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ORIGINAL RESEARCH

The effect of different tooth preparation designs on fracture resistance of porcelain laminate veneers: An in-vitro study

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ABSTRACT

Background: Ceramic veneers, which are chosen to provide excellent esthetics, are a well-established treatment method for conservative esthetic restoration of malformed, discolored, maligned, traumatized, fractured and worn anterior teeth. **Objective:** The present study was undertaken to evaluate and compare the fracture load of ceramic laminate veneers with different preparation designs. **Material and method:** The present study was carried out to comparatively evaluate the fracture resistance of porcelain laminate veneers with different preparation designs. This in-vitro study was conducted in the department of Prosthodontics and Crown & Bridge, PDM Dental College and Research Institute, Sarai Aurangabad, Bahadurgarh, Haryana, India. 40 extracted human permanent maxillary central incisors were divided randomly into 4 groups comprised of 10 specimens each as: **Group I (Control group):** No tooth preparation; **Group II:** No incisal reduction with bevel preparation; **Group III**: 1mm of incisal reduction with butt preparation; **Group IV:** 1mm of incisal reduction with 1mm height of palatal chamfer. The fracture strength of each sample was recorded in Newton (N). **Result:** The mean values of the fracture resistance of porcelain laminate veneers with different preparation designs were compared. Group IV shows highest fracture resistance (1026.10) while Group II shows lowest fracture resistance (345.10). Highest mean fracture resistance value (815.10 N) was observed for Group IV i.e. 1mm of incisal reduction with 1 mm height of palatal chamfer. **Conclusion:** In conclusion, the type of preparation design affected the fracture resistance of porcelain laminate veneers, Group IV demonstrated highest fracture resistance amongst all the groups and Group II demonstrated lowest fracture resistance amongst all the groups. Incisal reduction with palatal involvement significantly increased the fracture resistance when compared to incisal reduction**.**

Keywords: fracture resistance, Incisal reduction, ceramic laminate veneers, fracture strength.

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INTRODUCTION

An established treatment option for conventional aesthetic repair of distorted discoloured, maligned, traumatized, cracked, and worn anterior teeth is ceramic veneers, which are selected for their exceptional aesthetic qualities.

Compared to crowns, laminate veneers are more conservative. They are made of ceramic that is 0.5–1.0 mm thick and is resin cement-bonded to either prepared or unprepared teeth, allowing for improved translucency. Resin-bonded veneers are a great treatment option with a growing list of applications because of their excellent clinical efficacy, brilliant aesthetics, and low invasiveness. The labial surface must be evenly reduced by 0.5 mm within the enamel in order to prepare the porcelain laminate veneer.[1]

The literature describes several veneer preparation designs that involve the incisal edge of the abutment tooth. These include a palatal chamfer that extends into the palatal surface through a chamfer preparation, a feathered incisal edge (window) with a thin ceramic layer up to the incisal edge, butt joint, or incisal bevel with involvement of the incisal edge in ceramic.[1] In a few investigations, it was discovered that incisal

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reduction decreased stress concentration and that incisal coverage offers a broad vertical stop that resists vertical loads and serves as a protective factor.[2, 3]

However, incisal coverage was found to be a risk factor for failures in other investigations.[4,5] The best preparatory design, whether or not incisal covering is used, and the kind of palatal design (butt joint or palatal chamfer) are all up for debate.[6] One of the most argumentative issues pertaining to the fracture strength of porcelain veneers is still the geometry of the preparation itself. The repaired tooth's load tolerance increases with the conservativeness of the preparation geometry.

if a particular arrangement of tooth preparation is better than another or if it can impact the fracture strength of ceramic veneers is still up for debate. In order to assess and compare the fracture load of ceramic laminate veneers with various preparation schemes, the current study was conducted.

MATERIAL AND METHOD

Study Design

The present study was carried out to comparatively evaluate the fracture resistance of porcelain laminate veneers with different preparation designs. This in-vitro study was conducted in the department of Prosthodontics and Crown & Bridge, PDM Dental College and Research Institute, Sarai Aurangabad, Bahadurgarh, Haryana, India. The fracture resistance testing was carried out at Spectro Analytical Lab Ltd, Okhla Industrial area, Phase II, New Delhi, India.

Selection of the extracted teeth

40 maxillary central incisors were selected as per the aforementioned criteria and the selection was irrespective of age, sex, size or quadrant. The teeth were cleaned with ultrasonic scaler and stored in normal saline at room temperature from the day of extraction until the testing.

Table 1: Selection criteria

Inclusion criteria	Exclusion criteria
Tooth extracted for periodontal reason	Carious tooth
Non-carious	Fractured tooth
Unworn tooth	Fluoresced tooth
Unrestored	
Non attrited	

Sample size

40 extracted human permanent maxillary incisors were divided randomly into 4 groups comprised of 10 specimens each as: **Group I (Control group):** No tooth preparation; **Group II:** No incisal reduction with bevel preparation; **Group III**: 1mm of incisal reduction with butt preparation; **Group IV:** 1mm of incisal reduction with 1mm height of palatal chamfer.

Methodology

Mounting of the extracted teeth

All the teeth were mounted individually in a cube shaped acrylic block (2mmx 2mm x 1mm) leaving the entire crown portion and 2 mm apical to the cemento-enamel junction of the tooth structure exposed to have a better control during preparation. All the samples were randomly divided into four groups of 10 specimens each. Subsequently they were prepared according to the study groups by one clinician only to maintain the uniformity in preparation.

The specimens of **Group I** were not prepared. For **Group II,** the tooth preparation was started with horizontal grooves placement, with a self-limiting depth cutting diamond point of 0.5mm in depth. The horizontal grooves were marked and then levelled with 1.2 mm chamfer diamond rotary cutting diamond point to refine the preparation. Cervical finish lines were finished 1mm to the cemento-enamel junction with round-end tapered diamond point and kept labial to proximal contact area of the tooth. 0.2 mm bevel was then placed at 45º with a flame shaped diamond point. In **Group III**, standardized tooth preparation of the labial surface, proximal surface and establishment of chamfer finish line was done as in group II. Depth grooves of 0.8mm were prepared on the incisal edge and then levelled throughout the edge resulting in 1mm incisal reduction and 90º butt joint. For samples in **Group IV**, standardized tooth preparation of the labial surface, proximal surface, establishment of chamfer finish line and 1mm incisal reduction with 90º butt joint was done as in group III. In addition, 0.5 mm deep palatal chamfer was formed 1mm from the incisal edge on the palatal surface with 1mm round end tapered diamond point.

After finishing and polishing of the veneer preparations, wax spacer of 2mm thickness was adapted over the preparation and custom acrylic trays were fabricated with 2mm uniform thickness. After complete polymerization of the acrylic resin, the custom tray was removed from the specimens and wax spacer was removed. Tray adhesive (Dentsply Intl, NewYork, PA, USA) was applied on the entire impression surface and 1mm beyond the borders of the custom tray. After complete drying of the tray adhesive, the impression of prepared individual tooth was made by monophase impression technique using vinylpolysiloxane impression material (Aquasil Monophase, Dentsply Intl, New York, PA, USA).

The impressions were then poured in vacuum mixed type IV die stone (Ultrarock, Kalabhai) according to the manufacturer's water-powder ratio and mixing time. Stone dies were retrieved from impressions and sent to the laboratory for fabrication of respective veneers. Leucite-reinforced glass ceramic material was used for fabrication of veneers.

Before luting, all the veneers were placed without bonding medium on teeth to assess the fit. The bonding surfaces of all the veneers were then cleaned with 9.5% HF Gel for 60 sec and air dried followed

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by the application of the ceramic primer, which was allowed to dry for 5 sec. The prepared teeth surfaces were etched with 37% phosphoric acid for 15 sec and rinsed with water for 10 sec. This was followed by application of two coats of bonding agent on the tooth surface and was allowed to dry for 15 sec.

One coat of Rely X Veneer adhesive cement was then applied to the silane-treated bonding surface of veneer. The veneers were seated with gentle pressure and light cured for 5 sec. Excess cement was removed using scalpel blade. The ceramic veneers were then light polymerized at each area and margin for 30 sec using a light-emitting diode polymerizing unit. Finishing was then performed and the teeth were stored at room temperature under 100% humidity for next 48 hrs.

Fracture resistance testing and Statistical analysis

After cementation, the tooth was mounted at an inclination angle of 135º to the horizontal plane and this orientation was standardized with a customized mounting jig. Loading of the specimens was carried out in the universal testing machine (Instron) at a cross-head speed of 0.5mm/min, the loading of pin was done perpendicular to palatal surface of tooth 2.5mm from the incisal edge to check the fracture strength. The load was applied till a catastrophic failure occurred. The fracture strength of each sample was recorded in Newton (N). The collected data was analyzed by using the statistical software SPSS. Fracture strength measurements were obtained by using the One-way ANOVA (Analysis of Variance) for comparison of mean values of various groups. Various parameters were subjected to Post-hoc Tukey test and the '*p*' values were obtained with appropriate levels of significance.

RESULTS

The mean values of the fracture resistance of porcelain laminate veneers with different preparation designs were calculated as shown in Table 2.

Table 2: Distribution of samples in each group

Groups	No. of samples	Total
I	10	40
II	10	
III	10	
IV	10	

Group IV shows highest fracture resistance (1026.10) while Group II shows lowest fracture resistance (345.10). Highest mean fracture resistance value (815.10 N) was observed for Group IV i.e 1mm of incisal reduction with 1 mm height of palatal chamfer.

Table 3: Mean of fracture resistance (N) of Porcelain Laminate Veneers with different preparation designs

Groups	N	Mean	Std. Deviation(SD)	Minimum	Maximum
Group I	10	615.64	155.63	376.80	809.30
Group II	10	575.02	192.18	345.10	900.90
Group III	10	730.07	194.80	371.10	960.60
Group IV	10	815.10	168.31	491.10	1026.10
Total	40	683.95	196.47	345.10	1026.10

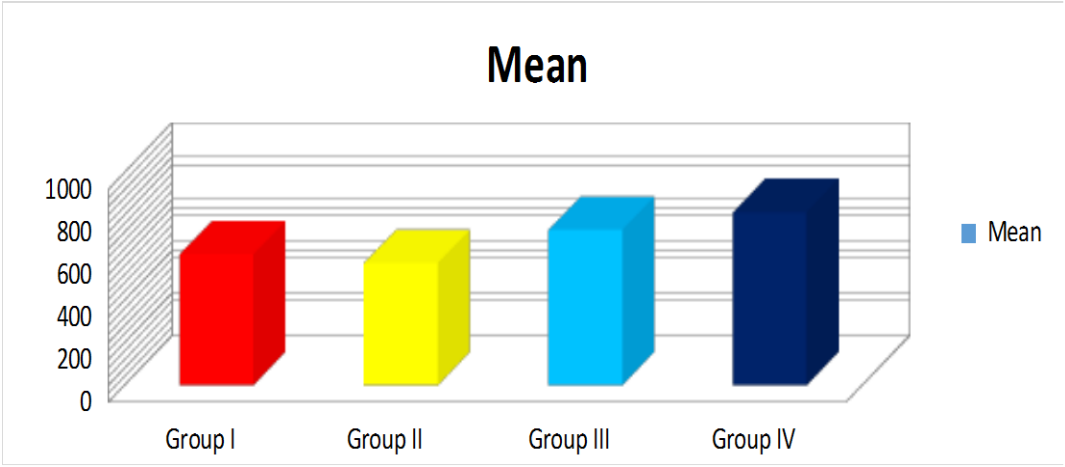

Fig 1: Comparison of mean of fracture resistance (n) of porcelain laminate veneers with different preparation designs is depicted.

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Insignificant difference (p>0.05) of mean fracture resistance of porcelain laminate veneers with different preparation designs was seen in while One-way ANOVA was applied as shown in Table 4.

Group wise comparison of fracture resistance of porcelain laminate veneers with different preparation designs was done and fracture resistance of Group I when compared to other groups (Group II, Group III, Group IV) was found to be statistically insignificant difference **(p> 0.05)**.

Similarly, when fracture resistance of Group II was compared to other Group III statistically insignificant difference **(p>0.05)** was found while it was significant when Group II was compared with Group IV **(p<0.05).**

When Group III was compared with Group IV statistically insignificant difference **(p>0.05)** was observed.

Table 4: Comparison of mean fracture resistance of porcelain laminate veneers with different preparation designs

Groups	Comparison groups	Mean Difference	p-value
Group I	Group II	40.62	0.956#
	Group III	-114.43	0.487#
	Group IV	-199.46	0.077#
Group II	Group III	-155.05	0.229#
	Group IV	-240.08	0.024*
Group III	Group IV	-85.05	0.713#

DISCUSSION

In the present in-vitro study, extracted natural human intact maxillary central incisors, were chosen as they are the teeth most commonly restored with porcelain veneers and optimally represent the clinical situation. The specimens chosen are in accordance with the studies conducted by Brunion et al [7] and Jankar et al[8].

In the present in-vitro study, specimens were stored in 0.9% sodium chloride a physiologically sterile solution which was in accordance with studies conducted by Jankar et al[8]. Tooth preparation was done by placing horizontal depth orientation grooves of 0.5 mm with a depth preparation and incisal edge reduction of 1 mm was done for group 2 and group 3. Impressions were made with poly vinyl siloxane (PVS) impression material

The leucite-reinforced and lithium disilicate ceramics are commonly recommended because of their optical properties and their ability to be acid etched. In the present in-vitro study, lithium disilicate glass-ceramic, E-Max (Ivoclar Vivadent) was utilized as in previous investigations conducted by Schmidt et al (2011)[9].

In the present study, bonding agent was applied and allowed to dry for 15 sec on the etched tooth surface, which was in accordance with the studies conducted by Schmidt et al (2011)[9]. Bonding of ceramic to tooth substance is based on the adhesion of luting cement and its bonding resin to the ceramic substrate together with the adhesion of luting cement to enamel and dentin.

Hydrofluoric acid selectively dissolves glassy or crystal-line components of the ceramic and produces a porous irregular surface that increases the surface area and facilitates the penetration of the resin into the micro retentions of the etched ceramic surfaces.[8] In the present study, 9.5% hydrofluoric (HF) acid for 60 sec was used to clean the surface of veneers. The HF acid treated intaglio surface of veneer was silanated with ceramic primer and was allowed to dry for 60 sec.

In the present study, Rely X Veneer (3M ESPE) cement, light curing resin cement was used for cementation of veneers. For cementation of porcelain veneers a light-curing luting composite is preferred because it allows for a longer working time compared with chemically curing materials.

Different angulations for the application of force during the loading tests have been used in the previous studies[10]. To prevent the universal testing device from sliding over the palatal surface of natural tooth, a mounting jig was fabricated[10] and the direction of force applied was at 135^0, which is the orthognathic inter-incisal angle [11], occurs on maxillary central incisors teeth during masticatory functions.

In the present study, the load was applied 2.5 mm from the incisal edge which was in accordance with the studies conducted by Castelnuovo et al[11], veneer-tooth system was loaded directly at the incisal edge. In the study conducted by Schmidt et al [9], the load was applied 1 mm from the incisal edge. In the present study the load (Newtons) was applied on the specimens at a crosshead speed of 0.5 mm/min which was in accordance with the studies conducted by Akoglu et al [12]. other previous studies conducted by Schmidt et al [11] have used loading speed of 0.05 mm/min, 1 mm/min and 1.5mm/min respectively. In the present study, the loading of veneer-tooth system was done till catastrophic failure in accordance with study conducted by Chaiyabutr et al [10].

In the present study, the mean fracture resistance of Group I, Group II, Group III and Group IV was 615.64, 575.02, 730.07, and 815.10 respectively. The mean fracture resistance of Group II (feathered incisal edge) was decreased in comparison to the mean fracture resistance of Group I (Control), but the difference was not statistically significant (p>0.05). These findings are in conformity with the study

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conducted by Stappert et al [13]. Also, Castelnuovo et al [11] found comparable fracture load findings of these two groups.

The mean fracture resistance of Group II (feathered incisal edge) samples was lower in comparison to the mean fracture resistance of Group III (butt-joint), but it was found to be statistically insignificant ($p>0.05$). These findings are in agreement with studies conducted by Castelnuovo et al [11], Stappert et al[13]. The difference in fracture resistance of veneers in Group II and Group III may be attributed to concentration of stresses on the incisal border close to the preparation margin in Group II samples, whereas in the Group III samples, the stresses are distributed throughout the entire surface of the preparation without overload on the incisal margin.[14,15] The increased fracture resistance of butt-joint preparation design exhibits least magnitude and distribution of intense stress over the smallest area, when loaded Centro vertically. Coverage of the incisal edge could be responsible for increasing the resistant surface area and lowering the concentration of stresses in the laminate. Including the incisal edge provided a wide vertical stop that resisted vertical loads.[15] Some clinical studies conducted by Smales et al [16] have also observed no difference in the clinical survival of ceramic veneers prepared with or without incisal overlapping. Nevertheless, more favorable results have been reported for the preparation without incisal involvement by Cotert et al [6].

In the present in-vitro study, the mean fracture resistance of Group II (feathered incisal edge) was decreased in comparison to the mean fracture resistance of Group IV (palatal chamfer) and was statistically significant ($p<0.05$). These findings concur with the results of Smales et al [16]. Whereas, previous studies conducted by Stappert et al[13] showed a statistically insignificant difference between the two groups. While, Meijering et al [17], Stappert et al [13] found no correlation between the survival rate of porcelain laminates and different incisal preparation designs.

The mean fracture resistance of Group III was increased in comparison to the mean fracture resistance of Group I and was statistically insignificant ($p>0.05$) which is in accordance with the studies conducted by Stappert et al[13].

Current study shows the mean fracture resistance of Group III was decreased in comparison to the mean fracture resistance of Group IV and was statistically insignificant ($p>0.05$) which was in accordance with the studies conducted by Stappert et al[13]. Previous studies conducted by Castelnuova et al[11] showed a statistically significant difference between Group III and Group IV. The difference in fracture resistance of Group IV and Group III may result from two factors. First, the ceramic that filled the palatal chamfer acted as a shear key, holding the veneer against a labial motion during loading. Second, during load application, the cement along the palatal chamfer underwent both shear and tensile stresses, with the tensile component being reduced over that in the incisal finish line due to the presence of the accompanying resisting shear stress Chaiyabutr et al [11].

The fracture resistance of Group IV is more in comparison with other groups as it has a lower maximum principal stress, a more uniform stress distribution in cement layer, and a high clinical success rate. In the present in-vitro study, the mean fracture resistance of Group IV was increased in comparison to the mean fracture resistance of Group I and was statistically insignificant ($p>0.05$) which was in accordance with the studies conducted by Stappert et al[13].

CONCLUSION

Within the limitations of the present study, following conclusions were drawn;

- The type of preparation design affected the fracture resistance of porcelain laminate veneers.
- Group IV demonstrated highest fracture resistance amongst all the groups. Group IV is superior than the other groups due to its high clinical success rate, more uniform stress distribution in the cement layer, and lower maximum primary stress. Incisal design preparation of 1 mm incisal reduction with 1 mm height of the palatal chamfer gives better aesthetical and functional result and hereafter, it must be encouraged.
- Group II demonstrated lowest fracture resistance amongst all the groups.
- Incisal reduction with palatal involvement significantly increased the fracture resistance when compared to incisal reduction.

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