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MARGINAL FIT AND FRACTURE RESISTANCE OF ADVANCED LITHIUM DISILICATE OCCLUSAL VENEER WITH DIFFERENT PREPARATION DESIGNS

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ABSTRACT

Aim: This study aimed to evaluate the effect of different preparation designs of advanced lithium disilicate (CEREC Tessera) occlusal veneer on marginal fit and fracture resistance.

Materials and methods: Twenty extracted mandibular molar teeth were used for occlusal veneers fabrication. Division of samples was carried out by the preparation design into two groups (n=10). group 1: The teeth were prepared with 90^0 shoulder finish line. group 2: The chamfer finish line was the technique of choice in teeth preparation. Both groups were subjected to thermocycling. The stereomicroscope was used to examine all samples for marginal fit before being subjected to the test of fracture resistance utilizing the universal testing machine.

Results: Marginal fit results showed that the shoulder finish line design had a significantly lower mean value (75.8±6.4 µm) than that using the chamfer finish line design mean value (128.1±12.6 µm). The fracture resistance results demonstrated that the shoulder design had a higher significant mean value (870.2±72.5 N) than that using the chamfer design (711.2±66.6 N).

Conclusions: Advanced lithium disilicate (CEREC Tessera) could be used in occlusal veneer restoration as their flexural strength and marginal fit values fall within the clinically accepted range. Regarding the preparation design, the shoulder design showed more resistance to fracture and better marginal fit than the chamfer finish line design after thermocycling.

KEYWORDS: Fracture resistance, marginal fit, lithium disilicate, occlusal veneer

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INTRODUCTION

It has been reported that tooth wear possesses a high as well as increasing prevalence, particularly in young patients. Tooth wear can be attributed to chemical (erosion) and/or mechanical (attrition, abrasion, and abstraction) causes. In addition to suffering from dental pain, patients can also suffer from disorders of the temporomandibular joint, muscles of mastication, psycho-social handicapped due to compromised esthetics, and orofacial pain. [1,2]

The options suggested for restorative treatment of badly worn dentition may include elective devitalization of teeth, lengthening of the crown, as well as multiple full-coverage restorations. Conventionally, to accommodate the design of préparation, these approaches require intact tooth tissue removal. An implementation of adhesive concepts to maintain the structures of the tooth have been utilized during the conservative approach in which restoration of tooth surface loss using direct resin composite is performed. Although this direct restoration of the tooth wears utilizing composite resin is not the perfect line of treatment attributing to its drawbacks regarding durability and esthetics. Occlusal veneers offer a more conservative and durable line of treatment. Yet, their survival rate depends upon the type of material and preparation design. Conservatism always has been the goal of any fixed prosthodontics. [3]

Both durability and aesthetics are provided by ceramic materials. Nevertheless, the fracture properties as well as the fabrication options determine the feasibility of ceramic materials implementation in terms of thin conservative preparations. Newly introduced advancements in CAD/CAM (computer-aided design/computer-aided manufacturing) technology and materials are providing new choices for restoring badly worn dentition as occlusal veneers. [4]

In 2021 Dentsply Sirona introduced new advanced lithium disilicate CAD/CAM blocks (CEREC- Tessera). The key feature of this ceramic is that it can be fired at a significantly rapid rate, only 4.5 to 12 min at 760˚C. The new ceramic composition has allowed for the fast-firing time, as Advanced Lithium Disilicate Glass Ceramic has a Two-part crystal composition (Lithium Disilicate + Virgilite) embedded in a glassy zirconia matrix, Virgilite is A new crystal, activated through the matrix firing process. The CEREC Tessera flexural strength is over 700 MPa. [5,6] Although not widely used for the construction of occlusal veneer, it would be a promising material regarding the marginal integrity and fracture resistance of occlusal veneer.[5,6]

One of the fundamental criteria that impact the success of dental restoration in the long term is marginal fit. The exposure of luting cement to the oral environment occurs due to the existence of marginal discrepancies in dental restoration. The greater the discrepancy, the more quickly the rate of periodontal diseases, cément dissolution in addition to problems pertinent to aesthetics that may ultimately lead to dental restoration failure. [7]

The features of ceramic material and preparation design might influence the fracture resistance and marginal fitness of occlusal veneers. Therefore, the objective of this study is to assess the impact of various preparation designs of occlusal veneer using Advanced lithium disilicate (CEREC-Tessera) on marginal fit and fracture resistance. [8]

The hypothesis: The current study's premise was that the different preparation designs of CEREC-Tessera occlusal veneer would not affect the marginal fit and fracture resistance.

MATERIALS AND METHODS

Twenty extracted mandibular molar teeth were used for the fabrication of occlusal veneers. Division of the samples was carried out into two groups in accordance with the preparation design (n=10). group 1: The 90^0 shoulder finish line was the technique of choice in teeth preparation. Group

2: Chamfer finish line was the technique of choice in teeth preparation.

The collection of extracted teeth was from the Oral and Maxillo-Facial clinic of the Faculty of Dentistry at Minia University for purposes such as diabetes, loose teeth, and periodontally affected and impacted teeth. Patients signed a consent of approval to use their teeth in scientific research. The proposal was submitted by research ethics committees of the Faculty of Dentistry at Minia University. After finishing this research, the researcher got rid of the used teeth in a safe way according to Occupational Safety and Health Administration (OSHA).

The teeth underwent thorough washing, scrubbing, as well as scaling to remove mucous, blood, and shreds of the periodontal ligament, calculus, and plaque. Storage of the teeth until usage was in distilled water. A self-cured acrylic resin was used for mounting the tooth in a vertical manner with the aid of a surveyor to ensure the placement of teeth in a standardized method. Crowns of the teeth were kept remaining free of acrylic and the coverage of the root was to a height 2 mm beneath the cementoenamel junction (CEJ) which is roughly the level of alveolar bone in an intact tooth.

Embedding of the root portion of each tooth was carried out in self-cured acrylic resin (Acrostone Cold Cure Special Tray Material, England). When the acrylic resin had achieved the dough stage, it was placed into a split cylindrical Teflon mold then the roots of each tooth were immersed into the center of the Teflon mold to the level that the (CEJ) was above the top of the Teflon mold by 2 mm. The excess acrylic resin was quickly eliminated using a metallic wax carver (United instruments, New Jersey, United States). Following the complete polymerization of acrylic resin, the mold was then opened, and each acrylic block containing tooth was removed, the samples were now ready for preparation.

For providing a uniform thickness of occlusal veneers an index for each tooth was made with silicone-based impression material (Zetaplus, Zhermac, Italy). The material was mixed following the manufacturer's instructions by hand mixing of the same operator and under the same temperature condition.

The preparation design criteria were the base upon which teeth were prepared. Considering the manufacturer's recommendations for the minimum occlusal thickness of the final restoration, the occlusal reduction for both groups was determined at 1 mm. In group 1, 90˚ shoulder preparation design was prepared. Depth grooves were formed through the occlusal surface matching the tooth's original anatomy using a cylindrical coarse diamond bur (Dentsply, Maillefer, Switzerland). The conical bur (Dentsply, Maillefer, Switzerland) was used to remove the enamel septa to connect the guiding grooves. The fine-grit diamond stone (Dentsply, Maillefer, Switzerland) was used for finishing occlusal preparation. Meanwhile flat-ended tapered diamond stone was utilized to prepare the axial walls creating a 90˚ shoulder finish line, which was accomplished with a fine-grit stone (Dentsply, Maillefer, Switzerland). Afterward, abrasive rubber points were used to polish the prepared surfaces. In terms of group 2, the preparation of choice was the minimally invasiveq1` chamfer preparation design. The occlusal reduction was conducted as demonstrated in group 1. Preparation of the marginal chamfer was carried out on the axial wall with the help of a specific tapered stone with a round end to create a chamfer finish line**.** Then finished with a fine grit bur and polished with abrasive rubber points.

Fabrication of occlusal veneers of CEREC Tessera ceramic (CAD/CAM machinable blocks, Dentsply Sirona/Germany) was performed as follows: a Dentsply Sirona InEos x5 extraoral scanner (Dentsply, Germany) was used to take the optical impression. Designing the restoration using CEREC CAD software (SW 5.1.3., Dentsply Sirona).

The proposed design was adjusted to ensure that the occlusal veneer had a one mm occlusal thickness. Then milling was performed using CEREC MC X (Dentsply Sirona), occlusal veneer samples underwent glazing utilizing Universal Spray Glaze and firing utilizing Ivoclar Programat CS furnace in accordance with instructions of manufacturer: (Closing Time (2:00min) Temperature Gradient (55°C) Holding Temperature (760°C) Holding time (2:00 min) 0 Vacuum). All restorations were finished and polished using finishing and polishing kits (Ivoclar vivadent) following manufacturer instructions. All restorations were double-checked using a caliper (Rohde&Schwarz USA), taking random multiple readings to ensure a uniform 1 mm thickness of the restorations. Each veneer was placed on the prepared tooth to check seating, marginal fit, and accuracy under proper visualization and magnification by magnifying loupes (2.5x).

Adhesive cement is recommended for ceramic restorations, hydrofluoric acid has been used to etch the restoration, and silane is applied to serve as a chemical link between the ceramic and the resin cement. The ceramic restorations were cleaned with copious amounts of tap water at room temperature and then dried, after which the 5% hydrofluoric acid gel (BISCO-Schaumburg USA) was used to etch occlusal veneers for 30 seconds in accordance with the manufacturer guidelines. Following etching, rinse the veneer with water for 40 sec. and then underwent drying utilizing air spray. Then, the veneers were brushed with a silane coupling agent for 60 sec. More silane is added in case the layer of silane is not liquid anymore. Blow-dry in a powerful air stream according to manufacturer instructions. Washing the prepared teeth with water was carried out and dried with air but taking into consideration not to over-dry the surface of the tooth. Then apply Total Etch 37.5% Phosphoric Acid etching gel (META Biomed, Korea) for 30 sec. on enamel, then rinsed and dried, leaving the prepared surface moist. A bonding agent (3M ESPE U.S. A) was applied to the prepared surfaces. Then the application of freshly mixed resin cement (Imicryl Nova Resin Turkey) on the fitting surfaces of occlusal veneers and seating of each veneer on its analogous preparation with a pressure of finger was carried out. The veneers were subjected to five minutes of seating pressure equal to 5kg of force, delivered by a universal testing machine. Removal of excess cement was carried out, and light cured (Ivoclar Vivadent, Zurich) for 20 sec. for each tooth surface. Storage of samples was in distilled water at room temperature till they were tested.

All samples were placed inside a thermocycling machine (The 100 SD mechatronic thermocycler, Germany) as well as subjected to 5000 cycles between two water baths, from 5°C and 55°C. Two tanks of hot and cold water make up the thermal apparatus. The filling of both tanks was carried out using tap water. A thermostat controlled and maintained the hot water bath's temperature at 55°C. Meanwhile, in contrast, the cold water's temperature was maintained at 5°C. Each cycle included a dwell time of 30 seconds at 5°C and 55°C along with a 10-second time of transfer, and repetition of the process was carried out for 5000 cycles.

Marginal fit measurement:

A USB Digital microscope accompanied by a built-in camera (MA 100 Nikon stereomicroscope Japan) connected to an IBM-compatible personal computer via a fixed magnification of 70x was used to photograph each sample. A system of digital image analysis (Image analysis Omnimet Buehler U.S.A software) was used for the measurement and evaluation of the gap width of each of the restored tooth's four surfaces (mesial, buccal, distal, and lingual). The number of measurement points per occlusal veneer sample was 12 points (3 points per surface).

All sizes, frames, limits, and measurement parameters are expressed in pixels within the image software. As a result, system calibration was performed to convey the pixels into absolute real word units. Calibration was accomplished by bringing into comparison an object of a known size (a ruler in this study) with a scale created by the image software. A custom-designed and fabricated holding device was used to hold samples in place. Shots of the margins were taken for each sample. Then morphometric measurement was carried out for each shot of four equidistant landmarks along the circumference of each sample surface (mesial, buccal, distal, and lingual). Repetition of measurement at each point was carried out three times.

Fracture resistance measurements:

All samples were loaded to fracture utilizing a computer-controlled universal testing machine (Instron model 3345 England, load cell 5000) using computer software (Blue Hill universal Instron England) until fracture occur. By applying a rising force using a stainless-steel stylus which is round and 5 mm wide into the restored teeth at a speed of 1mm/min, the samples' fracture resistance was tested. The positioning of the stylus tip was done over the central fossa in order to accomplish the tripodization of contacts through the cuspal inclines. A customized spreadsheet was created to register and collect the maximum load to fracture.

RESULTS

The IBM SPSS version 25 statistical package software was used to analyze the data. Data were expressed as mean ±SD and minimum and maximum range for parametric quantitative data. The analyses were performed between both groups for parametric quantitative data utilizing **Independent Samples T-test**. **P-value less than 0.05** was taken into consideration as statistically significant.

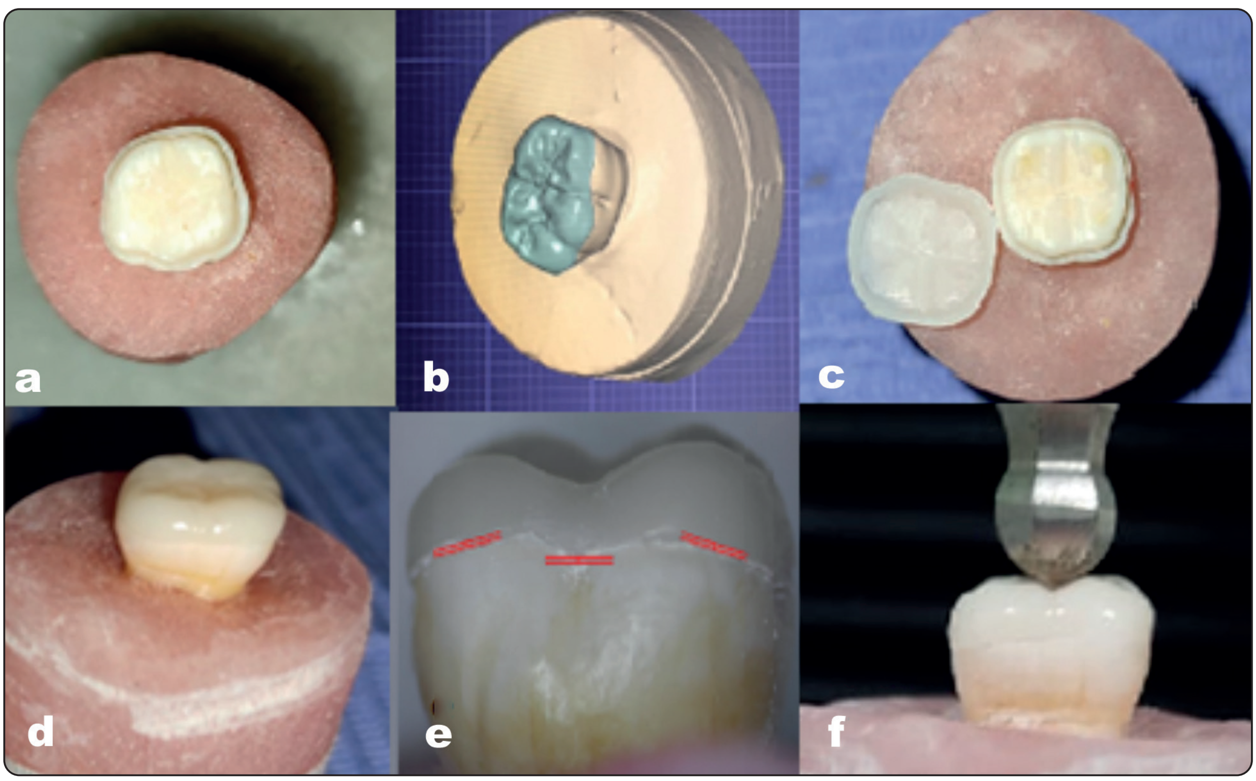

Fig. (1) (a) preparation (b) designing (c) try in (d) cemented occlusal veneer (e) Three points measurements of marginal fit (f) fracture resistance measurement of occlusal veneer.

1- Comparison of marginal fit between shoulder and chamfer design(μm)

TABLE **(1):** Range, mean, and standard deviation of marginal fit between shoulder and chamfer design.

		Shoulder N=5	Chamfer N=5	P value
Marginal fit	*Range*	(68.2-82.1)	(110.5-139.6)	*<0.001**
	Mean±SD	75.8±6.4	128.1±12.6	

***** Significant level at P value < 0.05***

Results demonstrated that the marginal fit of the shoulder finish line design had a significantly lower mean value (75.8±6.4 μm) than that of the chamfer finish line design mean value (128.1±12.6 μm). A significant difference between the two tested finish lines regarding marginal fit was evident as indicated by independent samples T-test (P value = 0.01<0.05). Both Values obtained are within the clinically accepted range, as some studies have shown that clinically acceptable marginal gap size is up to 150μm. [9,10]

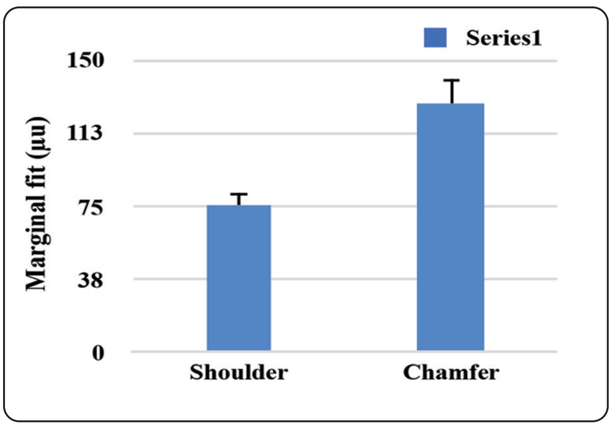

Fig. (2) Bar diagram shows the Marginal fit between the shoulder and chamfer design.

2- Comparison of Fracture Resistance between shoulder and chamfer design.

TABLE (2)**:** Range, mean, and standard deviation of fracture resistance between shoulder and chamfer design (N)

		Shoulder N=5	Chamfer N=5	P value
Maximum compressive load	*Range*	(784-934)	(619-790)	***0.007****
	Mean ± SD	870.2±72.5	711.2±66.6	

****: Significant level at P value < 0.05***

The comparison of the fracture resistance between the shoulder and chamfer design showed that the fracture resistance with the shoulder finish line design (870.2±72.5 N) was higher than that using the chamfer finish line design (711.2±66.6N). A significant difference between the two tested finish lines was evident. as indicated by Independent samples T test P value = 0.005< 0.05 and both values obtained are within the clinically accepted range as the maximal forces of occlusion have variations up to 500 Newton [11].

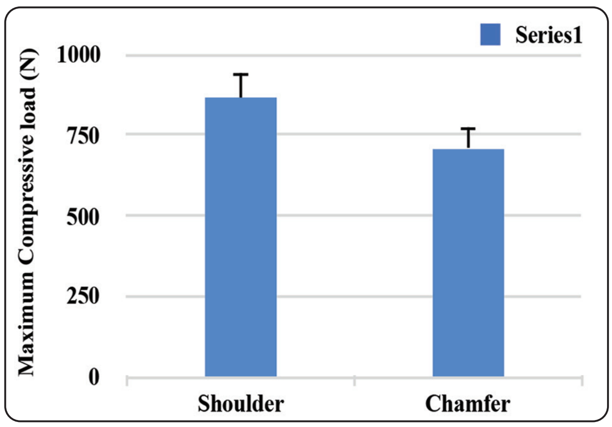

Fig. (3) Bar diagram shows fracture resistance between the shoulder and chamfer design.

DISCUSSION

One of the common complications caused by tooth wear is loss of occlusal vertical dimension also. Correctional therapy to regain OVD should be done as early as possible to avoid masticatory disorders which cause myofascial pain and TMD. Because of the predictable patient adaptation, the OVD increase should be accomplished by using fixed restoration instead of a removable appliance, whenever indicated. The occlusal veneer is the proper conservative line of treatment for rehabilitation of worn posterior occlusal table for treatment of loss of vertical dimension [12].

It has been demonstrated that occlusal veneers have a conservative alternative to conventional onlays and crowns of full coverage type for the treatment of severe abrasive/erosive lesions. Occlusal veneers are basically thin overlay restorations with a non-retentive design that permit the coronal structure conservation, usually averting root canal treatment. [13]

The use of all-ceramic materials in restorative dentistry has become remarkably growing as the patient demands enhancement of appearance are constantly increasing. All ceramic restorations have improved high biocompatibility, less accumulation of plaque, the resistance of abrasion, stability of color, low thermal conductivity, and esthetic features. [14,15] An attempt of enhancing the mechanical characteristics of ceramic materials and permitting metal-free restorations to be more predictable has been carried out by the developed technologies and research [16].

Recent advancements in the science of ceramic materials have led us to a level of superiorly strong materials which introduce more enhanced long-term durability as well as fracture resistance than conventional porcelain and other ceramic substitutes. Cerec Tessera is a completely new type of CAD/CAM block that allows for a fast path to results without shortcuts because it delivers leading esthetics with market-defining strength up to 32% stronger for glass ceramics with up to a 44% faster total processing time (Fast 4.5 min firing). [5,6]

. The first preparation design tested was the "Shoulder," directed by the occlusal surface anatomy. The standard preparation that guarantees adequate thickness for occlusal veneer restoration was accomplished using the depth groove stone to reduce 1 mm of cusp and 1 mm into the depth of the central fossa, moreover, the extension of the preparation was 1 mm on the tooth axial surface, the final step was shoulder finish line preparation. The second preparation design tested was the minimally invasive chamfer had the same features of occlusal reduction and more conservative preparation. As mentioned in studies by several authors, huge credibility went to the design of minimally invasive chamfer veneer preparation as it is a conservative line of treatment for cases diagnosed with badly worn dentition. Modifications to the first design aimed to improve the bonding strength of different available materials to the tooth structure. [17,18]

Permission of inadequacy of replicated periodontal ligaments was evident as it was predicted that among single crowns, the fracture resistance between teeth with and without this shock-absorbing layer surrounding the roots under a test of fracture resistance will be almost the same. Moreover, the thickness of the silicone layers simulating periodontium around the root of the abutments is more than that in clinical situations. Furthermore, uncontrolled mobility of abutment teeth might be caused by a non-standardized artificial silicone periodontium yielding more errors [19].

CAD/CAM technology has the capability to control the anatomy and thickness of restorations within the process of fabrication, so it was chosen. Furthermore, it permitted standardization of the internal fit of the restoration. Therefore, the operator variables, including the experience and training of the dental laboratory personnel in addition to the processes involved in the process of fabrication, were ruled out. This is especially important when using thin-thickness restorations. [20]

The bonding of ceramic to dental tissue relies on luting cement adhesion to the ceramic substrate, as well as the adhesion of luting cement to the enamel and/or dentin. It is indicated to use adhesive cementation for ceramic restorations. Silane is applied to serve as a chemical link between the ceramic and the resin cement. Silanization also increases the wettability of the ceramic surface and decreased microleakage. [21]

In order to provide a realistic representation of the clinical setting, construction of the occlusal veneers was carried out on natural molar teeth rather than a die material. Several laboratory experiments of marginal leakage, marginal gap, and strength of bond have included exposing restorations and crowns cemented on extracted teeth to cyclic thermal changes to imitate one of the numerous factors in the environment of the oral cavity. [22]

It is widely agreed that the marginal fit of an indirect restoration is a remarkable factor in terms of the assessment of restoration success. Decreased microleakage, caries recurrence, gingival inflammations as well as marginal discoloration are usually along with decreased marginal gaps [23,24]. The measurements of the gap assessed in this study shed light on the vertical marginal gap distance that showed the vertical distance from the margin of the restoration to the finish line of the preparation as demonstrated earlier in the literature. The evaluation of restoration's fit precision by this measurement has been shown to be reliable. [25,26] Both invasive approaches including cross-sectioning and impression replica and non-invasive approaches including direct viewing are used in the evaluation of restorations' marginal adaptation. In this study, direct viewing using a stereomicroscope for external measurements was conducted; it was emphasized that the same operator should make all measurements to avoid errors as much as possible. The number of measurement points per occlusal veneer sample was 12 points (3 points per surface), this was an average number among many studies. [27,28]

The clinically acceptable size of the marginal gap is reported to be lower than 120μm as demonstrated by some studies. Meanwhile, it has been demonstrated by other studies that a marginal gap size of up to 150 μm is clinically acceptable Characteristics of ceramic systems include different sintering shrinkage during firing causing an increasing marginal gap, as well as various milling systems with various accuracy [9,10].

A computer-controlled universal testing machine was used to load samples to fracture. It can be supposed that all the tested samples could bear the maximal intraoral posterior forces of mastication. The variation of the physiologic maximum occlusal forces can differ up to 500 Newton based on the morphology of the face as well as age. It has been demonstrated by the outcomes reported from numerous studies that the mean force of loading varied from 50 to 250 N, meanwhile within the parafunctional movements including bruxism and clenching the loads ranged between 500 and 800 N. [11,29].

It has been demonstrated by the results of marginal fit that a high discrepancy in marginal adaptation between the two designs was evident. It was found that the marginal fit of the shoulder finish line design recorded significantly lower mean values (better adaptation) than the chamfer finish line design (worst adaptation). This can be explained by the additional surface area for bonding as well as the adequate internal support of the shoulder finish line which led to better marginal adaptation than minimal invasive chamfer. It has been reported by many researchers that a shoulder design is preferred over other configurations of the finish line[30,31]. Moreover, studies by other investigators [32,33] demonstrated that minimal-thickness finish lines led to remarkably wider marginal gaps than the shoulder.

It was revealed by the results of fracture resistance that the shoulder design had higher significant fracture resistance mean value than the minimally invasive chamfer. This may be explained by the fact that the shoulder provides more support to the occlusal veneers and exposes more enamel at the margins increasing surface area for bonding and improving fracture resistance. [34] While in the minimally invasive chamfer design, there is less enamel exposed at the margins which decrease surface area for bonding which in turn decreases the fracture resistance, in addition to that thinner finish lines are generally contraindicated for all-ceramic restorations as they trigger wedging effect at the margins [35]. This results in agreement with Carl H et al. (2019) [36] and, Lorio et al. (2011) [37], who found that the shoulder design showed the highest fracture resistance mean value while the chamfer one recorded the lower mean value. To a statistically significant degree, the configuration of the finish line affected the fracture resistance for ceramic posterior occlusal veneers. On the contrary, this result is not in agreement with, Jalalian et al. (2011) [38], Hassan and Mekkawi (2020) [39], Jalalian and Aletaha (2011) [40]

From the previous results and discussion, the hypothesis of the current study was rejected.

There may be some possible limitations in this study that the samples were exposed to cyclic thermal changes only which is one of the numerous factors in the environment of the oral cavity. As well as the forces in the oral cavity are put through a different type of stress analysis.

Within the limitations of this study, the following conclusions can be drawn:

1. The tested occlusal veneers of CEREC Tessera lithium disilicate ceramic material proved to withstand normal average masticatory forces.
2. Marginal gap of both preparation finish lines fell within clinically acceptable limits of marginal opening.
3. The shoulder finish line design showed significantly more resistance to fracture and a more appropriate marginal fit than the chamfer finish line design.

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