ABSTRACT

The purpose of this study was to evaluate the fracture load of two CAD/CAM ceramic veneer materials (IPS Empress CAD and IPS e-max CAD), with three different preparation designs (window, butt-joint, and incisal overlap).

Thirty maxillary anterior teeth were restored with ceramic laminate veneers and divided into 6 groups as follows: group I-A (laminates made of IPS Empress CAD with window preparation design), group I-B (laminates made of IPS Empress CAD with butt-joint preparation design), group I-C (laminates made of IPS Empress CAD with incisal overlap preparation design), group II-A (laminates made of IPS e-max CAD with window preparation design), group II-B (laminates made of IPS e-max CAD with butt-joint preparation design), group II-C (laminates made of IPS e-max CAD with incisal overlap preparation design). Fracture load test was performed using the Universal Testing Machine (UTM). Data were statistically analyzed using One-way analysis of variance ANOVA followed by Tukey’s multiple comparison test.

The results of the fracture load test were recorded in Newton: (I-A: 233.7 N); (I-B: 252.1 N); (I-C: 200.3 N); (II-A: 227.6 N); (II-B: 283.5 N); (II-C: 256.7 N). Statistical analysis showed that the result of the butt-joint design (II-B) was significantly higher than other subgroups, and regarding the materials used, the IPS e-max CAD was significantly higher than the IPS Empress CAD material in fracture load test.

INTRODUCTION

The public’s demand for the treatment of unaesthetic anterior teeth is steadily growing. Accordingly, several treatment options have been proposed to restore the aesthetic appearance of the dentition. For many years, the most predictable and durable aesthetic correction of anterior teeth has been achieved with full crowns. However, this approach is undoubtedly the most invasive, requiring removal of large amounts of sound tooth structure and resulting in possible adverse effects on the pulp and adjacent periodontal tissues.
In search for more durable aesthetics, porcelain veneers have been introduced. The porcelain laminate veneers are considered as an integral part of esthetic dentistry where stained, mottled, malformed and misaligned teeth are now restored with excellent esthetic results. The laminate veneers are thin ceramic shells that are bonded to the labial surface of anterior teeth.

Many factors influence the long-term success of porcelain veneers, such as tooth surface, porcelain thickness, type of luting agent, marginal adaptation, periodontal response, tooth morphology, functional and parafunctional activities (1).

There are limited studies concerning the design and thickness of the preparation. Regarding the design of the preparation, basic types have been described: the window, the butt-joint, and the incisal overlapped preparation (2). As far as the thickness of preparation is concerned, the early concepts suggested minimal or no tooth preparation. Nevertheless, current beliefs support removal of varying amount of tooth structure, especially when mild malposition correction is aimed (3).

One of the controversial topics regarding porcelain laminate veneers is the geometry of preparation (4, 5). There is no agreement regarding the use of any design of the three preparation designs (window, butt-joint, and incisal overlap).

Consequently, this study was undertaken to evaluate the effect of three different preparation designs and two CAD/CAM ceramic materials on the fracture resistance of ceramic laminate veneers.

### MATERIALS AND METHODS

Thirty human maxillary teeth with no decay or restorations, extracted for periodontal reasons, were selected. Dental plaque, calculus, and periodontal fibers were removed. The specimens were divided into 2 main groups (laminate veneers fabricated from IPS Empress CAD ceramic blocks “group I” and laminate veneers fabricated from IPS e-max CAD ceramic blocks “group II”) and each group was subdivided into 3 subgroups (window, butt-joint, and incisal overlap preparation designs), as shown in table (1).

The thirty teeth were mounted individually in special molds (2.5 cm height □ 2 cm diameter) with epoxy resin, with the long axis parallel to the center of the mold. Each tooth was suspended in the middle of the mold using a Ney Surveyor to ensure vertical positioning of the tooth inside the mold, as follows: an analyzing metal rod of the Ney Surveyor was fixed to the center of the incisal edge of each tooth and along its long axis using sticky wax, and then it was attached to the vertically moving arm of the surveyor. When the axis of the tooth was positioned correctly, epoxy resin was poured into the mold. All specimens were embedded up to 2mm below the CEJ to simulate the natural biologic width.

Silicone putty impressions were done on all of the teeth specimens before their preparation. These impressions were used as templates to evaluate the amount of tooth reduction. Blue inlay wax was poured to form veneers with uniform thickness of 0.5 mm. it was checked with a digital caliper.

<table>
<thead>
<tr>
<th>TABLE (1) Groups and subgroups of this study.</th>
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<tbody>
<tr>
<td><strong>Preparation design</strong></td>
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<td></td>
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<tr>
<td><strong>Window</strong></td>
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<td><strong>Butt-joint</strong></td>
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<tr>
<td><strong>Incisal overlap</strong></td>
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</table>
Standardized preparations were done in the labial surface of all teeth. The reduction was guided by a diamond 3 wheel depth cutter wheel. By using this standardized diameter instrument, equal preparations were approximately of about 0.5 mm depth, the preparations were completed using a stones with round end. For the Window preparation: teeth were prepared labially up to the height of the incisal edge, but the edge was not reduced, for the butt-joint preparation: teeth were prepared with a 2 mm incisal reduction without palatal chamfer, and for the incisal overlap preparation: teeth were prepared with a 2 mm incisal reduction and 1 mm height palatal chamfer. Any sharp angles that might serve as a focal point for stress concentration were removed, particularly at the junction of the incisal line and point angles to both the labial and lingual surfaces.

To obtain a three dimensional image for each specimen (including both prepared tooth and its wax-up pattern) on the computer screen of the CEREC in- Lab (3.1) software system (Sirona Dental Systems, Bensheim, Germany), the following steps were performed: (1) The wax-up pattern was sprayed using the CEREC Propellant and powder mix to be scanned using the infra-red lens of the in-Eos machine (Sirona Dental Systems, Bensheim, Germany), then the captured picture was transferred to the occlusion catalogue in the software. (2) The corresponding prepared tooth was sprayed using the CEREC Propellant and powder mix to be scanned using the infra-red lens of the in-Eos machine, then the captured picture was transferred to the preparation catalogue in the software. (3) With the aid of both the CEREC inLab software (3.1) and the correlation option available, this allowed the wax-up to be correlated to the preparation in order to construct a virtual ceramic veneer identical to the scanned wax-up pattern. (6) Ceramic laminate veneer thickness was checked by the software in order to standardize the thickness of all samples.

Then, the milling process of the 30 samples started as follows: (1) The type of block (either IPS Empress CAD or IPS e-max CAD) as well as the size was selected and confirmed with “OK”. (2) The selected ceramic block of the required size was inserted in the spindle of the milling chamber of the CEREC in-lab machine and fastened with the set screw. This was followed by closure of the milling chamber door. (3) The milling process was fully automated without any interference with the two diamond stones acting together simultaneously in the shaping process, with copious water cooling sprayed from both directions. (4) Each design was milled five times of each ceramic material used in this study. (5) After completion of the milling process, the veneers were separated manually from the block holder with a diamond cutting instrument. (6) All laminate veneers were checked over their corresponding preparations (figure 1).

The IPS empress CAD ceramic laminates were fired in a one-step firing cycle using the ceramic furnace according to the manufacturer instructions, to obtain their maximum functional and esthetic results. While the IPS e-max CAD ceramic laminates, appear to be in their pre crystallized format after milling where they have the bluish-gray color. They were fired in a short 30 minutes firing cycle in a ceramic furnace. This process imparts the glass-ceramic with its final strength and esthetic properties. Glazing was then done to all laminate veneers.

Surface treatment of all laminate veneers was done using 5 % hydrofluoric acid gel (IPS Ceramic Refill) according to the manufacturer instructions for 60 seconds for IPS Empress CAD veneers and 20 seconds for IPS e-max CAD veneers. The laminates were then washed thoroughly with air/water spray for 30 seconds. They were then dried using compressed air. Then, all laminate veneers were primed for resin onto their inner surface using a silane coupling agent (Monobond-S) for 60 seconds, then air dried before cementation. Surface
treatment of the prepared teeth was also done using 37% phosphoric acid etching gel (Total-Etch) for 15-20 seconds, then the Adaper Single bond 2 Adhesive was applied for 20 seconds with a micro-brush on the etched enamel surfaces of all teeth.

A dual-cure composite resin luting agent (Rely X ARC) was used to lute the veneers. The paste and catalyst were mixed in a 1:1 ratio on a mixed paper pad for 10 seconds using a spatula according to the manufacturer’s instructions. A thin layer of the resin cement was applied to the center of the intaglio surface of the veneer. A light finger pressure was exerted on the restoration. The excess composite luting agent was carefully removed. Light curing was performed to the facial, palatal, and incisal surfaces for 40 seconds according to the manufacturer’s instructions, using a light curing unit (GNATUS, Optilight Digital. Brazil).

Each specimen along with the epoxy mold was fitted in a specially designed mounting device that allowed the tooth to be loaded from the incisal direction at an angle of 135° to the long axis of the tooth. This was done to simulate the clinical situation as closely as possible. A layer of tin foil (2 mm) was placed on the incisal edge of each tooth to perform a generalized load (figure 2).

The fracture load test performed using a Universal Testing Machine (Model LRX-plus; Lloyd Instruments Ltd., Fareham, UK). Load was applied at a crosshead speed 1.0 mm/min with a custom load applicator (steel rod with a flat end 3.6 mm diameter, placed at the incisal edge of each tooth) attached to the upper movable compartment of the machine. The maximum load to produce fracture for each specimen was automatically recorded in Newton (N) using computer software (Nexygen-MT; Lloyd Instruments).

**RESULTS**

The fracture load values and standard deviations for all samples are indicated in table (2). In group I (IPS Empress CAD), the butt-joint design (subgroup B) showed the highest values (252.1 N), followed by the window design (subgroup A) (233.7 N), and the lowest values were observed in the incisal overlap design (subgroup C) (200.3 N). While, in group II (IPS e-max CAD), the butt-joint design (subgroup B) showed the highest values (283.5 N), then the incisal overlap design (subgroup C) (256.7 N), and the lowest values were observed in the window design (subgroup A) (227.6 N).

Data analysis was performed in several steps. Initially, One-way analysis of variance ANOVA followed by Tukey’s multiple comparison test to evaluate the significance between subgroup, separate analysis was performed with t-test between subgroup. A two factorial analysis of variance ANOVA was used to examine effects...
TABLE (2) Fracture resistance (Mean ± SD) for both ceramic materials according to the preparation designs.

<table>
<thead>
<tr>
<th>Material</th>
<th>Preparation design</th>
<th>Mean</th>
<th>SD</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>IPS Empress CAD</td>
<td>Window</td>
<td>233.7</td>
<td>30.2</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Butt-joint</td>
<td>252.1</td>
<td>13.2</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Incisal overlap</td>
<td>200.3</td>
<td>12.2</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>228.7</td>
<td>27.5</td>
<td>15</td>
</tr>
<tr>
<td>IPS e-max CAD</td>
<td>Window</td>
<td>227.6</td>
<td>53.4</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Butt-joint</td>
<td>283.5</td>
<td>32.3</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Incisal overlap</td>
<td>256.7</td>
<td>26.8</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>255.9</td>
<td>43.3</td>
<td>15</td>
</tr>
</tbody>
</table>

DISCUSSION

For many years, the most predictable and durable aesthetic correction of anterior teeth has been achieved by the preparation of full crowns. However, this approach is more invasive with substantial removal of large amounts of sound tooth structure and possible adverse effects on the adjacent pulp and periodontal tissues. Due to the growing patient demand for esthetic restorations and more conservative trends in restorative dentistry, the use of porcelain veneers has become a widespread, reliable and successful technique for restoring discolored, worn, malformed or fractured teeth. Laminate veneers are among the most beautiful and long-lasting of all dental restorations.

In the present study, human central incisor teeth were selected for specimen fabrication to mimic the natural conditions as they have flat labio-lingual width, and they are the most commonly restored teeth with laminate veneers.

Regarding the depth of the preparations, standardized labial reduction was done (0.5 mm), to ensure the whole
preparation confined into enamel. This allows better bonding, higher strength, less leakage, and excellent color matching without overcontouring (3,10,11,12).

Early concepts regarding the preparation of teeth for laminate veneers suggested minimal or no preparation to allow for the minimal thickness of porcelain (13). Nowadays, these concepts have been changed and supported the removal of varying amount of tooth structure (3,14).

In this study, three frequently preparation designs for veneers were selected in this study. The designs were: (A) window preparation design, teeth were prepared labially, but the incisal edge was not reduced. (B) butt-join preparation design, teeth were prepared with a 2mm incisal reduction without palatal chamfer. (C) incisal overlap preparation design, teeth were prepared with a 2mm incisal reduction and 1 mm height palatal chamfer.

Although some researchers (9,10,15) used gum resin of different impression materials as a simulation of periodontal ligament in their studies. It was not used in this study because the progressive load applied on the coronal portion of the embedded tooth would not have been mitigated by the interposition of a softer medium between the root of the tooth and the surrounding epoxy resin. Therefore, it was not necessary to use (3,16,17).

In this study, laminate veneers were fabricated from two ceramic materials; IPS Empress CAD and IPS e-max CAD. IPS Empress CAD is a highly esthetic leucite reinforced glass ceramic available for the CEREC systems. It was chosen as it is the ideal material for all veneers, crowns, inlays and onlays, featuring a natural appearance in shade, translucency and fluorosence (18). While, IPS e-max CAD is lithium disisiclate glass ceramic. It is used for its unique combination of strength (360 Mpa) and esthetic properties as natural tooth color, excellent translucency and brightness (19,20).

The CAD/CAM technology was used in this study, as we used the CEREC inLab milling machine for fabrication and milling of our laminate veneer specimens, for its several advantages; increased quality in a shorter period of time, reduced hazards of infectious cross-contamination associated with conventional multi-stage fabrication of indirect restorations (21).

Laminate veneers were treated with hydrofluoric acid, as the microstructure of the ceramic is changed by the hydrofluoric acid attack of the glassy phases of dental porcelain. This phase is dissolved preferentially to create pores and grooves which result in an appropriate microstructure for bonding. Because the ceramic has components bondable to silane such as silica, the cementation process can be enhanced by application of silane coupling agent. These agents are capable of forming chemical bonds between the inorganic phase of the ceramic and the organic phase of the resin (3,22,23).

Surface treatment of the prepared tooth structure was also essential to enhance the bonding process.

In this study Rely X-ARC, a dual cure adhesive resin was used for cementation of laminate veneers to prepared teeth, as it’s indicated for cementing esthetic indirect restorations. This cement provides high bond strengths to the tooth and restoration to allow the needed retention.

In order to simulate the clinical condition as closely as possible, the specimens were mounted onto a specially designed mounting device and a 2 mm layer of tin foil was placed on the incisal edge of each tooth specimen to perform a distributed load. Load was applied at a 135˚ angle at a cross head speed of 1 mm/min in an incisal direction using the Universal Testing Machine.

The results of our study showed significant differences in the butt-join preparation design compared to other subgroups. Some researchers agreed with this result and justified that it as the butt-join configuration permitted the preservation of the peripheral enamel layer around all margins, especially at the palatal surface which is ef-
fective in tooth-ceramic bonding and counteracting the shear stresses\(^{(3)}\). Another study, reported that the butt-joint preparation design was preferred for laminate veneers as it increased the ratio between ceramic and luting composite thickness and therefore prevented cracks after loading \(^{(15)}\). Also it was preferred because it provided adequate ceramic thickness at the incisal edge, improved translucency of the restoration which is an important factor for laminate veneers, and made the seating of laminate veneers easier during cementation \(^{(26)}\).

The incisal area and the cervical margin are confirmed to be the weakest link of a prosthetically prepared tooth. Even being the butt-joint preparation design a more invasive technique than the window preparation design, but it provided an incisal margin completely made up of ceramic, so limiting the stresses transferred to the cement layer and then to the tooth, this means a more favorable geometry for stress distribution than the window preparation design \(^{(1)}\).

However, a clinical study showed no correlation was found between the survival rate and different incisal preparation designs \(^{(4,8)}\).

The average masticatory forces in the anterior region vary between 155 N and 200 N \(^{(11,25)}\). The results of the current study exhibited mean values ranging between 200.3 N and 283.5 N, indicating that both types of ceramic materials and all three different preparation designs of laminate veneers used could be considered strong enough to withstand anterior forces.

**CONCLUSIONS**

- Ceramic veneers with butt-joint preparation design were the strongest and showed the highest values in the fracture load test.
- Both ceramic materials used in the fabrication of laminate veneers are strong enough to withstand anterior biting forces.

**REFERENCES**


