Fracture strength of veneers using different restorative material, s and techniques. In vitro study

Dr Anil K Tomer¹, Dr. Hysum Mushtaq², Dr. Leena Tomer³, Dr Afnan Ajaz Raina⁴, Dr Anila Krishna Saxena⁵, Dr. Ayush Tyagi⁶, Dr. Shivendra Ahlawat⁷

PROFESSOR & Head, Department of conservative dentistry & endodontics Divya Jyoti College Of Dental Sciences & Research, Center Modinagar, Ghaziabad (U.P.)¹

PostGraduate Students Department of conservative dentistry & endodontics Divya Jyoti College Of Dental Sciences & Research Center, Modinagar, Ghaziabad (U.P.)²,³,⁴,⁵,⁶,⁷

PROFESSOR Dr Leena Tomer, Department of Prosthodontics Divya Jyoti College of Dental Sciences & Research Center, Modinagar Ghaziabad U.P.³

Corresponding author: Dr Anil K Tomer

ABSTRACT

Aim of the study: The purpose of this study was to evaluate the fracture strength of the laminate veneers in maxillary anterior, fabricated from either composite (direct and indirect techniques) or ceramic CAD/CAM blocks.

Materials and Methods: Forty sound human maxillary incisor teeth were used in this in vitro study. Teeth were divided randomly into one control group and three experimental groups of ten teeth each;

control group
Group A: Restored with direct composite veneer (IPS IMPRESS),
Group B: Restored with indirect composite veneers (Tetric Ceram),
Group C: Restored with zirconia CAD/CAM block.

Standard preparations were done using Ceramic Veneer Set. Indirect laminate veneers were cemented with the Veneer Cement and all specimens were stored in distilled water. The load was applied on the occlusal part of the veneer at 90°long axis of the tooth using universal testing machine. Results were analyzed with one-way ANOVA and LSD tests.

Specimens were examined by stereomicroscope at a magnification of 20x to evaluate the mode of failure.

Results: Control group showed higher mean of fracture strength with highly significant difference in comparison to the experimental groups (P<0.01). (Group C) showed higher mean of fracture strength with statistically significant difference in comparison to (Group A and Group B). On the other hand the difference between (Group A and Group C) was statistically highly significant. Statistically non-significant difference was found among the two groups restored with composite restoration.

Conclusions: All veneers used in this study can be considered as acceptable treatment in the of choice in patients with normal biting force. Direct composite veneer is the most favorable technique in term of fracture strength, while zirconia laminate veneers are least likely to fracture and most likely to completely debond.

Keywords: Laminate veneers, direct composite, indirect composite, zirconia CAD-CAM, fracture strength.

I. Introduction:

The increasing esthetic demand of the patients and clinicians are the main reason for the search of ultimate restorative materials. Nowadays, restorative materials is not only to restore dental tissues lost because of caries or trauma, but also to correct the form and color of teeth for social acceptance. Crown preparation involves significant removal of tooth structure and may cause pulpal irritation and irreversible pulpitis. While laminate veneers are more conservative than crowns and maintain the biomechanics of the original tooth. (1) Most of the veneers have a success rate of approximately 93% over 15 years of clinical use. (2) The most frequent failure modes associated with laminate veneers are fracture and debonding. Fractures of laminate veneers represented 67% of the total failures of such restorations over a period of 15 years of clinical performance. (3)
II. Materials And Methods:

Forty sound human maxillary incisors were selected for the study, which were extracted due to periodontal diseases. The occluso-cervical and mesio-distal dimensions were measured. To determine that the enamel was free from cracks, all teeth were visually examined under blue light transillumination. Teeth were cleaned by scaling and stored in distilled water at room temperature (4,5). Teeth were then randomly divided into four groups of 10 specimens each:

- Control group: Intact teeth.
- Group A: Restored with direct Composite veneers\ IPS Empress
- Group B: Restored with indirect Composite veneers\ Tetric Ceram
- Group C: Restored with ceramic Zirconia CAD/CAM

The teeth were mounted individually in specially designed, locally-manufactured rubbermold (20 mm height × 20 mm diameter) with cold-cure acrylic with the long axis of the tooth parallel to the center of the mold. All specimens were embedded up to 2 mm apical to the CEJ to simulate the natural biologic width as seen in (Fig.1).

Figure 1: Teeth mounted in acrylic block 2mm apical to CEJ.

Primary impression and primary model was prepared for all experimental teeth which was used to fabricate copyplast template for group A and group B, while for group C the primary model was used to take a biocopy for creating laminate veneers of the original size and shape of the teeth. A copyplast template was fabricated for each tooth in Group A and Group B using 0.5 mm thick vacuum pressed polyethylene plastic template in a vacuum forming machine. Then a sectional index was produced using a putty polyvinylsiloxane material was made to evaluate the amount of tooth reduction.

Before starting, the outline of the preparation was painted with a waterproof color marker. The tooth preparation procedure was done under constant water irrigation. Standardized preparations were done for all the teeth using ceramic veneer system preparation bur set (porcelain veneers kit Shofu). The facial reduction was 0.4 mm at the cervical third and 0.5 mm at the middle and incisor thirds. The preparation ended 1 mm occlusal to the cement-enamel junction. Proximally, the preparation was extended without destroying the contact area. Where possible, all the preparations were confined within the enamel. However, the exposure of some dentin often occurred.

This not only produces a highly predictable and stable bond, but also the enamel provides stiffness to the tooth. After that, all the line angles were rounded with white stone using slow speed handpiece.

Finally, the preparation was checked from the lateral view to ensure that the necessary reduction of the facial surface was done properly.

Final impression was taken for all teeth in group B and C with addition silicone impression material using two-stage putty-wash technique. Each impression was boxed using sheet wax and poured with type III dental stone. After setting, the die was trimmed and numbered according to its respective tooth.

Group A: restored with direct composite veneers using IPS Empress. The prepared tooth was cleaned with fluoride-free pumice using polishing cup and then etched with 35% phosphoric acid (Scotchbond™ Etchant, 3MESPE) for 15 seconds, rinse for 10 seconds and air dried gently for 5 seconds according to manufacturer’s instructions.

Immediately after drying, two consecutive coats of adhesive were applied with gentle agitation for 15 seconds using a fully saturated brush, the adhesive then was gently air thin for 5 seconds to evaporate solvent and light-cure with LED curing light (Woodpecker, China) for 10 seconds according to manufacturer’s instructions. The labial third of the template was then packed with the composite material and the template was seated on the tooth. The excess composite extruded from the hole was removed and the composite was light-cured using LED curing light for 20 seconds according to manufacturer’s instructions. After removing the template, the veneer was finished and polished using Optidiscs finishing and polishing system (Shofu).

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Group B: Restored with indirect composite veneers with (Tetric Ceram). After fabrication of the stone die, two coat of die spacer was applied with a brush on the prepared part of the die (1 mm) away from the margins. Standard thickness of the laminates in the original form of the teeth was achieved using the previously prepared copyplast template in the same manner used for direct composite and light cured for 10 seconds. After that, the veneer was removed from the tooth and light cured for another 10 seconds according to manufacturer’s instructions. The thickness was checked with measuring device.

Finally, the veneer was placed on the prepared tooth and the margins were checked with dental explorer. After optimal fitness had been verified, the veneers were finished and polished with Optidiscs and prepared for cementation.

Group C: restored with CAD/CAM veneers (zirconia). The veneers were completed in four phases. Firstly, in “ADMINISTRATION” phase, veneer was selected as restoration type from single restoration options. Maxillary first incisor tooth was selected as abutment tooth, “bigeneric copy” was chosen as the mode of design and the type of materials and manufacture (zirconia CAD CAM) defined.

Secondly, in the “SCAN” phase three dimensional images were obtained by scanning the models by (Dental wings 3 series scanner). Bio-copy was taken first by nonscanning the primary model from buccal, mesial, and distal side to obtain three images for each model, then the scanning of the die was accomplished by rotational scan in which the die was fixed on the rotation mouse at 60°, which automatically takes 8 snap shot for each diemold, then only 3 images were chosen. After that, both scans were automatically analyzed and correlated with each other by the system which automatically takes the 3-dimensional image of the primary models on top of the 3-dimensional image of dies correctly. The designing of veneers was then started in “MODEL” phase with preparation trimming by hiding image regions outside the preparation, the margin of preparation was automatically detected by the system and in copyline section, and the area to be copied from the bio-copy was delineated to design a laminate veneer identical to the original tooth form.

After that, other veneer parameter was defined in “DESIGN” phase such as minimum veneer thickness (0.4 mm) and spacer (8 μm) which were determined according to manufacturer’s instructions. The milling process of the samples started as follows: a) the selected ceramic block (zirconia blocks) was inserted in the spindle of the milling chamber of the In Lab MC XS Dentsply miller and fastened with the setscrew. The milling process was fully automated without any interference with the twodiamond cutting instrument acting togethersimultaneously in the shaping process, with copious water cooling sprayed from both directions.

After completion of the milling process, the restoration was separated automatically, 30 minutes firing cycle in a ceramic sintering furnace (Ivoclar/Vivadent/technical, Germany) according to manufacturer’s instructions. The internal bonding surface of indirect veneers was treated according to their manufacturers’ instructions as follow:

a) Indirect composite veneers (Group B) were sandblasted with 50 μm Al2O3 particles for 10 seconds at maximum pressure of 2 bars (30 psi), and then cleaned by ultrasonic cleaner with distilled water for 5 minutes.

b) Zirconia CAD veneers (Group C) was acid etch with 5% hydrofluoric acid gel (IPS Ceramic Refill) for 20 seconds washed and thoroughly with air/water spray for 30 seconds according to the manufacturer instructions (7). Then veneers were silanated with RelyX Ceramic Primer (3M ESPE) which was brushed onto the internal surface of the veneer and light cured for 5 seconds to evaporate the solvent.

All indirect veneers were cemented by the 3M RelyX veneer cement using two steps etch and rinse technique and the translucent shade cement.

The same procedure was followed for all indirect veneer according to the manufacturer’s instructions of the cement. The veneers were then stored in distilled water at 37° for 2 weeks before testing. The fracture strength test performed using a Universal Testing Machine (universal testing machine, China). Load was applied at crosshead speed 0.5 mm/min (5) with a customized plunger (steel rod with a flat end 3.6 mm diameter) attached to the upper movable compartment of the machine (7), placed at the incisor part of the laminate veneer (16). The load was applied to the long axis of the tooth. This orientation was standardized with a specially designed, locally manufactured, mounting jig (Fig. 5). The maximum load to produce fracture for each sample was automatically recorded in Newton (N). Modes of failure were assessed with stereomicroscope at 20x magnification. The results of this study were analyzed with one-way ANOVA and LSD test.
The means and standard deviations of fracture strength were calculated for each group shown in (Table 1).

Table 1: Descriptive Statistics: Mean and standard deviation of fracture strength in Newton.

<table>
<thead>
<tr>
<th>Group</th>
<th>No.</th>
<th>Mean</th>
<th>SD</th>
<th>Std.error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>10</td>
<td>410.20</td>
<td>12.557</td>
<td>2.39003</td>
</tr>
<tr>
<td>Group A</td>
<td>10</td>
<td>238.20</td>
<td>9.750</td>
<td>3.08329</td>
</tr>
<tr>
<td>Group B</td>
<td>10</td>
<td>210.40</td>
<td>12.807</td>
<td>4.05024</td>
</tr>
<tr>
<td>Group C</td>
<td>10</td>
<td>320.30</td>
<td>7.557</td>
<td>2.39003</td>
</tr>
</tbody>
</table>

The results of this study showed that the highest mean of fracture strength was recorded for the control group (410.20 N), followed by group C (320.30 N), next group A (238.20), while the lowest mean value of fracture strength was recorded by group B (210.40) (as shown in table 1). ANOVA test revealed statistically highly significant differences among the five groups (Table 2).

Table 2: Comparison among the groups using one-way ANOVA test

<table>
<thead>
<tr>
<th>Source of Variance</th>
<th>Sum of squares</th>
<th>Df</th>
<th>mean square</th>
<th>F</th>
<th>sig</th>
</tr>
</thead>
<tbody>
<tr>
<td>between groups</td>
<td>241446.275</td>
<td>3</td>
<td>80482.092</td>
<td></td>
<td>0.00</td>
</tr>
<tr>
<td>with groups</td>
<td>4307.700</td>
<td>36</td>
<td>119.658</td>
<td>672.599</td>
<td>0.001</td>
</tr>
</tbody>
</table>

Table 3: Multiple Comparisons LSD test

<table>
<thead>
<tr>
<th>GP</th>
<th>mean difference</th>
<th>std.error</th>
<th>sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group A vs Group B</td>
<td>18.800</td>
<td>4.89200</td>
<td>0.00</td>
</tr>
<tr>
<td>Group A vs Control</td>
<td>-172.000*</td>
<td>4.89200</td>
<td>0.00</td>
</tr>
<tr>
<td>Group A vs Group C</td>
<td>-103.100*</td>
<td>4.89200</td>
<td>0.00</td>
</tr>
<tr>
<td>Group B vs Control</td>
<td>-190.800*</td>
<td>4.89200</td>
<td>0.00</td>
</tr>
<tr>
<td>Group B vs Group C</td>
<td>-121.900*</td>
<td>4.89200</td>
<td>0.00</td>
</tr>
<tr>
<td>Group C vs Control</td>
<td>68.900*</td>
<td>4.89200</td>
<td>0.00</td>
</tr>
</tbody>
</table>
The results of ANOVA test showed that there were statistically highly significant differences ($p < 0.01$) among the four groups (table 2). The results of LSD test shows that there were statistically highly significant difference in the fracture strength of control group as compared with all the experimental groups (A, B, and C). Also statistically highly significant difference was found between group C and groups. Additionally, there were statistically significant differences in fracture strength between group A and group C and between group B and group C. On the other hand, no statistically significant differences were found among the direct and indirect composite groups (Group A and B).

IV. Discussion

According to the results of this study, the control group presented the highest mean fracture load among the groups; these results come in agreement with the results of Akoglu and Gemalmaz (4), and the differences between control group and other test groups were found to be statistically highly significant. In comparison between the mean of the directly restored group and the indirectly restored groups, the mean of fracture strength of direct composite veneer (Group A) was statistically significantly higher than that of group restored with composite indirect technique (Groups B), this could be explained by the elimination of cement layer in the direct composite veneer as cement is considered the weak restorative link (5). Composite luting materials are vulnerable to water sorption, polymerization shrinkage, and microleakage (11). This finding comes in agreement with Duzyol et al. (6) results.

The fracture strength of group B was found to be significantly lower than that of group A. This result may be attributed to the effect of surface conditioning (sandblasting and ultrasonic cleaning) of the indirect composite veneer prior to cementation in addition to the presence of the weak cement interface. This result comes in agreement with Borba et al. (7) and Duzyol et al. (6) who found statistically highly significant differences between fracture strength of directly and indirectly fabricated composite veneers. While disagree with Gresnigt and Ozcan (9) who found that direct and indirect resin composite laminate veneers showed comparable mean of fracture strength, owing to the differences in materials used for the construction of direct and indirect composite veneers.

According to LSD test there was a statistically highly significant difference between group A and group C. However, this result disagrees with the results of Batalocco et al. (10) study in which they found that there was no significant difference in fracture strength between composite resin veneers and porcelain veneers. This may be due to the difference in the test condition as they performed testing of the restorative materials under the wet condition.

The lowest mean of fracture strength presented by group B (220.4 N), this could be attributed to the combination of high strength (250 MPa) combined with high modulus of elasticity (10.5 GPa), which translates to lower resiliency, which is the capability of the material to absorb energy when it is deformed (8). So this might result in load transition to the weak link of the restoration (the cement layer).

Failure analysis of the fractured laminates in this study showed mainly fracture of the veneer restoration followed by veneers debonding which coincides with the finding of Gresnigt and Ozcan (9). Clinically, these types of failure could be considered more favorable, since it allows for intraoral repair options. Fracture of veneers was observed in 100% in groups (A, B) as the dominant type of fracture. Fracture of the laminate veneer was attributed first to the good adhesion of the laminate veneer to either dental tissue or the cement layer (9). Another explanation for this could be the relatively lower flexure strength of the materials, based on the fact that the flexural strength of the veneer cannot protect the tooth, the veneer will fracture before the loading force is transferred to the tooth (11).

Debonding of laminate veneers, on the other hand, showed the weak link between the cement/tooth and the laminate veneer and was observed only in zirconia CAD group with 100% as the only mode of failure. This could be attributed to the lower resiliency of the material which results in high stresses that develop directly below the loaded area at the cement interface. Interfacial stresses arise because ceramic has a higher elastic modulus than the tooth or cement (11). A higher incidence of bond failure was observed at cement/veneer interface 70% and the remaining 30% of debonding was at tooth/cement interface due to compromised bonding between the resin cement and the veneer surface.

In other words, most failures are caused by complete debonding at the porcelain/cement interface. Significant amount of crystalline debris that contaminates the porcelain surface and may reduce bond strength by 50% and this may be considered as another explanation for the lower bond strength at cement/veneer interface (12).
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V. Conclusion

This result indicates that both techniques direct and indirect are all the three different materials used for fabrication of laminate veneers could be considered strong enough to withstand normal biting forces but for patients with parafunctional habit other treatment modality should be considered. Further investigation is required to study bonding of zirconia CAD veneers, which were least likely to fracture but the most likely to completely debond.

These results may provide the clinicians a guideline for the selection of restorative treatment modality when they provide an aesthetic veneer restoration. It has been observed that the mechanical strength of the material would not be a determining factor, but other factors such as predictable and durable esthetics, reliability of the bonding and/or the cost of treatment could be determining factors to select the specific restoration.

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