Original Article

An *in vitro* comparison of incisal preparation design on load-to-failure of ceramic veneers

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Abstract

Introduction: This *in vitro* study aimed to compare the load-to-failure values of two different ceramic veneers (IPS e.max Press [Ivoclar Vivadent] and Vintage lithium disilicate [LD] press [Shofu]) with incisal preparation designs under standardized conditions.

Materials and Methods: Twenty-two intact extracted maxillary incisors were selected and divided randomly into two groups ($n = 11$). The veneer tooth preparation was standardized in both groups where a butt joint incisal preparation was done along with chamfer margin. Group 1 included veneers made from IPS e.max Press (Ivoclar Vivadent) and Group 2 included veneers fabricated from Vintage LD Press (Shofu). Veneers were luted to their respective abutment teeth using standardized bonding protocols and resin cement for both groups. Later, every specimen was loaded to failure utilizing a universal testing machine, and the outcomes were noted in Newtons (N).

Results: The mean load-to-failure value obtained for Group 1 (IPS e.max Press) was 1386.46 N while that obtained for Group 2 was 1777.07 N. Statistically significant difference was found in this intergroup comparison ($P = 0.006$).

Conclusion: The load-to-failure value of Vintage LD Press veneers (Shofu) was greater than that of IPS e.max Press veneers (Ivoclar Vivadent).

Keywords: Butt joint incisal preparation; ceramic veneers; IPS e.max Press; load-to-failure; vintage lithium disilicate press

INTRODUCTION

One of the most important and challenging procedures for dentists is the re-establishment of a patient's lost dental esthetic appearance. There are various treatment modalities to correct these anomalies using direct or indirect techniques such as full-coverage crowns or laminate veneers. There is a rising prevalence in the use of veneers which are more conservative as compared to the full-coverage crown prosthesis. Veneers are commonly used in cases of extreme discoloration, such as those caused by tetracycline staining, fluorosis, and age-related darkening, small enamel defects such as microcracks, fractured, worn out teeth or malpositioned teeth, multiple spacing between the teeth, teeth with developmental anomalies such as amelogenesis imperfecta, and abnormally shaped teeth such as peg laterals and rotated teeth.[1]

Ceramic veneers are susceptible to several types of failures, including debonding, fracture, and microleakage. Among these, fracture accounts for 67% of all recorded failures during the clinical observation period of up to 15 years.[2] It has been seen that incisal preparation design has a major impact on the fracture resistance of ceramic veneers.[3] Various studies have been undertaken to understand which tooth preparation design offers better retention and resistance form. According to Castelnuovo *et al*., the butt

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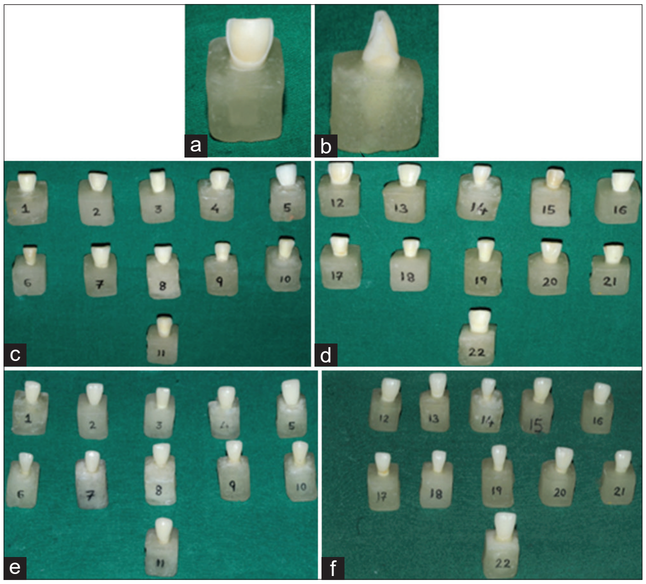

Figure 1: (a and b) Labial and proximal view of veneer tooth preparation, respectively (c and d) Veneer tooth preparation of samples in Groups 1 and 2, respectively (e and f) Ceramic veneer bonded to all samples in Group 1

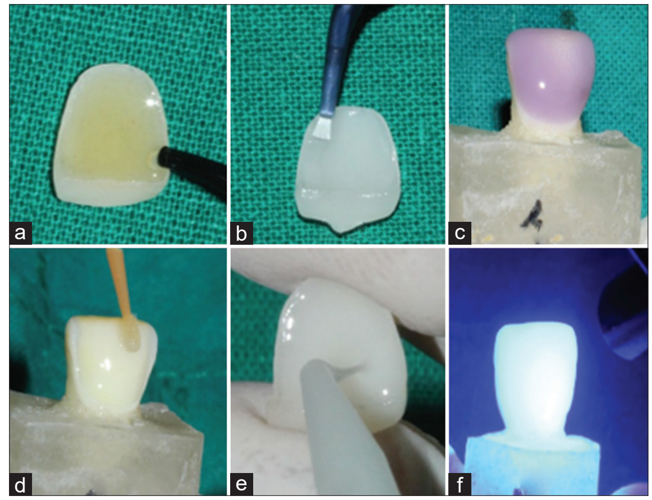

Figure 2: Steps in bonding of ceramic veneer to tooth sample (a) Application of 5% Hydrofluoric acid to intaglio surface of ceramic veneer (b) Application of silane coupling agent to veneer (c) Etching tooth surface with 37% phosphoric acid (d) Dentin bonding agent applied to tooth surface (e) Application of luting agent (dual cure resin cement) to veneer (f) Ceramic veneer tacked in place and light cured

joint preparation design demonstrated superior retention and resistance form in comparison to the incisal overlap design.[4] In addition, Arora *et al*. discovered that a butt joint design incorporating 2 mm of incisal reduction yielded higher fracture resistance for ceramic veneers than the incisal overlap design.[5] Chai *et al*. compared butt joint preparation with feather edge incisal preparation and showed that the latter had the least load-to-failure values.[3]

Hence, this study chose butt joint design for incisal preparation in both groups to Standardise the tooth preparation.

While there are a number of companies producing lithium disilicate (LD) ceramics for the fabrication of laminate veneers, this study conducted a comparative evaluation of load-to-failure of ceramic veneers fabricated using IPS e.max Press (Ivoclar Vivadent) and Vintage LD press (Shofu).

This *in vitro* study was conducted to compare the load-to-failure values of two different ceramic veneers (IPS e.max Press [Ivoclar Vivadent] and Vintage LD press [Shofu]) with incisal preparation designs under Standardised conditions.

The null hypothesis was that there is no difference in the load-to-failure values of the two ceramic veneers.

MATERIALS AND METHODS

This study received ethical clearance from the Institutional Ethics Committee (TDC/EC/27/2020). Minimum sample size calculated was 22 (11 per group) based on mean values obtained using G*Power 3.0.10 software (Franz Faul, Universitat Kiel, Germany). Twenty-two human permanent maxillary incisors were selected.

The criteria for sample selection were as follows: noncarious, intact, and unrestored maxillary incisors. Endodontically treated teeth and those with caries, fractures, attrition/abrasion, and enamel hypoplasia were excluded from the study.

The samples were cleaned using an ultrasonic scaler and stored in normal saline solution until use. All teeth were embedded in Standardised molds made of methacrylate resin, below the level of CEJ. All samples were randomly divided into two Groups, each containing 11 samples. Group 1 (IPS e.max, Ivoclar Vivadent) samples were numbered from 1 to 11, whereas samples of Group 2 (Vintage LD press, Shofu) were numbered from 12 to 22 [Figure 1].

Tooth preparation

All samples were prepared with butt joint incisal preparation. Using a straight fissure diamond bur (SF 41, Mani Inc., Japan), an incisal reduction of 1.5 mm was done such that a flat incisal surface was obtained. Using a self-limiting depth-cutting disk (DM-305, Mani Inc., Japan), grooves of 0.5 mm depth were made on the labial surface, which was merged with a tapered round diamond bur (TR 12, Mani Inc., Japan). Chamfer margins were obtained using fine-grit diamond point and Arkansas Stone (Dura White Stone, Shofu Dental, India) any unsupported enamel margin was removed, sharp line angles were rounded off and finishing of margins was achieved.

Veneer fabrication

Samples were sent to the dental technician laboratory where veneers of Group 1 were fabricated using IPS e.max Press ingots (Ivoclar Vivadent) and those of Group 2 were made from Vintage LD Press (Shofu) ingots.

Bonding of veneers to teeth

After veneer fabrication, their marginal fit was confirmed by placing them on their corresponding prepared teeth. The bonding protocols were followed alike, for both groups. Manufacturers' instructions were followed for the use of etchants and bonding agents. Following were the steps done for the veneer bonding [Figure 2]:

Surface preparation of ceramic veneer

The inside surface of veneer was etched with 5% hydrofluoric acid (CeraEtch, Prevest Denpro Ltd, India) for 90s. It was thoroughly rinsed with water and dried. This was followed by the application of a silane coupling agent (Silane X, Prevest Denpro Ltd, India) which was allowed to stay for half a minute before air dispersion.

Surface preparation of tooth

Prepared tooth surface was etched with 37% phosphoric acid (Prime Dental Products Ltd, India) for 15s, followed by thorough rinsing with water and drying, before the application of a 5^{th} generation bonding agent (Te-econom, Ivoclar Vivadent, Switzerland).

Application of luting cement

A thin layer of dual-cure adhesive resin (Calibra universal, Dentsply Sirona) was applied on the center of the inside surface of the ceramic veneer. The veneer was tacked in place on the tooth, following its path of insertion. All surfaces (facial, palatal, and incisal) were light-cured for 20s after the removal of excess cement. The samples were later stored in normal saline till further use.

Fracture testing

A universal testing machine (Instron Corp, Massachusetts, USA) with a maximum load of 5000 N was used. The specimens were mounted onto a jig to undergo loading at a 20° angle to the long axis of the tooth. The load was applied at incisal edge of the tooth at a crosshead speed of 1.0 mm/min until it fractured. The highest load required to produce a fracture was recorded in Newton (N) for each specimen.

Data management and analysis

Data entry was performed using Microsoft Excel Spreadsheet, and statistical analysis was conducted using SPSS software (Version 17.0, IBM, USA). The data were analysed using an unpaired Student's *t*-test, and the analysis was performed by a biostatistician.

RESULTS

The mean load-to-failure values were calculated for both the groups and a comparison was made between them. Descriptive statistics revealed higher load-to-failure values of Vintage LD press (Shofu) ceramic veneers as compared to IPS e.max Press (Ivoclar Vivadent). The mean load-to-failure value obtained for Group 1 (IPS e.max Press) was 1386.46 N while that obtained for Group 2 was 1777.07 N [Table 1] statistically significant difference was found in this intergroup comparison ($P = 0.006$).

DISCUSSION

Since conventional full-coverage crowns resulted in extensive tooth preparation, ceramic veneers became the treatment of choice as they require minimal tooth preparation and provide optimum esthetics.[6]

Beier *et al*. (2012) reported the survival rate of ceramic veneers as 94.4% after 5 years and 93.5% after 10 years and found that the main reasons for failure were ceramic fracture.[7] Layton and Walton also showed supporting results, which highlighted a survival rate of 96% after 10 years and 91% after 20 years.[8] Etemadi and Smales (2006) reported a survival rate of 95% for ceramic veneers throughout 7 years.[9]

It has been stated that the bond strength of porcelain with enamel is much superior to that with dentin or other restorative materials.[10] Hence, care was taken that the preparation design was restricted to the enamel.

Nattress *et al*. have suggested that free-hand tooth preparation may result in variable depths of preparation and exposure of dentin.[11] To minimise such variations, a 0.5-mm self-limiting depth-cutting bur was utilised for controlled tooth preparation. This approach was consistent with the recommended tooth preparation designs of various authors.[12,13]

During the functional jaw movements, the stress-bearing capacity at the palatal concavity areas and the incisal edge is lesser as compared to the cervical, mid-facial, and cingulum regions of the tooth. Tooth preparation design can modify the stresses that develop within veneers and teeth, thereby minimising the potential for failure.[6]

The two most common preparation designs provided are butt joint and feathered-edge, of which, the butt joint

Table 1: Mean load-to-failure values and standard deviation of Groups 1 and 2

Group	Mean	SD	*P*
1 - e.max press, Ivoclar	1386.45	381.83	0.006
2 - Vintage LD press, Shofu	1777.0745	803.38	

SD: Standard deviation

preparation design had the least debilitating effect on the strength of the tooth and veneer.[14] Butt joint design enables the preservation of the surrounding enamel layer at the margins. This results in improved resistance against shear stresses, better bonding between the tooth and ceramic, elimination of microleakage at the tooth-restoration interface, and more favorable stress distribution within the tooth.[15] Therefore, in this study, butt joint design was chosen for incisal preparation in both groups.

For the fracture testing of samples, Instron universal testing machine was used which provides a maximum load of 5000 N and a linear pattern of force application that best simulates the chewing force patterns.[14] A dynamic load was applied to the specimen where a constantly increasing force was exerted until fracture.

Some authors have applied a 90° load to the long axis of the tooth to assess the horizontal component of force[16,17] while others have examined the vertical component (0°).[18] In addition, some studies have utilised a loading angle of 135°, aligned with the orthognathic interincisal angle.[19,20]

However, none of these studies correlated with functional movements. The amount of force applied to the incisors during functional movements is largely determined by the interincisal angle (45°).[21] However, pretesting at a 45° loading angulation resulted in excessive bending force and tooth fracture before veneer failure.[3] As a result, the current study adopted a lesser loading angulation of 20° based on these findings. In the current study, by standardising other parameters such as tooth preparation design, type of ceramic material (LD), adhesive system, method of fabricating veneers, and direction and region of applied load during load-to-failure testing, a comparison of load-to-failure was made purely between two different ceramic veneers - IPS e.max Press (Ivoclar Vivadent) and Vintage LD press (Shofu).

According to a study conducted by RM Saleh *et al*. (2021), Shofu HC exhibited the highest fracture resistance when compared to IPS e.max CAD and Vita Enamic. The study attributed their success to the densely packed nanofiller embedded in 61% zirconium silicate which can better resist crack propagation. Moreover, their lower modulus of elasticity offers greater deformation and stress absorption.[22]

Contrary to the present study, a study performed by Ohashi *et al*. showed that the biaxial flexural strength of IPS e.max Press (Ivoclar Vivadent) was significantly greater than that of Vintage LD Press (Shofu).[23]

Within the limitations of present study wherein, materials and methods for tooth preparation, veneer fabrication and bonding were standardised for both groups, there was a significant difference observed in the load-to-failure values. This could be attributed to the variation in the microstructure of IPS e.max Press and Vintage LD Press. The former consists of about 70% lithium disilicate crystals (3–6 μm in length) while Vintage LD Press consists of more compactly interlocked acicular crystals of lithium disilicate embedded in a glass matrix. Moreover, the crystalline structure of porcelain also has an influence on light transmission and polymerisation of resin luting cement which may affect the load-to-failure values of bonded ceramic veneers. A study performed by Naliani et al showed that hardness of resin cement under Vintage LD press was more as compared to that under IPS e.max Press at same porcelain thickness.[24]

- Several limitations to the present study are as follows:
    - It was challenging to Standardise the bonded interface due to varying age and quality of extracted human maxillary incisors
    - Teeth were embedded in acrylic resin which did not simulate the periodontal ligament
    - Thermocycling was not performed which otherwise could have impacted the values of the fracture resistance
    - No comparison was made between different incisal preparations and loading angles.

CONCLUSION

Within the limitations of the present study, the following conclusion was made. The load-to-failure of Vintage LD Press veneers (Shofu) was greater than that of IPS e.max Press veneers (Ivoclar Vivadent). However, further research is needed to assess the load-to-failure of veneers bonded to teeth.

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Conflicts of interest
There are no conflicts of interest.

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