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EFFECT OF PREPARATION DEPTH ON THE FRACTURE RESISTANCE OF TWO MONOLITHIC CERAMIC LAMINATE VENEERS

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ABSTRACT

Aim: This study aims to measure and compare the fracture resistance of two CAD/CAM monolithic ceramic veneers with and without dental preparation.

Materials and methods: Twenty-eight extracted mandibular premolars were selected and randomly assigned into four groups (n = 7): Group NP/ED = No preparation with 0.3 mm thick ceramic veneer (IPS e.max CAD); Group P3/ED = Tooth preparation with 0.3 mm depth and 0.3 mm ceramic veneer (IPS e.max CAD); Group NP/TT = No preparation with 0.3 mm thick ceramic veneer (Top translucent zirconia, Upcera); and Group P3/TT= Tooth preparation of 0.3 mm and 0.3 mm ceramic veneer (Top translucent zirconia, Upcera). In all groups, the veneers extended 1 mm to the occlusal surface of the buccal cusp. All the preparations were digitally scanned, and the veneers were milled using CAD/CAM milling machine. After surface treatment and cementation of veneers, all groups were thermocycled (2000 cycles, 5°C–55°C) and subjected to fracture resistance test under the occlusal compressive load at cross-head speed 0.5 mm/min. The failure mode analysis was inspected at X 25 maginifications. Data were statistically analyzed with one-way analysis of variance (ANOVA), followed by post-hoc test for pairwise comparison of the groups, Differences were considered significant at $P<0.05$.

Results: The mean fracture resistance (M±SD) was 436.71± 63.68 in NP/ED, 561.43±88.21 in P3/ED, 458.57±46.70 in NP/TT, 582.86±66.51 in P3/TT. There were significant differences in the mean values of fracture resistance between the groups ($P \leq 0.001$). NP (no preparation) showed mean fracture resistance values significantly lower than P3 (0.3 dental preparation depth) groups irrespective to the ceramic veneering material type. However, ED veneers showed non-significant differences mean fracture resistance values lower than TT veneers irrespective to the preparation depth. Cohesive failure mode (laminate fracture) was predominant in P3/ED group. While mixed failure was common in NP/ED group. On the other hand, in both NP/TT and P3/TT (translucent zirconia veneer groups), showed more adhesive failure. Root fracture is uncommon in all groups.

Conclusions: Preparation within the enamel is necessary to increase the fracture resistance of the veneered premolars. The type of ceramic material had an impact on the failure mode of laminate veneers.

KEYWORDS: Ceramic veneer, translucent zirconia, lithium disilicate, fracture resistance, failure mode

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INTRODUCTION

Patients are more concerned about dental aesthetics, as well as a healthy, conservative, and harmonious dentition. Because of their superior aesthetic characteristics and translucency, ceramic veneers have become a popular treatment modality for conservative aesthetic restorations [1, 2]. Mainly, veneers are indicated in cases of discoloration, fracture, and congenital malformations of anterior teeth, but they can also be suggested in posterior teeth due to increased esthetic needs by the patients [3].

Thorough treatment planning and proper teeth preparation are essential for maximum performance and esthetics of laminate veneer restorations [4]. Ceramic laminate veneer was introduced as an esthetic and prosthetic restoration which enables a significant proportion of the natural enamel to be conserved. However, some clinicians advocated placing veneers without any tooth preparation, as the absence of reduction eliminates the need for temporary restorations. Also, there is no finish line, which simplifies the impression technique [5]. On the other hand, over contouring and the liability of periodontal inflammation are considered the main disadvantages [6].

To achieve proper contours and better marginal adaptation, 0.3 to 0.5 mm intra enamel tooth preparation of the buccal surface is necessary to obtain an acceptable emergence profile, veneer strength, and restoration retention [7]. Furthermore, it is still considered a minimally invasive preparation, and the restorations may have better bonding to enamel, as well as less patient discomfort and sensitivity. Deep dental preparations (greater than 0.5 mm) might expose dentin in the cervical third [4] and the possibility of the restoration's failure will be increased [8].

Selection of a suitable ceramic material for laminate veneer restorations is also important to ensure their long-term clinical success [9]. To enhance shape, color, anatomy, and teeth position, many materials and techniques have been available for the restoration fabrication [10]. The minimally invasive preparation designs using CAD/CAM technology was shown to be a successful treatment choice based on the evidence from the dental literature [11]. With minimally invasive preparations or no preparations, lithium disilicate glass-ceramics can be used to construct veneers of thin thicknesses [12]. These ceramics have high fracture toughness and excellent optical properties [13]. Moreover, it revealed better adhesion to resin cement through the conditioning with hydrofluoric acid and silanization [14]. On the other hand, high translucent zirconia ceramics have introduced recently with high fracture strength and can be used in manufacturing veneers and ultrathin veneers [15]. However, because zirconia is polycrystalline and cannot be etched with hydrofluoric acid, it is less efficient in bonding with resin cement compared with silica-based ceramics [16]. Therefore, several zirconia surface treatments have been tried to improve adhesion with resin cement and reduce the risk of veneer debonding [15, 17].

Fracture resistance should be considered in the selection of ceramic veneering material, especially in the posterior teeth, to achieve proper stress distribution during mastication, which affects the durability of the restoration [11, 18]. Furthermore, the ceramic veneer thickness and the tooth preparation depth play a significant role in the fracture resistance and the clinical performance of laminate veneer restorations [18].

Consequently, the aim of this study was to compare the fracture resistance of two CAD/CAM monolithic ceramic veneers with and without dental preparation. The null hypothesis was that: (1) the preparation depth as well as (2) the type of ceramic veneering material would affect the fracture resistance of the laminate veneer restorations.

MATERIALS AND METHODS

Twenty-eight extracted mandibular premolar teeth for periodontal or orthodontic reasons were used in the study. The teeth should be sound and free from caries or cracks. Any calculus or soft tissue debris was removed and cleaned, then stored at room temperature in saline.

To simulate the periodontal ligament, each tooth was marked on the root surface two mm below the cemento-Enamel Junction (CEJ) and the root part was dipped into molten wax to the marked depth. A 0.2 to 0.3 mm wax spacer approximating the average thickness of the periodontal ligament was obtained [19]. An auto polymerizing resin was mixed and poured into a Teflon mold where the tooth inserted vertically in the resin till the 2 mm mark on the root. After the first signs of polymerization, the tooth sample was removed from the resin and the wax spacer was eliminated by a hot water. Light body silicon-based impression material (Speedex, Coltène whaledent, Switzerland) was injected into the resin mold and the tooth was reinserted in the same position. After setting, the excess of the impression material out of the acrylic block was removed with a sharp scalpel.

Two types of monolithic ceramic veneering materials were used in this study: Lithium disilicate glass ceramic ED (IPS e.max CAD, Ivoclar Vivadent, Schaan, Liechtenstein, Germany) and translucent zirconia TT (Top translucent zirconia, Upcera, Shenzehn, Guangdong, China). Also, two types of preparation depths involved in this study: a. (NP): No preparation with 0.3 laminate veneer thickness on the buccal surface and extended 1 mm on the occlusal surface of the buccal cusp. b. (P3): Prepared teeth with 0.3 mm depth on the buccal surface and 0.3 occlusal reduction of the buccal cusp. The veneer thickness was 0.3 mm on the buccal surface and extended 1 mm on the occlusal surface of the buccal cusp (figure 1).

Samples grouping:

All teeth samples were divided randomly into four groups (N=7) according to the ceramic veneering material and the depth of preparation on the buccal surface of lower premolars:

Group 1: NP with ED (IPS e.max CAD).

Group 2: P3 with ED (IPS e.max CAD).

Group 3: NP with TT (Top translucent zirconia, Upcera).

Group 4: P3 with TT (Top translucent zirconia, Upcera).

Teeth preparations

The preparation of 14 mandibular premolar teeth were done with the same operator. A putty silicone index (Speedex, Coltène whaledent, Switzerland) was fabricated for each tooth in group 2 and 4

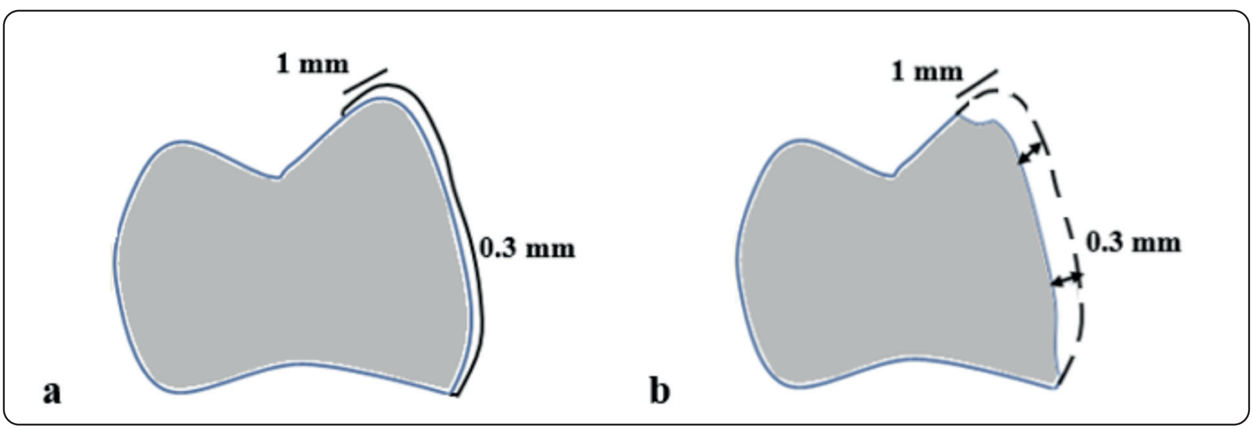

Fig. (1): Veneer thickness and preparation design of experimental groups: [a] NP (GP;1 and 3), [b] P3(GP; 2 and 4). A continuous line denotes the veneer thickness, and a dotted line is the preparation depth to evaluate the amount of tooth reduction. For preparation standardization, 0.3 mm depth cut wheel diamond stone was used. The teeth were prepared using a high-speed contra angle with cooling under a magnifying loupe (3.5x). The preparation started with the corresponding depth cutter across the buccal surface horizontally then, the depths were marked by a pencil. A round end tapered diamond stone was used to complete the buccal preparation until reaching the marked depth to obtain a precise and uniform thickness reduction. The preparation was extended 1 mm occlusally.

Fabrication of laminate veneers

The 28 teeth samples of all groups were digitally scanned using the InEos X5 scanner (Dentsply Sirona, Bensheim, Germany) and saved. Then, the data was sent to a Sirona inLab MC X5 (Dentsply Sirona) CAD/CAM machine. The standardized veneer design was performed for lower premolars of each group using the machine software, then milling was done for fabrication of all veneer restorations.

The fourteen fabricated CAD/CAM lithium disilicate (IPS e.max CAD) ceramic laminate veneers were fired in a ceramic furnace (Ivoclar Vivadent) to obtain the desired properties of esthetics and strength. While the fourteen translucent zirconia veneers were prepared by milling blanks of Upcera top translucent (TT) zirconia with 20% larger sizes. Then the veneers were sintered in a special sintering furnace (InFire HTC speed; Dentsply Sirona) according to manufacturer instructions. The veneers thickness of each group was checked and verified using a digital caliper. In each group, the veneers were tried in their corresponding teeth. The veneers were cleaned using rubber cups and pumice paste.

Cementation of laminate veneers (figure 2):

For the two groups of ED (IPS. e.max CAD), the fitting surfaces of laminates were etched using 9.5% hydrofluoric acid gel (Porcelain Etch, Ultradent, USA) for 20 seconds, then, washed thoroughly with air/water spray for 30 seconds. They were then dried using compressed air and ultrasonically cleaned with distilled water for 5 minutes. A silane coupling agent (Ultradent Products, Inc USA) was applied onto the inner surfaces of the veneers and waited for 60 seconds, then air dried before cementation. For the other two groups of TT (Upcera top translucent zirconia), the bonded surfaces of laminates were surface treated with airborne particle abrasion for 10 s at 0.2 MPa pressure using 50 µm AL_2O_3 particles, followed by application of ceramic primer [20] (iTENA C-RAM BOOSTER, France).

The buccal surface and the one mm of the occlusal area of all teeth were etched using 37% phosphoric

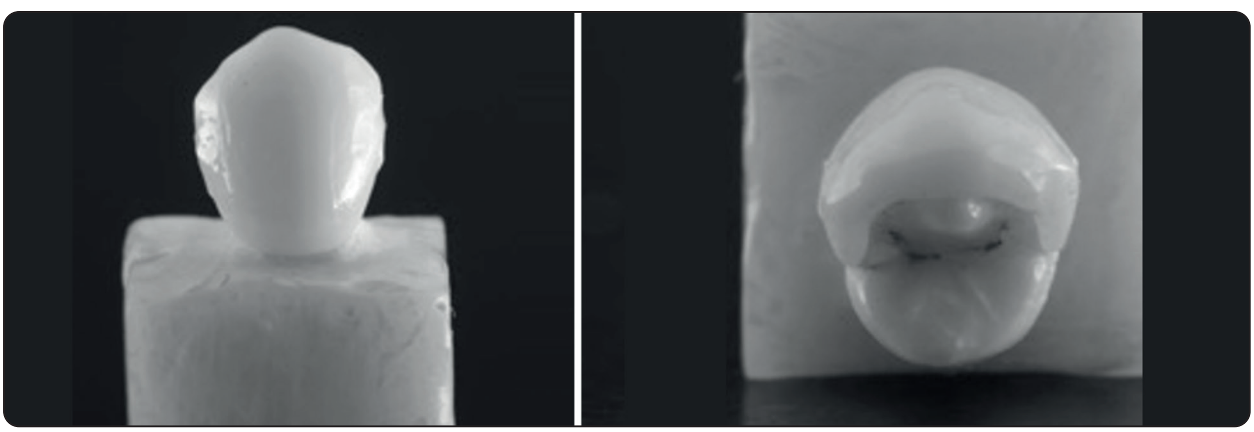

Fig. (2): Cemented Specimen

acid gel (Ivoclar Vivadent AG, Liechtenstein) for 30 seconds, rinsed by water spray, then dried with oil free air spray. A light cured bonding agent (ADHESE Universal, Ivoclar Vivadent AG, Liechtenstein) was applied using disposable brush to both the tooth surface and the veneer restorations, air thinned. A dual-curing resin cement (Multilink Automix; Ivoclar Vivadent) was applied to the intaglio surface of veneers, then, fitted to the buccal area of the tooth. A light finger pressure was exerted on the restoration and the excess resin luting agent was carefully removed at the margin area. Light curing was performed to the buccal and occlusal surfaces for 40 seconds using a light curing unit.

Thermocycling

To simulate aging, all specimens were received thermocycling using a thermocycler (Robota automated thermal cycle; BILEGE, Turkey). They undergo 2000 cycles of water baths at 5º and 55ºC with a 5 second dwell time [11].

Fracture resistance test

Each sample was mounted on universal testing machine (Model 3345; Instron Industrial Products, Norwood, MA, USA) and secured to its lower fixed partition. Fracture resistance test was done by applying a compressive load occlusally at the buccal surface of veneers. The load was applied using a metal rod with a spherical tip diameter of 5.6 mm and a tin foil sheet was introduced between the rod and occlusal surface to allow a consistent stress distribution. The load was performed, at cross-head speed 0.5 mm/min, until failure which manifested by a complete or partial fracture of the samples. The load required to fracture was recorded in Newton (N).

Failure modes:

For each specimen after loading, the mode of fracture was inspected using a digital microscope (Scope Capture Digital Microscope, Guangdong, China) at × 25 magnifications and classified as follows [21]: a) laminate veneer fracture (cohesive failure), b) debonding of laminate veneer (adhesive failure), c) mixed (adhesive and cohesive failure), and d) root fracture.

Statistical analysis:

Statistical package for Social Science (SPSS) version 22.0. was used to perform the statistical analysis. Data were recorded and the fracture resistance mean values were analyzed with one-way analysis of variance (ANOVA) to compare between groups with a 5% significance level, followed by post-hoc test for pairwise comparison of the groups, when the ANOVA test is positive. Differences were considered significant at $P<0.05$. The numbers and percentage of types of failures were assessed.

RESULTS

The mean values and standard deviation of fracture resistance of the tested groups in (N) regarding the preparation design and the ceramic material type are represented in table (1) and graphically drawn in figure (3). ANOVA showed significant differences between the groups ($P \leq 0.001$). The mean fracture resistance (M±SD) observed was 436.71± 63.68 in NP/ED, 561.43±88.21 in P3/ED, 458.57±46.70 in NP/TT, and 582.86±66.51in P3/TT.

Regarding to the preparation depth, NP (no preparation) showed mean fracture resistance values significantly lower than P3 (0.3 dental preparation depth) groups either for ED lithium disilicate (E-max) or TT translucent zirconia laminate veneer groups, However, as regard to the ceramic veneering material type, ED showed non-significant differences mean fracture resistance values lower than TT either between NP or P3 groups (table 2).

TABLE (1): Descriptive statistics of fracture resistance of laminate veneers according to preparation design and ceramic material type with One-way ANOVA test results

No	Groups	N	Mean (M)	Std. Dev. (SD)	Std. Error	Min.	Max.	F	p-value
1	NP/ED	7	436.71	63.68	24.070	350	550	8.08	0.001
2	P3/ED	7	561.43	88.21	33.340	420	680		
3	NP/TT	7	458.57	46.70	17.651	380	520		
4	P3/TT	7	582.86	66.51	25.139	480	680		

Data expressed as mean ± SD, F=one way ANOVA test

TABLE (2): Tukey post hoc test for comparison within the groups

(I) Group	(J) Group	P-value
NP/ED	P3/ED	0.011*
	NP/TT	0.930
	P3/TT	0.003*
P3/ED	NP/TT	0.043*
	P3/TT	0.934
NP/TT	P3/TT	0.011*

**** The mean difference is significant at ≤ 0.05 level.***

The percentage of each type of failure in each group is presented in Table (3). Cohesive failure mode (laminate fracture) was predominant in P3/ED group. While mixed failure was common in NP/ED group. On the other hand, in both NP/TT and P3/TT (translucent zirconia veneer groups), showed more adhesive failure. Root fracture is uncommon in all groups.

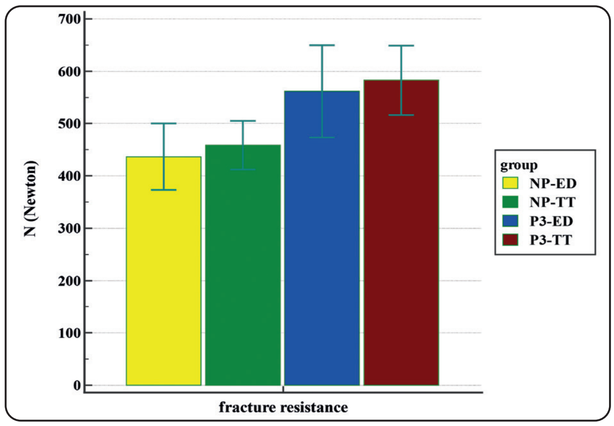

Fig. (3): A bar chart representing the mean values of fracture strength (N) in the different experimental groups

Table (3): The percentage of failure mode observed in each group

No	Groups	(a) Cohesive	(b) Adhesive	(c) Mixed	(d) Root fracture
1	NP/ED	2 (28.5%)	-	5 (71.5%)	-
2	P3/ED	4 (57.2%)	-	2 (28.5%)	1 (14.3%)
3	NP/TT	1 (14.3%)	4 (57.1%)	1 (14.3%)	1 (14.3%)
4	P3/TT	2 (28.5%)	3 (42.9%)	1 (14.3%)	1 (14.3%)

DISCUSSION

Clinical performance of laminate veneers over time is determined by a variety of parameters, including the mechanical strength of the restorative material and the bonding features. The increased esthetic demands dictate the minimally invasive esthetic ceramic restorations. Therefore, the scientific research has been directed on such ceramic materials especially lithium disilicate and translucent zirconia.

Premolars were chosen for this investigation because of the growing patient demand for aesthetics involving the posterior teeth, and few studies have examined the fracture resistance of laminate veneer on mandibular premolars. Depth cutting bur was used to standardize the preparations in the prepared specimens to make sure uniform and even reduction. The reduction depth was 0.3 mm to ensure that all preparations were limited to enamel, resulting in better bonding.

In this study, the effect of two preparation designs; non-prep and 0.3 mm preparation depth on the fracture resistance of two CAD/CAM monolithic ceramic veneers was assessed.

The (NP) no-prep veneers resulted in significant lower fracture resistance values than ceramic veneer associated with a tooth preparation of 0.3 mm (P3) for either ED or TT groups. So, the first null hypothesis was accepted. The results were consistent with the results of Linhares et al. (22) who explained that the enamel reduction at any depth is required to remove the aprismatic enamel, which increases the bond strength of resin cement to the enamel surface and increases the fracture resistance of the restoration. As well, bond strength to the non-prepared enamel is found to be lower by 15% than the prepared enamel (23). Furthermore, Magne (9) and Belser stated that tooth preparation is necessary to improve the fit of the ceramic laminate veneer and avoid ceramic over contour. Shaini et al (24) in their retrospective study concerning the clinical performance of ceramic veneers, concluded that the survival rate of ceramic laminate veneers was lower in cases where adhesive cementation was applied on non-prepared teeth. On the contrary, Smielak et al (25) in their prospective comparative analysis study found that the survival rate of no-prep veneers surpassed that of traditional veneers over a 9-year observation period.

The results of this study also showed that translucent (TT) laminate veneer ceramic had a higher non-significant difference in the fracture resistance mean values than lithium disilicate glass-ceramic (ED) irrespective to the preparation depth. Therefore, the second hypothesis was rejected.

Lithium disilicate glass ceramic is indicated in fabrication of laminate veneers due to its high mechanical properties (26). The presence of silica makes it an acid-sensitive ceramics. Acid etching of lithium disilicate ceramic creates surface pits and roughness, which allow strong adhesion between ceramic and resin cement. E-max CAD being a rigid ceramic material, it acts as a shield to the underlying tooth structure, which results in strengthening the tooth restoration complex (27).

Because of its high crystalline content, zirconia has high mechanical properties such as fracture resistance and flexural strength, allowing it to be used in minimally invasive restorations while conserving tooth structure. In vitro studies have revealed that fracture of zirconia is significantly higher than Lithium disilicate ceramic (28). However, the increasing amount of yttrium oxide in translucent zirconia to improve the optical properties can decrease the mechanical properties especially after aging (29). Malallah and Al Kazaz (30) in their study, concluded that aging significantly decreases the fracture strength of translucent zirconia laminate veneers while it doesn't affect the fracture strength of lithium disilicate veneers.

Regarding the analysis of failure mode, cohesive failure (laminate fracture) was found to be common in group (2), explaining the strong bond strength of lithium disilicate veneer (ED) to the prepared enamel. While, mixed failure (laminate fracture and deponding) was prevalent in group (1), which explained why (ED) had a lower bond strength to unprepared enamel compared with the bond strength with prepared enamel. In group (3) and (4) of translucent zirconia veneers (TT), adhesive failures were more predominantly. This type of failure demonstrated that zirconia bonding to tooth structure remains challenging. The percentage of catastrophic failure (root fracture) is less in all groups, owing to the preservation of as much tooth structure as possible, either by minimal tooth reduction without exposing dentin or no reduction at all.

CONCLUSIONS

Within the limitation of this in vitro study, it can be concluded that:

- Preparation within the enamel is necessary to increase the fracture resistance of the veneered premolars.
- No significant difference in the fracture resistance between translucent zirconia and lithium disilicate CAD/CAM ceramic laminate veneers.
- The type of ceramic material had an impact on the mode of failure of laminate veneers.

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