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*Original Research Article*

# Influence of Preparation Design and Presence of Class IV Composite Resin Restoration on Fracture Resistance of Ceramic laminate Veneer

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## Abstract

The objective of the study was to evaluate the fracture resistance of ceramic veneer bonded to class IV composite resin restoration using two differentincisal preparation designs.

Twenty-eight extracted intact human maxillary incisors free from cracks and of equal dimensions were randomly divided into two main groups; G1 (control): intact teeth without class IV composite restoration, G2: teeth with class IV composite restorations. Each group was further divided according to the preparation design of the laminate veneers (n=7); A: incisal butt joint design and B: incisal overlap design. Class IV was prepared with obliqueincisal margin.Etching and bonding were performed and a nanohybrid composite resin was applied. Two veneer preparation designs were made; butt joint with shoulder finish line and incisal overlap with palatal chamfer. The impression were made usinga 3D-scanner. The veneers were fabricated with a heat pressed all ceramic material (IPS-Emax, IvoclarVivadent) according to manufacturer's protocol.The internalveneer surface was etched with 5% hydrofluoric acid then silanated.Dual cure resin cement (Variolink N base and catalyst, IvoclarVivadent) wasused for cementation.Fracture resistance measurement was recorded using universal testing machine.

The veneer incisal preparation design had a statistically significant effect on mean fracture resistance of PLVs whereas presence of class IV restoration had no statistically significant effect on mean fracture resistance.The incisal overlap design showed statistically significantly higher mean fracture resistance than the incisal butt joint design.

The preparation design affected the fracture resistance of PLVs bonded to class IV composite restorations. Yet,the presence of class IV composite restorations did not affectthe fracture resistance of bonded PLVs. The incisal overlap design seemed to protect PLVs bonded to class IV restorations.

## الخلاصة

كان الهدف من هذه الدراسة هو تقييم تأثير تصميم الحد القاطع على مقاومة كسر الوجوه الخزفية الملتصقة بحشوات الكومبوزيت من الصنف الرابع.

قسمت ثمانية وعشرين من القواطع العلويةعشوائيا إلى مجموعتين رئيسيتين؛ G1: أسنان سليمة مع عدم وجود حشوات من الصنف الرابع، G2: أسنان ذات حشوات من الصنف الرابع. تم تقسيم كل مجموعة أيضا وفقا لتصميم الحد القاطع للوجوه الخزفيه (ن = ٧)؛ A: تصميم الحد القاطع على شكل كتف،B: تصميم الحد القاطع على شكل كتف ذو حافة مشطوبة في السطح الحنكي. أعيد ترميم الأسنان بوضع حشوه نانو هايبرد راتنج من الصنف الرابع.وتم تحضير الحد القاطع بالشكلين المذكورين سابقا. وقد تم الصاق الوجوه الخزفية (IPS e.max, IvoclarVivadent) بأسمنت راتنجي ثنائي التصلب(Variolink N, IvoclarVivadent). وتم قياس قيم مقاومة الكسر (N) باستخدام جهاز اختبار عالمي.

كان لتصميم الحد القاطع للوجوه تأثير هام بشكل إحصائي على مقاومة الكسرولكن لم يلاحظ أي تأثير إحصائي لوجود حشوات الكمبوزيت من الصنف الرابع على مقاومة الكسر للوجوه الخزفية. أظهر تصميم الحد القاطع ذو الحافة المشطوفة في السطح الحنكي مقاومة للكسر أعلى جدا بشكل إحصائي من تصميم الحد القاطع على شكل كتف.

ضمن حدود هذه الدراسة المخبرية, إن حشوات الكمبوزيت ذات الصنف الرابع لم يكن لها أي تأثير على مقاومة الكسر للوجوه الخزفية. في المقابل كان لشكل تحضير الحد القاطع تأثير كبير على مقاومة الكسر للوجوه الخزفية حيث أن التحضير على شكل كتف ذو حافة مشطوفة حنكيا قد أظهر مقاومة للكسر أفضل بكثير من التحضير على شكل كتف.

## Introduction

Composite resins have been successfully used to restorecarious class IV cavities and fractured incisor teeth. Advances in composite resin and adhesive technology have enabled high survival rate. However, it was shown that the most common reason for class IV composite resin replacement was bulk fracture (29%), followed by secondary caries (20%) and marginal fracture/degradation (18%)[1]. Each time a restoration is replaced, the cavity becomes larger, the tooth becomes weaker and veneering the entire labial surface may be necessary.

In recent years ceramic veneers have become one of the revolutionary minimally invasiveesthetic treatment options for restoration of fractured, malformed, discolored, misaligned, and worn anterior teeth. Ceramic veneers requireone-quarterthe amount of tooth reduction needed for full-coverage crowns [2]or even less. Moreover, previous studies revealed low clinical failure rateof ceramic laminate veneers, approximately 5.6 % to 6.5% between 10 to 12 years [3, 4].

Their success was attributed to conservation of the tooth structure, reliable bonding and good esthetics.

Recently, the use of ceramic veneers for treatment of coronally fractured as well as worn anterior teeth has increased. These treatment conditions maybe challenging for clinicians because preparation may necessitate removal of healthy tooth structure[5].Since preservation of tooth structure to the maximum is crucial to improve long-term success,veneer preparation can be done over the existing composite restoration.

Different designs of tooth preparationfor ceramic veneers have been described,such as the feathered incisal edge, the intraenamel (or window), incisal shoulder (or butt joint) and the incisal overlapped edge preparations (with palatal chamfer) [6].

The relation between the preparation design and the strength of the ceramic veneer restoration was evaluated in several in vitro studies and continues to be one of the most controversial aspects. Some studies concluded thatincisal shoulder finish line should not extend into a palatal concavity since an extending preparation with a palatal chamfer did not provide increased strength for ceramic veneers and generated a thin extension of ceramic in an area of maximum tensile stress [7,8].While other studies advocated the incisal overlap preparation with palatal chamfer for better stress distribution [9,10].A recent meta-analysis of the most indicated preparation design for porcelain laminate veneer concluded that the butt joint is the type of preparation that least affects the strength of the tooth and the chamfer preparation type is more susceptible to ceramic fractures [11].

Although investigators have evaluated the effect of preparation design on strength of ceramic veneers, limited information is available regarding the effect of preparation design in association with existing class IV composite resin restoration on fracture resistance of ceramic veneers.

The objective of the study was to evaluate the fracture resistance of ceramic veneer bonded to class IV composite resin restoration using two different preparation designs. The null hypothesis was that no difference in the fracture resistance for the two incisal preparation designs of the ceramic veneer bonded to class IV composite resin restoration.

## Materials and Methods

### Study design

For this in vitro study, 28extracted intact human maxillary incisorswere selected. Tissue tags and calculus were removed from teeth with an ultra-sonic scaler (Suprasson, Satelec, France). To ensure similarity in the dimensions of the teeth, the mesio-distal and inciso-cervical labial surfaces were measured with a caliper (Iwansson caliper). Teeth were autoclaved (VELA 165A, Satelec, France) and storedin distilled water at room temperature.Teeth were randomly divided into two main groups; G1 (control): intact teeth without class IV cavity preparation, G2: teeth with class IVcomposite restorations. Each group was further divided according to the preparation design of the laminate veneers (n=7); A: incisal butt joint design and B: incisal overlap design. The experimental groups and number of specimens are schematically presented in figure 1.

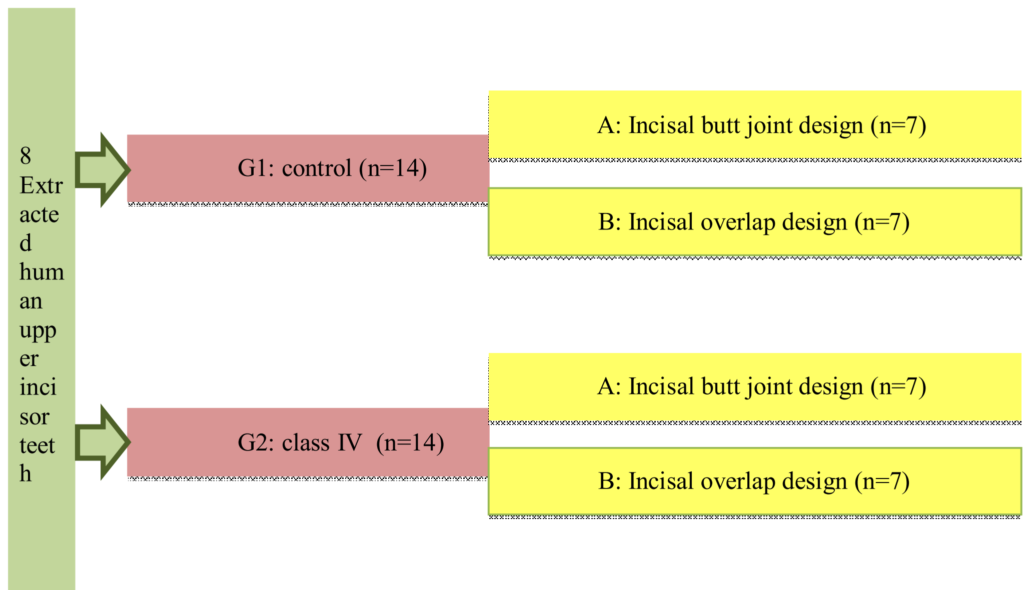


**Figure 1:** Schematic presentation of experimental groups and number of specimen depending on the size of class IV cavity and the preparation design of laminate veneers.

**Sample preparation**

For G2, class IV with enamel bevel wasprepared using diamond stone (MANI, dia-burs). For standardization of cavity dimension, each coronal surface was measured and equally divided into three thirdscervico-incisally and mesio-distally. The preparation was extended obliquely from the middle of cevical third cervico-incisaly to the middle of distal third mesio-distally. AutoCAD program was used to calculate the area of remaining amount of tooth structure in percentage after class IV cavity preparation. The materials used in this study are listed in table 1.

**Table 1:** The materials used in this study

| Product name | Description | Composition | Lot no. | Manufacturer |
|---|---|---|---|---|
| **Tetric N-Ceram** | Nanohybrid resin composite | Dimethacrylate, barium glass, ytterbium trifluoride, copolymers, additives, catalysts | S30869 | IvoclarVivadent, Schaan, liechtenstein |
| **Tetric N-Bond** | Bonding agent | Phosphoric acid acrylate, HEMA, Bis-GAMA, urethane dimethaacrylate | S50390 | |
| **Monobond N** | Primer | Silane methacrylate, phosphoric acid methacrylate, sulphide methacrylate | S02134 | |
| **Syntac primer** | Bonding agent | Triethylene glycol dimethacrylate, polyethylene glycol dimethacrylate, malic acid, acetone | S28435 | |
| **Syntac adhesive** | Bonding agent | polyethylene glycol dimethacrylate, glutaraldehyde | S32771 | |
| **Heliobond** | Bonding agent | Bis-GMA, Triethylene glycol dimethacrylate, stabilizers, catalysts | S40936 | |
| **Variolinc N** | Dual cure resin luting composite | Bis-GMA, urethane dimethacrylate, triethylene glycol dimethacrylate, inorganic fillers, initiators, stabilizers, pigments | S25641 S01619 | |
| **Total Etch** | Enamel /dentine etching gel | 37% phosphoric acid, thickening agent, colour pigments | S29081 | |
| **Ceramics Etch** | Ceramic etching gel | < 5 % hydrofluoric acid, < 10 % sulphuric acid | 37460 | VITA, Germany |
| **Honigum-Heavy** | Impression material | vinylpolysiloxanes, cilicium dioxide based fillers, additives, platinum catalyst | | DMG, Germany |
| **IPS e.max** | Galss ceramic | Lithium disilicate glass-ceramic | S33463 | IvoclarVivadent, liechtenstein |

A total-etch approach was used for composite resin bonding as per manufacture instructions. After etching with 37% phosphoric acid gel, a thick layer of a single component dentine-bonding agent was applied and brushed gently into dentine for 10 seconds. The excess was removed by gentle stream of air andthen light polymerized for 10 seconds using LED-curing unit. A nanohybrid composite resin was applied incrementally and light polymerized for 40 seconds. Restorations were finished and polished using tungsten carbide finishing burs and Soflex discs. A putty reference was made before veneer preparation to guide in standardization of the thickness of veneerpreparation.

For both G1 and G2, a self-limiting depth cutting bur (Komet) for a cutting depth of 0.3 mm for cervical surface and 0.5 mm for middle and incisal surface was used for laminate veneers preparation. A tapered diamond stone with round endwas used for tooth preparation. A chamfer finishing line, 1 mm away from the cemento-enamel junction was made and the preparation was smoothed with a finishing bur.

For both G1A and G2A, a 2 mm incisal edge reduction was made without palatal extension, while for G1B and G2B, the preparation was extended to the palatal side with a palatal chamfer. All of line angles were rounded and the margins were finished.

The impression of the prepared teeth were made usinga 3D-scanner (Cercon eye, DeguDent, Germany). The 3D-image was processed in a special software and a resin copy milling was fabricated in the milling machine (cercon brain expert, DeguDent). The veneers were fabricated with a heat pressed all ceramic material (IPS-Emax, Ivoclar Vivadent) according to manufacturer’s protocol. One lab technician fabricated all veneers. The veneer thickness was checked and the fit was verified on the master die and any interference was removed with medium grit diamond bur then glazed. The internal surface was air-abraded with 50 μ alumina particles at 2-bar pressure at a distance of 10 mm for 5 seconds then washed and dried by compressed air. The internalveneer surface was etched with 5% hydrofluoric acid (Vita ceramic etch, Germany) for 60 seconds and then thoroughly rinsed for 1 minute with water then dried. Silane coupling agent (Monobond N,Ivoclar Vivadent) was applied by a microbrush to the pre-treated veneer surface, allowed to react for 60 seconds and then the excess were dispersed with strong stream of air.

The prepared teeth were cleaned with a fluoride-free polishing paste (Proxyt, IvoclarVivadent) and dried. The resin composite restorations were roughened with a fine-grit diamond bur. A 37% phosphoric acid gel (N-Etch, Ivoclar Vivadent) was applied on the labial surface of each tooth for 30 seconds then washed with a vigorous amount of water for 15 seconds (figure 12)and silane-coupling agent (Mono bond N, ivoclarvivadent) was applied on the class IV composite restorations and allowed to react for 60 seconds and then dispersed with strong stream of air [12, 13]. Syntac primer (IvoclarVivadent) was applied with a brush and allowed to react for 15 seconds; then the primer was dispersed and dried. Syntac adhesive (Ivoclar Vivadent) was applied and left for 10 seconds and thoroughly dried with air. Heliobond was applied on both tooth surface and restoration surface and blown to be a thin layer and kept without light polymerization [6].Dual cure resin cement (Variolink N base and catalyst, Ivoclar Vivadent) was mixed in a 1:1 ratio for 10 seconds as per manufacture's instruction and then applied to the restoration surface.

The veneers were positioned on the corresponding teeth and held in place with finger pressure. The excess cement was removed and the veneers were light cured for 40 seconds from each surface. Finally the laminate veneers were finished and polished using polishing discs. Teeth roots were embedded in metallic mold filled with self-cure resin (Acrostone, Cairo, Egypt).The mold used has two brass parts:an internal cylindrical split; 20 mm height and 16mm diameter and an external hexagonal one; 21 mm height and 18.5mm diameter with tightening screws.A specially designed device was used for teeth investing and aligning in acrylic resin. For the artificial periodontal ligament simulation, a single layer of addition-type silicone impression material was coated on and around the root. Roots were embedded; 2 mm lower than the lowest margin of the anatomical cervical line. Fracture resistance measurement was recorded using universal testing machine (NEXYGEN, Lloyd Instruments, UK).A typical clinical model with a facio-lingual tooth inclination of $45^o$ angle was chosen for fracture resistance test, secured to the lower fixed compartment of a computer controlled materials testing machine (Model LRX-Plus; Lloyd Instruments Ltd., Fareham, UK).

Failure loads were measured under a static loading test using the machine with a load cell of 50 Nat a crosshead speed of 1 mm/min and at angle of 135° against the tooth axis. Load was applied with a custom made load applicator, which has a steel rod with round tip 3.4 mm diameter that was placed at the palatalincisal, 1.5mm away from the incisal edge of the restored teeth and attached to the upper movable compartment of the machine. The data were recorded using Nexygen computer software (Nexygen-MT; Lloyd Instruments, UK)The failure type and location were investigated visually. Failure was categorized as adhesive failure between the tooth and laminate, cohesive failure within the laminate or mixed failure.

**Results**

Two-way ANOVA test was used to study the effect of incisal preparation design, Class IV composites and their interactions on mean fracture resistance. Bonferroni's post-hoc test was used for pair-wise comparisons when ANOVA test is significant.Failure mode was presented as frequencies (n) and percentages (%). Chi-square ($x^2$) test was used to compare between failure modes with different incisal preparation designs as well as fracture modes without and with Class IV.The significance level was set at P ≤ 0.05. Statistical analysis was performed with IBM® SPSS® Statistics Version 20 for Windows.

The Two-way ANOVA revealed a statistically significant effect of incisal preparation design on mean fracture resistance of PLV(P < 0.05);however, the presence of class IV composite restoration and the interaction between the two variables revealed no significant effect on mean fracture resistance of PLV (Table 2).

**Table 2:**Two-way ANOVA for the effect of different variables on mean fracture resistance

| Source of variation | Type III Sum of Squares | df | Mean Square | *F*-value | *P-value* |
|---|---|---|---|---|---|
| Incisal preparation design | 38876.8 | 1 | 38876.8 | 4.9 | 0.038* |
| Class IV restoration | 396.5 | 1 | 396.5 | 0.1 | 0.825 |
| Design x Class IV restoration interaction | 3618.5 | 1 | 3618.5 | 0.5 | 0.507 |

*: Significant at P ≤ 0.05

The incisal overlap design group revealed significantly higher mean values of fracture resistance of PLV than incisal butt joint design group in both, the control (without class IV) and the class IV composite group (table 3, figure 2). On the other hand, when comparing the effect of the presence of class IV composite, there was no significant difference between mean values of fracture resistance of PLV with both preparation designs used in the study (table 4, figure 3).

**Table 3 :** Mean, standard deviation (SD) values and results of comparison between incisal preparation designs without and with Class IV cavity

| | Incisal overlap | | Incisal butt joint | | *P*-value |
|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | |
| Control (No Class IV) | 400.4 | 71.7 | 346.5 | 46.0 | 0.047* |
| Class IV | 431.9 | 134.9 | 330.7 | 69.7 | 0.020* |

*: Significant at P ≤ 0.05.

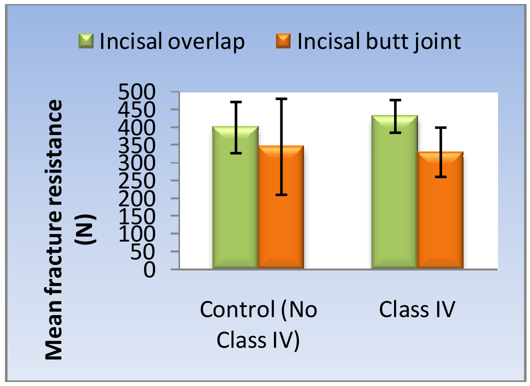


**Figure 2 :** Bar chart representing mean and standard deviation values of fracture resistance of incisal preparation designs without and with Class IV.

**Table 4 :** Mean, standard deviation (SD) values and results of comparison between fracture resistance without and with Class IV with each incisal preparation design

| Incisal preparation design | Control (No Class IV) | | Class IV | | *P*-value |
|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | |
| Incisal overlap | 400.4 | 71.7 | 431.9 | 134.9 | 0.795 |
| Incisal butt joint | 346.5 | 46.0 | 330.7 | 69.7 | 0.583 |

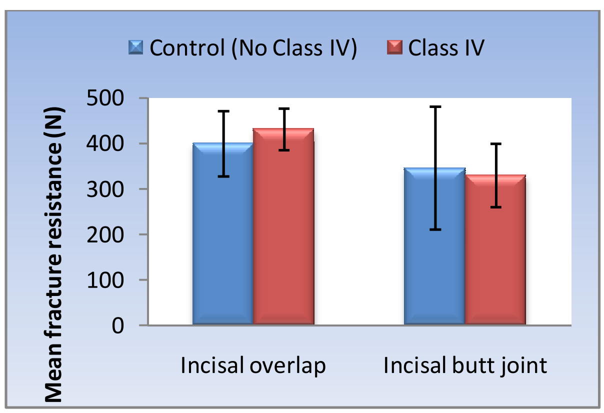


**Figure 3 :** Bar chart representing mean fracture resistance without and with Class IV with each incisal preparation design.

All types of failure modes were observed (adhesive, crown and/or laminate fracture, root fracture). However, there was no statistically significant difference between failure modes with incisal overlap or incisal butt joint design groups (table 5, figure 4).When comparing the effect of the presence of class IV composites, there was no significant difference between failure modes with incisal overlap design group; while there was a statistically significant difference with incisal butt joint design group.The control group showed higher prevalence of adhesive failure androot fracture, whereas the class IV group showed higher prevalence of crown and/or laminate fracture (table 6, figure 5).

**Table 5 :** Frequencies (n), percentages (%) and results of comparison between failure modes after using the two incisal preparation designs

| | **Incisal overlap** | | **Incisal butt joint** | | ***P*-value** |
|---|---|---|---|---|---|
| | **n** | **%** | **n** | **%** | |
| **Control (No Class IV)** | | | | | |
| Adhesive failure | 3 | 50.0 | 3 | 50.0 | 0.223 |
| Crown and/or Laminate fracture | 2 | 33.3 | 0 | 0.0 | |
| Root fracture | 1 | 16.7 | 3 | 50.0 | |
| **Class IV** | | | | | |
| Adhesive failure | 1 | 14.3 | 3 | 42.9 | 0.559 |
| Crown and/or Laminate fracture | 6 | 85.7 | 4 | 57.1 | |
| Root fracture | 0 | 0.0 | 0 | 0.0 | |

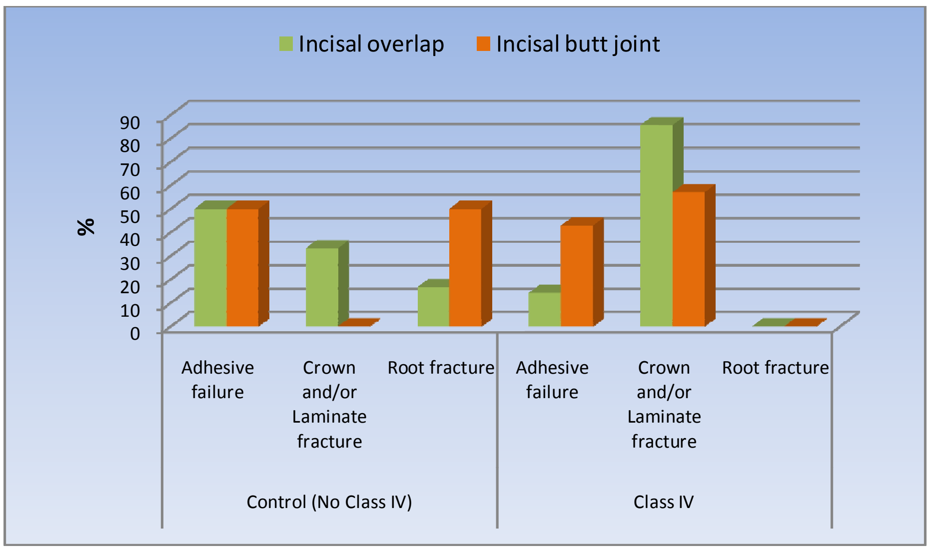


**Figure 4:** Bar chart representing failure modes with the two incisal preparation designs.

**Table 6:** Frequencies (n), percentages (%) and results of comparison between failure modes without and with Class IV.

| Incisal preparation design | Control (No Class IV) | | Class IV | | *P*-value |
|---|---|---|---|---|---|
| | n | % | n | % | |
| **Incisal overlap** | | | | | |
| Adhesive failure | 3 | 50.0 | 1 | 14.3 | 0.139 |
| Crown and/or Laminate fracture | 2 | 33.3 | 6 | 85.7 | |
| Root fracture | 1 | 16.7 | 0 | 0.0 | |
| **Incisal butt joint** | | | | | |
| Adhesive failure | 3 | 50.0 | 3 | 42.9 | 0.031* |
| Crown and/or Laminate fracture | 0 | 0.0 | 4 | 57.1 | |
| Root fracture | 3 | 50.0 | 0 | 0.0 | |

*: Significant at $P \leq 0.05$

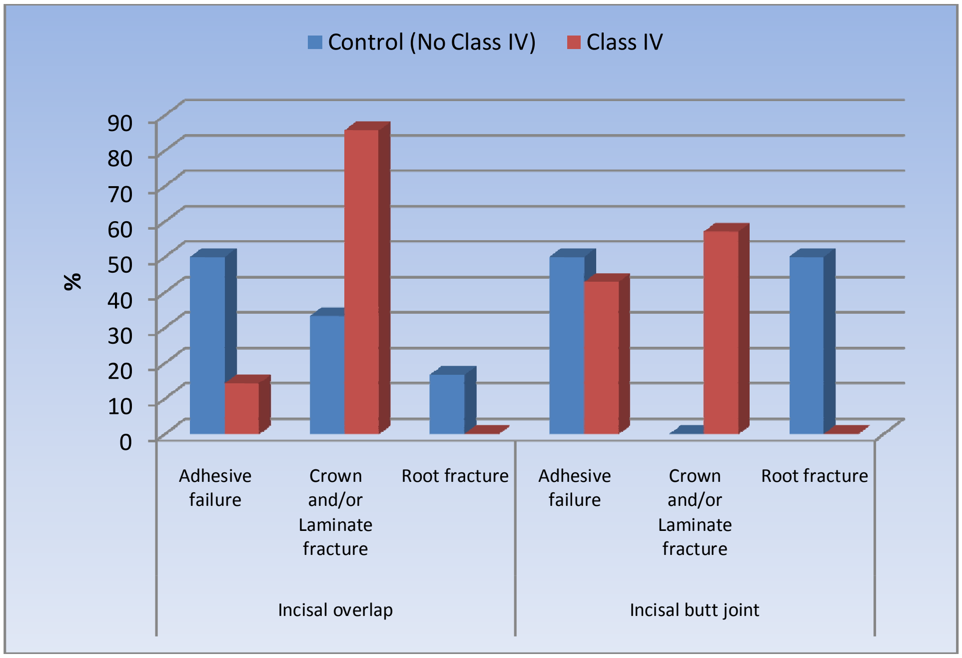


**Figure 5:** Bar chart representing failure modes without and with Class IV.

**Discussion**

In the present study, there was no significant difference in the fracture resistance between teeth restored by PLVs bonded to class IV composite fillings and PLVs bonded to intact teeth. Whereas there was a statistically significant effect of the preparation design, the incisal overlap revealed significantly higher fracture resistance than incisal butt joint design. Therefore, the null hypothesis was rejected for the preparation design of ceramic veneerbonded to class IV composite restoration.

Human teeth were used in this study because they have unique properties, such as bonding characteristics, elasticity and strength. However, the use of human teeth also presents some limitations. For example, it is difficult to standardize human teeth based on size and age. For this reason, the teeth, which have considerable difference in size or having cracks, were excluded from this study. All measurements were made, and the dimension of the preparation was adjusted.

In clinical situations, coronal fracture is common in the anterior teeth. When laminate veneers bonded to fractured incisors, there is an increasing risk of adhesive failure because of decrease in enamel bonding. This may influence the choice of preparation design for PLVs. Class IV cavity preparation wasdone with oblique incisalpreparation to simulate the common oblique fracture and AutoCAD software was used to calculate the remaining amount of tooth structureto facilitate standardization.

In the present study, only surface roughening was used to increase the micromechanical retention of the resin cement on the composite filling. This treatment is simple and requires no specific equipment as silica coating used in other studies[14].

The dimensions of class IV cavity used in this study represented approximately 35% ± 3loss in the tooth structure, which were replaced by composite fillings. Apparently, the remaining amount of enamel as well as the presence of composite filling in the missing part is sufficient to provide reliable strength of the bonded PLVs. The results of this study is in accordance with Gresnigt et al. [15] who found that the fracture strength of teeth restored by PLVs with existing class III and IV composite fillings was higher than that of teeth with no restorations, although the difference was not significant. They attributed the high strength results to the surface treatment of composite restoration using intra oral silica coating. Conversely, another study by Sadighpour et al.[16] reported significantly lower fracture resistance values with class IV cavities. In this study, composite filling was removed and replaced with porcelain. This may increase the amount of unsupported porcelain and may weaken the final restoration.

In this in vitro test, the results of incisal preparation design were significant. Incisal overlap design was significantly higher values of fracture resistance than incisal butt joint. This could be attributed to betterstress distribution throughout the entire surface of the preparation without overloading the incisal margin[9]. Other researchers found that using of palatal chamfer margin design significantly increased the load to failure [5,17,18].

Regarding failure mode results,there was no significance between control and class IV groups withthe incisal overlap designwhile there was a statistically significant difference with incisal butt joint design group.The control group showed higher prevalence of adhesive failure and root fracture, whereas the class IV group showed higher prevalence of crown and/or laminate fracture. These results may confirm the better stress distribution in incisal overlap design than butt joint design.

Within the limitations of this study, it was an interesting finding that the presence of class IV composite restorations did not show significantly different fracture resistance values of PLVs.

Nevertheless, future studies are mandatory and must include clinical trials to validate the longevity of porcelain laminate veneers on class IV composite restoration.

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