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Assessment of Fracture Resistance of Occlusal Veneers With Buccal or Lingual Extensions Compared to Conventional Occlusal Veneers Restoring Worn Molars After Thermo-Mechanical Aging

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Abstract

Background: Worn molars often require extensive restoration, and conventional occlusal veneers, while preserving tooth structure, have limited durability. To address this, the concept of increasing enamel surface area for bonding by extending occlusal veneers to buccal or lingual surfaces has been proposed to potentially improve fracture resistance. The aim of this study was to evaluate the fracture resistance of occlusal veneers with buccal or lingual extension compared to conventional occlusal veneers when restoring worn molars relying on the concept of increasing enamel surface area to gain more bond strength.

Methods: Twenty-Four extracted sound molars were collected and randomly divided into three groups as follows according to the design of the preparation. Group I Conventional Occlusal veneer design, Group II Occlusal veneer with buccal extension, and Group III Occlusal veneer with lingual extension. Immediate dentin sealing protocol was applied for all samples. All the restorations were fabricated from Lithium Disilicate (Ivoclar Vivadent, Germany). The sealed dentin was sandblasted and total selective etching was applied. A dual cured resin cement (Multilink speed, IvoclarVivadent) was used to cement the occlusal veneers. After storage for 7 days the samples were subjected to 10,000 Thermocycles followed by 150,000 cycles at the chewing simulator. Fracture resistance was tested using Universal testing machine.

Results: Kruskal-Wallis test was used for statistical analysis to compare between groups. There was no significant difference between all groups. The mode of fracture of occlusal veneers with buccal extension showed 42.8% vertical fractures in restoration and tooth structure. Different extension showed no significant statistical difference in fracture resistance values.

Conclusion: There was no significant difference between conventional occlusal veneers design compared to buccal and lingual extension groups. However, occlusal veneers with buccal extension seemed to cause weakening of tooth structure. Occlusal veneer restorations of worn molars should be defect oriented, there is no need for unnecessary sound tooth involvement to enhance bonding.

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1 Introduction

Restoration of worn dentition is of a major controversial issue, where dentists are always challenged due to the variety of prosthetic options[1]. Diverse wear patterns are seen resulting from different etiologies; attrition, erosion or abrasion which lead to tooth structure loss[2,3].

When wear pattern is confined to the occlusal surface adjunct with complete loss of enamel and loss of vertical dimension, occlusal functions as well as vertical dimension should be restored. Preservation of the remaining structure is crucial in order to preserve the retention and resistance forms of any restoration, preventing gross weakening of the remaining tooth structure targeting to maintain the proper physiologic occlusion [4, 5].

Previously, full coverage restorations were the only prosthetic approach as no adhesive restoration would have tolerated the occlusal forces. Lately, following the conservative approach combined with the recent advances in adhesive dentistry and innovations of ceramic materials; prosthetic options such as veneers and occlusal veneers have been broadened [6, 7].The need for traditional massive amounts of reductions became obsolete, relying more on the adhesive strength than the mechanical retention thus preserving more of the natural tooth structure [8].

Immediate dentin sealing (IDS) protocol showed promising results, which relies on sealing the freshly cut dentin before the collagen fibers collapse and before impression taking, resulting in fewer gaps, lower bacterial micro-leakage, increase in the shear bond strength and reduction in the post-cementation sensitivity [6,9].

Throughout the dental practice, dental ceramics have proven their biological acceptance and high survival rates[10]. Lithium disilicate is the most widely used and is the strongest glass ceramic with flexure strength of ±400 Mpa, natural translucency along with its'high bond strength [11, 12].

Restoration of worn dentition with reduced vertical dimension and exposed dentin substrate is puzzling using adhesive restorations; however the use of immediate dentin sealing protocol and design modifications could add a value in increasing the bond strength and increasing the fracture resistance of these restorations.

Accordingly, this study aimed to assess the fracture resistance of lithium disilicate occlusal veneers with buccal or lingual extension compared to conventional lithium disilicate occlusal veneers when restoring worn molars.

A null hypothesis was set stating that no significant differences will be found in fracture resistance between conventional occlusal veneers and occlusal veneers with buccal or lingual extension when restoring worn molars with exposed dentin occlusally.

2 Materials and Methods

2.1 Ethical Approval:

This study was approved by the institutional review board of the Faculty of Dentistry of October University for Modern Sciences and Arts. Ethical approval number ETH21.

2.2 Sample size calculation:

A power analysis was designed to have adequate power to apply a statistical test regarding the null hypothesis stating that there is no difference regarding the fracture resistance of occlusal veneers made using three different preparation designs. By adopting an alpha (α) level of 0.05 (5%), a beta (β) level of 0.05 (5%) i.e. power=95%, and using the effect size (f=0.819) calculated based on the results of Vianna et al in 2018 [13]; the predicted sample size (n) was found to be (18) samples i.e. (six) for each group. Sample size calculation was performed using G*Power version 3.1.9.21. However, eight samples were selected for each group in the study to compensate for possible dropouts.

2.3 Samples selection:

Twenty-four extracted sound lower molars were collected from out patient's Oral Surgery Department clinics, MSA University. Informed consents were collected from patient after thoroughly explaining steps of research. The teeth were sound, free of caries and fillings and were extracted for periodontal purposes. The teeth were cleaned from calculus deposits and soft tissues debris using ultrasonic scaler and prophylaxis paste and brush.

For standardization purpose all teeth were scanned using Medit lab scanner and dimensions measured using Exocad software **(Fig. 1)**. The teeth were selected to be around nine mm mesiodistal with an accepted range IG=9 + 1 at maximum convexity and buccolingual acceptable range of IG=7+1 at maximum convexity All teeth were stored in distilled water during the duration of the study, which was changed every week[14]. After cleaning using the ultrasonic scaler teeth were then examined under light microscope 20x to make sure they were free of cracks.

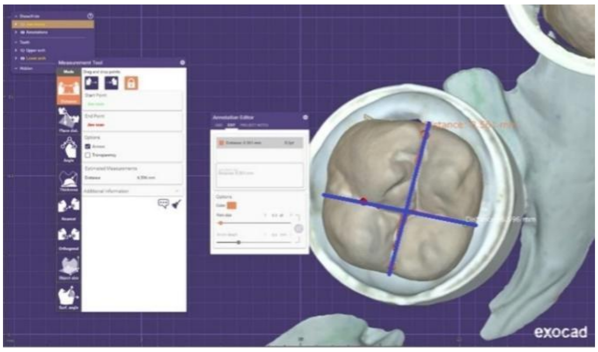

Figure 1. Measuring buccolingual and mesiodistal dimensions of samples at maximum convexity.

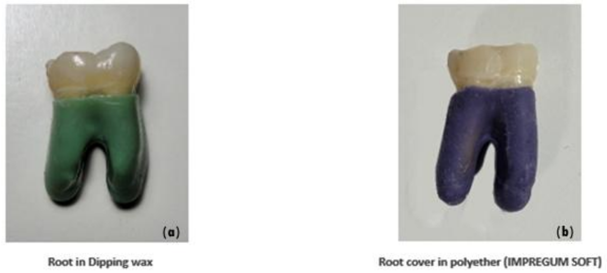

Figure 2. (A) Root dipped in wax (B) Root covered in Polyether.

Roots of the sample teeth were dipped one time in molten wax dipping wax (Bego, Germany) Putty impressions were made of the wax covered roots. The wax was then scrapped off the root surface. The polyether material of medium consistency (3M Impregum soft) was syringed inside the mold [15].The teeth were then immersed in the polyether material till the mark below the cemento enamel junction **(Fig. 2B)**. This resulted in a thin layer of 0.3 mm simulating periodontal membrane.

A silicone holder was fabricated to simulate the exact dimension of the chewing simulator's sample holder. The teeth were marked with vertical lines along the long axis and held perpendicularly using molten wax to the carrier attached to the paralleling device. The teeth were then embedded in epoxy resin held by the custom-made silicone holder until two mm below cemento-enamel junction. The assembly was stored to set in a vacuum over night to avoid any voids in the resin material [16].

2.4 Samples grouping and randomization:

All the 24 samples were numbered and randomized by sealed envelope. Samples were divided into three groups (N=8) and blindly assigned by the Co-author. All groups shared a common occlusal reduction of 2.5 mm depth to ensure a dentin substrate with circumferential enamel collar. The first group was assigned as conventional occlusal veneer with no axial extensions. It involved a reduction of 2.5 mm occlusal reduction.

The second group was assigned as occlusal veneer with buccal extension. In addition to the occlusal reduction, a buccal reduction of 0.3 mm cervically and 0.5 occlusally was prepared. The third group was assigned as occlusal veneer with lingual extension. In addition to the occlusal reduction, a lingual reduction of 0.3 mm cervically and 0.5 occlusally was prepared.

2.5 Teeth preparation:

Occlusal Surface Preparation

The occlusal surface was to be reduced as to resemble wear patterns, a non anatomic preparation. All samples were prepared occlusally in the same manner and by the same operator. Depth Cutters of one mm were used **(Fig. 7)**, and then Occluso-Shaper was used to prepare the occlusal surface until the markings of the depth cutter disappeared. This process was repeated twice to gain a two mm preparation. A 0.3 mm depth cutter was used on the occlusal surface, the surface was then prepared in same manner using the occluso shaper. The reduction was finished using a fine Grit finishing stone bringing the total occlusal reduction to 2.5 mm. The angulation between the buccal and lingual occlusal slopes was measured to be 150 degrees. At this step identification of dentin and enamel was done by short etching[10] for three seconds followed by drying, where dentin appeared shiny while circumferential enamel appeared chalky [17].

Figure 3. Depth Cuts on the Occlusal Surface.

Figure 4. Occlusal Surface after Preparation.

Buccal and lingual surface preparation

The buccal surface was reduced as to have a two plan reduction, and a 0.3 mm finish line1 mm above the cemento-enamel junction the functional cusp was beveled. The 0.3-millimetre depth cutters were used to prepare the axial surface of the preparation which ended one millimeter above cemento enamel junction.

A tapered round end diamond stone was used to prepare the lingual or buccal surface to achieve a 0.3-millimetre reduction at the cervical half and 0.5 mm at the occlusal half. A fine grit stone was used to finish the prepared surfaces and slightly bevel the occluso buccal line angel to provide a thickness of 1.5 mm at the second plan of buccal or lingual reduction.

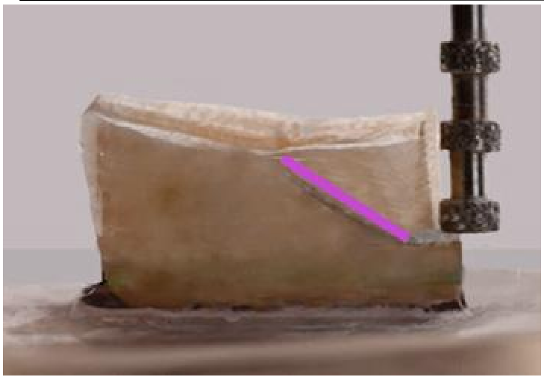

Figure 5. Finish line position on the proximal surface.

The finish line on the proximal surface of preparation was sloping from the central groove toward the cervical third of the buccal or lingual surface **(Fig. 7)**. Undercuts were removed in order to achieve a path of insertion for the final restoration. Finally, smoothening and roundation of all edges was carried out and the final preparation was as shown in **(Fig. 10)**. All steps were performed by the main researcher.

Figure 6. Diagram showing finishing in Preparation Proximal view.

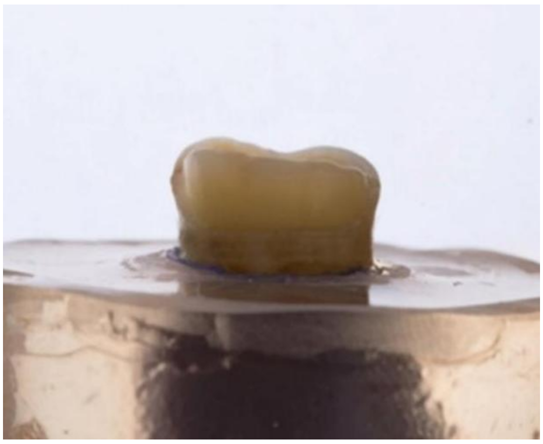

Figure 7. Diagram showing finished Preparation in Buccal view.

Immediate Dentin Sealing

The immediate dentin sealing protocol was used on the freshly cut dentine surface. Dentin was etched with 37% phosphoric acid (Meta, Biomed, Korea) for 15 seconds and then rinsed thoroughly with water for 20 seconds [17].

Dentin bonding agent (Single bond, 3M ESPE Seefeld, Germany) was applied on dentin. The bond brush was used in gentle brushing motion to make sure the bonding agent penetrated the etched dentin, and then air dried for five seconds to remove the excess adhesive. The bonding agent was then light cured[13] for ten seconds[9] .Then Oxygen Inhibition Paste (KYL, Johnson & Johnson, India) was applied on the surface of the sealed dentin to prevent oxygen inhibition, then the surface was light cured for another ten seconds. The paste was rinsed away thoroughly. All the samples were stored in distilled water [6, 9, 14].

Scanning, Designing and Milling Procedures

Digital impressions of the prepared samples were made using Medit Lab Scanner. All data was transferred to Exocad design software. Samples were allocated into three groups and designed according to preparation design. The occlusal surface was designed as follows. Cusps height was set to be 1.5 mm while the thickness at the central groove was 1 mm. The axial extensions of group 2 and group 3 were designed to have a thickness of 0.5 mm at the occlusal half of the buccal or lingual extension, and 0.3 mm at the cervical finish line. The angulation between the buccal and lingual cusps was standardized for all samples to be 134 degrees. Die spacer was set at 0.04mm. All samples were milled out of CAD wax first to test of the fit and adaptation to finish line. Following checking of accuracy of fit, all 24 samples were milled out of lithium Disilicate blocks using a Coritec5-axis wet milling machine. Restorations were crystallized in a furnace (Programat EP 3010, Ivoclar) according to manufacturer's instructions. After Crystallization all restorations were polished using Emax polishing kit for standardization and to avoid lab errors during glaze applications.

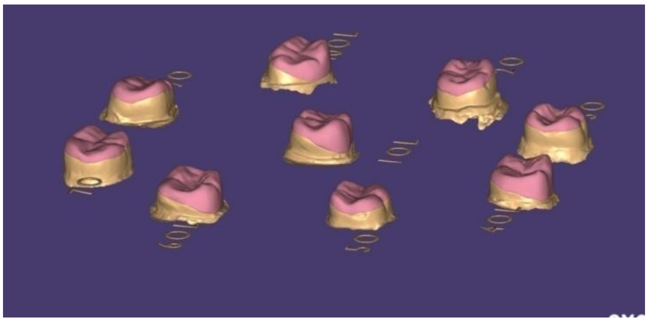

Figure 8. Exocad designs for occlusal veneers

2.5 Bonding procedure:

Preparation of Restorations for bonding:

Restorations were prepared for bonding using etching and priming. First, hydrofluoric acid 9.5% (BISCO dental) concentration was applied on the intaglio surface of the occlusal veneers for 20 seconds, and then rinsed for 60 seconds. Second, Porcelain Primer (BIS-Silane, BISCO Dental) was applied on the etched surface and left for 60 seconds according to the manufacturer's instructions. Excess primer was air dried with oil free air syringe [18].

Tooth surface preparation for bonding:

All the IDS surfaces were pre-treated by sandblasting using 50um Alumina Oxide Particles at ten mm distance at two bar pressure using Renfert sandblasting machine(Renfert GmBH, Germany) [6, 19].

All samples were prepared using selective etching for enamel and dentin. Acid-etch was applied on the prepared enamel for 15 seconds selectively followed by the application of the acid-etch on the previously sealed dentin for fifteen seconds. Totally enamel was etched for thirty seconds, and dentin was etched for fifteen seconds [6]. Bonding agent was applied on the etched surfaces. The bonding agent was applied with a bond brush with a gentle scrubbing for 20 seconds and gently air dried for five seconds [6, 9].

A dual curing luting resin cement (Multilink, Ivoclar Vivadent, Schaan, Liechtenstein) was applied on the intaglio surface of the restorations and gently evenly distributed using a brush. The restoration was then seated on the fitting surface with a load of 5 kg. Tack curing using Elipar Light Cure for 3 seconds was used. Excess cement was removed using a sharp instrument. Oxygen inhibition paste was then applied to all margins of the restoration and further light curing for 20 seconds was carried out [6,9].

2.6 Thermocycling and Mechanical aging simulation:

Thermo-cycling

After cementation the samples were stored in distilled water for 7 days. The samples were then subjected to ten thousand thermo cycles from 0 to 55 °C for 30 seconds dwell time at each temperature to simulate one year of clinical service [20].

Dynamic loading

Following thermocycling computerized dynamic loading was carried out in the chewing simulator (SD Mechatronik) for 150,000 cycles to simulate one year of clinical service [16, 21]. A loading cycle frequency of 2.0 Hz with a lateral component of 0.3 mm towards the central fissure was applied. The descending velocity was 30 mm/s, ascending velocity was 55 mm/s while the vertical motion was six mm/s. The antagonist tooth was simulated by a steatite ceramic ball five mm in diameter which contacted the buccal cusp and slide down to the central groove for 0.3 mm [22].

The chewing simulator was made of four chambers designed to hold one sample each. The samples were held in place using the fixation screw in order to guarantee it was held and stabilized in place. After loading the samples, a weight of five kilograms was chosen to produce the required amount of force, the chambers were filled with water during function [16, 21, 22]. After the procedure was completed, all samples were dried and examined for cracks. Only one sample was excluded for cracks from group 3: occlusal with lingual extension.

2.7 Fracture resistance testing:

All surviving samples (N=23) were loaded to fracture using Universal testing machine. The samples were loaded with steel bar with a six mm ball end at the central groove in order to distribute the load evenly on the triangular ridges of cusp. Additionally, a 0.6 mm of tin foil was placed on the tooth surface in order to evenly distribute the forces and avoid early fracture. The steel bar was descended with a cross head speed of one mm / min. the computer software recorded the maximum load to fracture in Newton's. By the end of the fracture resistance testing two samples of group1 and group 2 were excluded due to fracture of epoxy resin apically. The rest of the samples were inspected using a light microscope to analyze the modes of factures.

2.8 Statistical Analysis:

Data were presented as mean, standard deviation, median, minimum and maximum values. Kruskal-Wallis test was used for between group comparisons. Significance level for statistical tests was set at $p < 0.05$. Statistical analysis was performed using SPSS software (IBM Corp. Released 2017. IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY: IBM Corp.

3 Results

Fracture resistance:

The mean and standard deviation values of fracture resistance were 2909.4 (905.8) N in the occlusal group, 2649.3 (763.2) N in the occlusal with buccal extension group and 2479.1 (620.8) N in the occlusal with lingual extension group. The median and range values were 2887 (1645 – 4100) N in the occlusal group, 2600 (1682 – 3845) N in the occlusal with buccal group and 2369 (1456 – 3374) N in the occlusal with lingual group. There was no significant difference in the fracture resistance between the three groups (p = 0.662).

Table 1. Statistical Results.

	Occlusal	Occlusal with buccal	Occlusal with lingual	*p*-value
Mean	2909.4	2649.3	2479.1	0.662
SD	905.8	763.2	620.8	
Median	2887	2600	2369	
Min	1645	1682	1456	
Max	4100	3845	3374	

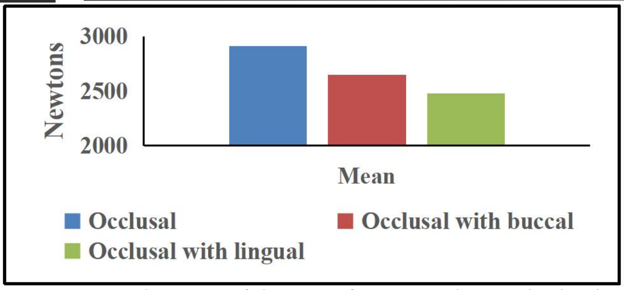

Figure 9. Histogram of the mean fracture resistance in the three groups.

Table 2. Fracture Modes.

Type (I)	Fracture in restoration
Type (II)	Fracture in restoration and enamel
Type (III)	Fracture in restoration, enamel and dentin
Type (IV)	Fractures including enamel, dentin and pulp.

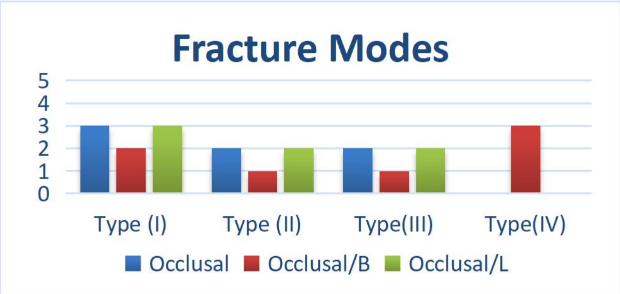

Figure 10. Histogram showing Fracture modes for different occlusal veneer designs.

4 Discussion

Wear patterns differ according to its etiology. Preserving natural teeth structure is crucial because more invasive approaches violate the biomechanical equilibrium [23]. In-vitro studies aids in elimination of human variables; parameters are set similar for all samples and therefore a more comparable outcome for different interventions [23].

This study aimed to evaluate occlusal veneers with different designs when restoring worn molars. The set hypotheses suggesting that "no significant differences will be found in fracture resistance between conventional occlusal veneers and occlusal veneers with buccal or lingual extension when restoring worn molars with exposed dentin occlusally" were accepted.

Occlusal veneers have been suggested as a treatment modality for worn dentition; different designs have been tested including different finish line designs and inter-coronal preparations, which were compared in terms of different thicknesses or in terms of different fabrication materials [24, 25].

Immediate dentin sealing always showed significantly higher bonding results Compared to delayed dentin sealing and regardless of the way of treatment [9, 26]. Accordingly, immediate dentin sealing was used as the bonding protocol.

Magne et al. in 2010 [27], suggested the use of separate primer instead of using the self-priming resins. They declared that the use of selective etching and priming resulted in a higher bonding strength value compared to self-etching adhesives. They advocated these results to their higher penetration in the dentinal tubules thus forming a hybrid layer.

Following Lee and Park in 2009 [28], who reported that the application of dentin bonding agent in thin layers provides space for occlusal veneer and allow better stress distribution throughout the restoration. Gentle brushing of the dentin bonding agent and air drying was done. Enamel surface was cleaned from excess bonding agent before impression taking to ensure no dimensional changes after scanning or weak bond at the enamel surface.

Lithium disilicate was the material of choice due to its proven success in restoring worn dentition [18, 29, 30]. Veneers were fabricated in a thickness of 1.5 mm occlusally, where thin occlusal veneers significantly affect the survival rate of the restorations [31]. CAD/CAM technology was implemented for accurate designing and milling moreover, standardization of the occlusal veneers dimensions and the internal fit of the restorations [31].

Restorations were fabricated with a cusp thickness of 1.5 mm, grooves thickness of one mm and occluso axial surface thickness of 0.5 mm sloping to 0.3 mm at the cervical finish line. Dentin surfaces were sand blasted in accordance to Dillenburga et al in 2009 [19], who stated that the use of sand blasting with or without application of phosphoric acid and an application of second layer of bonding agent positively affect dentin bond strength.

Bonding agent was cured for ten seconds followed by the application of glycerin containing gel for oxygen inhibition in the bonding layer and the resin cement and then curing further continued [27,32].

Results of the present study showed no statistical difference in fracture resistance values of the three tested groups with means of Group 1 (2909.4 N), Group 2 (2649.3 N) and Group 3 (2479.1). Numerically the conventional occlusal group showed the highest fracture resistance values compared to occlusal with buccal extensions and occlusal with lingual extensions. These results were in agreement with Gierthmuehlen et al. in 2022 [33], who concluded that a non-retentive occlusal restoration on dentin with enamel collar is not significantly different than a restoration with a proximal box or labial extension. Also, Channarong et al. in 2022 [34], who tested different axial wall extensions on buccal and lingual surfaces with different lengths; one, two, and three mm compared to sound molars as a control. They reported no statistically significant difference between different extensions.

Luo et al. in 2022 [35], compared different axial wall extensions, they found that occlusal veneers with one mm distal extensions mechanically performed better than occlusal veneers with no extensions. This might be explained by different stress distribution exhibited by the buccal and lingual cusps dynamic loading. Moreover, the extensions in their study were thicker dimension, which might have increased fracture resistance of the restorations. Kotb. et al. in 2019 [25], designed an occlusal veneer with a circumferential finish line preparation, extending one mm on axial walls with a one mm thickness chamfer finish line. They compared this design with the conventional preparation. They found no statistically significant difference; however, the mean value for fatigue resistance was higher for preparations with circumferential finish lines, which indicated that thickness of one mm extension may influence the fracture resistance.

Regarding the mode of fracture both conventional and lingually extended occlusal veneers showed higher repairable fractures, 43% of occlusal veneers with buccal extension showed type (IV) fractures including enamel, dentin and pulp space, and even extending cervical. Cracks initiating at the functional cusps usually lead to fractures below the cervical line as, this was in accordance to Bader et al. in 2004 [36] and Channarong et al. in 2022 [34]. On the other hand, Huang et al. in 2020 [37], stated that the enamel collar with external bevel caused better force distribution in their study.

5 Conclusion

Within the limitations of this study it can be concluded that; conventional occlusal veneers and those with axial extensions can be considered viable prosthetic options. No statistically significant differences were revealed among the three designs of occlusal veneers tested.

Authors' Recommendations

1. Occlusal veneers with different extensions could be used whenever needed to include buccal or lingual surface defects and still maintain fracture resistance values similar to intact molars.
2. Conventional occlusal veneers to restore worn molars with loss of enamel make an acceptable line of treatment
3. Restoration of worn teeth should be defect oriented only following the guidelines of conservatism.

Conflict of interest

The authors declare that they hold no competing interests.

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