition silicon was used for periodontal ligament simulation to link the experimental data with the clinical conditions was done as ***Soares CS, et al (2005)*** **[12]** *and* ***Nawafleh N, et al (2020)*** **[13]**. As a result, it has been proposed that PDL simulation be included in experimental models as a fundamental stage in fracture test modelling.

Preparation was performed according to the recommended all ceramic restorations guidelines as discussed in ***Rocca, G. et al (2007)***[14] (65) (with an occlusal reduction of the Occlusal cavity with a depth of 2 mm and 1/2 of the buccal-lingual distance, 2 mm butt joint occlusal reduction of the functional cusp. With 0.5 mm chamfer finish line in labial surface for veneer preparation design. All line angles will be rounded, and all margins will be finished.). And the other preparation design was done by the same operator and same condition but without involving the functional cusp (palatal cusp intact).

Scanning of the prepared tooth was done by a high accurate extra-oral scanner (Medit i710) whose accuracy of scan reached to 2 micros and all samples were sprayed with optical spray

In order to produce restorations with proper dimensions that mimic the natural premolar tooth, the designing of restorations was done by adjusting the minimal thickness of restorations by 2mm at the occlusal surface. This coincides with the results of a study accomplished by ***Chen, S. E et al*** [15] who stated that when there are high elastic modulus substrates like enamel, minimal thickness E.max crowns may be a viable restorative option. Also, the cement gap space was adjusted to 60 microns as it was shown that fracture resistance of restoration is highly affected by cement gap space as in ***Kale E, et al (2016)***[16]study.

In this study milling of restorations was performed with chair side Sirona MCXL milling machine which provides the highest accuracy up to 10 microns as ***Kirsch, C et al,***[17] (9)who stated that MCXL milling machine allows fabrication of homogenous and accurate restorations. however, chairside milling results from the 4-axis CEREC MCXL extra-fine mode were comparable to those of 5-axis milling systems with reduced milling time.

Surface treatment of the restorations was performed as described by ***Li, R., et al.***[18] in order to improve the bond strength between lithium disilicate restorations and resin adhesive in this investigation. By optimizing the surface treatment, there is a lot of opportunity for improving the bond strength for all-ceramic restorations. As a result, all restorations were acidly etched for 20 seconds with hydrofluoric acid to create a micro retentive surface, and then a silane coupling agent was applied to form a chemical bond between the ceramic silica and the adhesive resin by producing a bifunctional group.

According to ***Stamatacos, C., et al (2013)*** [19] Cementation was carried out with dual cure self-adhesive resin cement, which allows for a quick bonding technique and eliminates the need for multi-step adhesive materials.

As in ***Palacios R P, et al (2006)*** **[20]** study to ensure standardization of the seating method for all samples, a specifically developed loading device was employed to deliver a uniform and standard load (50 N) during the cementation of the restorations to the corresponding tooth. In this study, all bonded samples were subjected to thermocycling using an automated thermal cycling machine. [21]

Regarding measuring the fracture resistance of all samples, a universal testing machine (Model 3345; Instron Industrial Products, Norwood, MA, USA) was used to apply vertical load via a spherical tip (4 mm diameter) traveling at a crosshead speed of 1mm/min and contacting the occlusal surface of the restoration at cuspal inclinations. To promote homogeneous stress distribution, a thin foil sheet was inserted between the occlusal surface and the metallic rod. Then, using the computer software bluehill universal Instron England, data was calculated and recorded. This was in agreement with ***Gallicchio V, et al (2022)*** [22]

Regarding to effect of preparation designs on the fracture resistance of lithium disilicate ceramics. Results showed that full coverage crown restoration recorded the best results of all tested designs and the least result in more conservative preparation designs. These results agreed with ***Alberto Jurado, et al (2022)*** [23] who concluded that the restorative design and material type had an effect on the fracture resistance and fracture pattern of CAD/CAM full and partial coverage crowns restorations. Also, ***Jurado C, et al (2022)*** [24] Found that CAD/CAM lithium disilicate full coverage crown in premolar has fracture resistance value greater than overlay restorations. The result shows that increasing the cusp coverage, the greater the fracture resistance of restoration. This was also in agreement with ***Alassar R, et al (2021)*** [25]

The result also found that all the tested designs fractured at a higher level than the maximum occlusal load so we can use more conservative preparation designs in normal occlusal cases as ***Findakly M, et al (2019)***[26] and ***Guess P, et al (2012)***[27]who said that Failure loads above normal mastication forces were found in all premolar restored by lithium-disilicate glass ceramic partial coverage restorations, indicating that minimally invasive ceramic can be used as onlay restorations in premolars. Within this study, occlusal complete-coverage onlay restorations were didn't shown to be more advantageous than partial-coverage onlay restorations.

Regarding the pattern of failure, the samples failed by a fracture within restorations only or fracture in restoration and tooth structure. However, a fracture within restoration only was more prominent. This agreed with ***Falahchai M, et al (2020)*** [28] who concluded that in all preparation designs used, Failure modes seen were retrievable.

On the contrary, there are several studies [29] [30] against the result of this study and the disagreement may be due to the concept of preserving more amount of sound tooth structure increasing the fracture resistance.

In disagreement with ***Stappert, et al (2008)***[31] results who evaluated the effect of compromised cusp preparation designs on masticatory fatigue, fracture resistance, and marginal discrepancy in ceramic partial-coverage restorations When compared to less invasive partial-covering restorations, ceramic coverage of damaged cusps did not exhibit an increase in fracture resistance of restoration.

The results of this study were in disagreement with the study of ***Vianna A, et al (2018)***[32] who reported that conservative onlay preparations, such as those without occlusal and proximal boxes, exceeded conventionally prepared ceramic onlay restorations in terms of biomechanical function. Furthermore, in molars restored with lithium disilicate CAD-CAM ceramic onlays with conservative preparations resulted in improved fracture resistance.

CONCLUSIONS

- Fracture resistance is greatly affected by preparation design, the full coverage crown restoration shows the highest fracture resistance followed by vonlay preparation involving functional cusp and least fracture resistance in vonlay preparation without involving functional cusp. But all the tested samples fractured at levels higher than the clinical occlusal stresses, so a more conservative preparation design is favorable in normal occlusion cases with normal masticatory force and shift for more coverage restoration in abnormal heavy occlusal force cases.
- The most failure pattern is a fracture of restorations without fracture of tooth structure (favorable failure).

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