Marginal Adaptation of CAD-CAM Fabricated Ceramic Inlays: An in-Vitro Evaluation

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Abstract: Background: Ceramic restorations can be fabricated by using traditional methods like heat-pressing as well as contemporary methods like Computer Aided Designing and Computer Aided Manufacturing (CAD-CAM). Existing evidence regarding the marginal adaptation of CAD-CAM fabricated ceramic inlays is contradictory. Aim: The main objective of the study is to determine the marginal gap widths of CAD-CAM fabricated lithium disilicate ceramic inlays in comparison with heat-pressed ceramic inlays using scanning electron microscopic examination. Materials and methods: Thirty-six intact, caries-free, maxillary first and second premolars were used in the study. Standardized class II disto-occlusal inlay cavities were prepared and were distributed into two groups of 18 specimens, each based on the method of fabrication. The two groups contained CAD-CAM (Group A), and heat-pressed ceramic inlays (Group B). In group A, the prepared inlay cavities were scanned with an intraoral scanner, designed, and milled from IPS e.max CAD blocks. In group B, the ceramic inlays were fabricated by manual impression making and lost wax technique using IPS e.max PRESS ingots and Programat EP 3610 furnace. The fabricated inlays were placed on the prepared cavities of the respective specimens. The scanning electron microscope was used to evaluate the marginal adaptation of specimens at 12 predetermined points for each specimen by a single examiner. The data were subjected to statistical analysis. Results: The mean marginal gap values for CAD-CAM group and heat-pressed were 83.27µm and 87.11µm, respectively. The CAD-CAM ceramic inlays exhibited better marginal adaptation than heat-pressed ceramic inlays with an insignificant difference between the two groups. Conclusion: CAD-CAM method of fabrication did not differ significantly from heat-press method when marginal adaptation property is considered. Moreover, all class II ceramic inlays exhibited minimal gap values. Clinical relevance: CAD-CAM fabricated ceramic inlays exhibited a comparable marginal adaptation with that of heat-pressed inlays. Thus, CAD-CAM fabrication is a better alternative to the conventional fabrication method, which can avoid multiple patient visits.

Keywords: Marginal integrity; CAD/CAM; heat-pressed; class II inlays

1. Introduction

The definitive goal of restorative dentistry is to maintain the health and integrity of the stomatognathic system. There is an increase in demand for esthetic restorative materials nowadays. Composite resins, glass-ionomer cement, and compomers are the tooth-colored materials used for direct restorations. None of these materials are suitable for restoring areas of the tooth subjected to heavy occlusal stresses. In these areas, the use of ceramics is considered as the best option due to their superior esthetics, improved mechanical properties, and biocompatibility. Ceramic materials are available in a wide range and are fabricated by using different methods like sintering, casting, and heat pressing [1]. Tremendous advances in software technology revolutionized dentistry with improved precision and reduced fabrication time. Computer-aided designing and computer-aided manufacturing (CAD-CAM) software help in the processing of indirect restorations in one appointment [2], [3].

Marginal adaptation is vital for the longevity of restorations as it affects the clinical outcome. Marginal gaps and irregularities cause luting cement exposure, which may result in marginal leakage and dissolution of the luting cement. In such conditions, marginal gaps act as portals of entry for microorganisms and oral fluids that can lead to secondary caries, pulpal disease, and periodontal inflammation[4].

Several researchers [4]-[7] investigated the marginal integrity of CAD-CAM ceramic inlays and heat-pressed ceramic inlays, but the evidence was contradictory. Few studies [6] reported that heat pressed technique resulted in better marginal adaptation, whereas other studies [4], [7] reported better adaptation with CAD-CAM technique. Another study [5] reported an insignificant difference in the marginal integrity of CAD-CAM and heat-pressed technique. The available evidence is contradictory and inadequate as many studies compared different types of ceramics for different fabrication techniques rather than using the same type of ceramic with different fabrication techniques. Thus, the study aimed to determine the marginal adaptation of lithium disilicate ceramic inlays fabricated using CAD-CAM and heat-press techniques when assessed with a scanning electron microscope.

The null hypothesis tested was that there would be an insignificant difference in the marginal adaptation of CAD-CAM fabricated IPS e.max CAD ceramic inlays and heat-pressed IPS e.max PRESS ceramic inlays.

2. Materials and Methods

The study protocol was approved by Institutional review board and Ethical Committee.

2.1 Screening and selection of specimens

The sample size estimation was done based on the marginal adaptation values of an earlier study[8]. Thirty-six extracted human maxillary premolars were selected for the study. Age and gender of the patient were not considered during the collection of specimens. The teeth were examined with magnifying loupes for fracture lines and minor defects. The inclusion criteria were fully formed intact maxillary
premolars with crowns of 7±0.5mm width. Teeth with caries, fracture lines, cracks, noncarious defects, and restorations were excluded. Extracted teeth were handled as per Centre for Disease Control (CDC) and institutional guidelines.

2.2 Specimen preparation

All the samples were cleaned with an ultrasonic scaler to remove the surface deposits and polished with pumice to remove plaque and debris. Later they were immersed in a 0.1% thymol solution for disinfection and storage until the experimental period. The root portions of the teeth were wrapped in aluminum foil and mounted in acrylic resin. Standardized disto-occlusal cavities of 2mm buccolingual width and 2mm pulpal depth were prepared on occlusal surfaces of maxillary premolars. All these disto-occlusal cavities were prepared with intact mesial marginal ridges of 2mm thickness. Proximal box depth was 4mm occlusogingivally, and width was 4mm buccolingually. The gingival seat was placed 1mm cervical to the cement-enamel junction. A taper of 8 degrees per wall was maintained with a 90° cavosurface angle. Rounding of internal line angles was done to reduce stress concentration.

2.3 Grouping of specimens and restorative techniques

All the samples were allocated randomly into two groups (n=18) group A and group B. In group A (CAD-CAM group), the prepared inlay cavities were scanned with an intraoral scanner (3Shape TRIOS, Copenhagen, Denmark). Scanning was performed by positioning the scanner over the occlusal surface along a long axis such that all the cavosurface margins and the internal line angles were recorded completely. Later the proximal surfaces were scanned to get the final optical impressions. Subsequently, restorations were milled from IPS e.max CAD blocks using imes-icore milling machine. The restorations were glazed and crystallized using a ceramic furnace at 840°C. Surface contaminants were removed from the restoration using a brush and try in of restorations were done.

In group B (heat-pressed), the restorations were replicated using polyvinylsiloxane impression material, and dies were prepared using type IV gypsum. Wax patterns were fabricated and invested. Then they were placed in the preheated furnace, which was heated up to a temperature of 850°C for 45 minutes. The assembled investment ring with IPS Alox Plunger was positioned centrally in the hot press furnace (Programat EP 3010) for heat pressing. The ring was left to cool to room temperature for 60 minutes, sectioned using a separating disk followed by microblasting and ultrasonic cleaning. The sprues were separated by using a fine diamond disk, and tints were added. After foundation firing for 20 minutes, ceramic inlays were then cleansed, seated on the master die, and the fit was verified.

2.4 Evaluation of marginal adaptation

The roots of the teeth specimens were sectioned horizontally 4mm apical to the CEJ. The specimens with restorations were gold sputtercoated (E1010 ion sputter) and evaluated using a scanning electron microscope at 10 kV and 800X magnification by a single examiner. The marginal adaptation was analyzed at 12 predetermined points, six points on the occlusal, and six points on proximal surfaces (Figure 1).

Figure 1: Predetermined points for marginal gap measurement

All the marginal gap values at 12 locations were recorded in micrometers (Figure 2 & 3) and averaged for every specimen.

Figure 2: Scanning electron micrographs at a, b, c, d, e & f on occlusal surface and g, h, i, j, k & l on proximal surface of CAD-CAM ceramic inlays

Figure 3: Scanning electron micrographs at a, b, c, d, e & f on occlusal surface and g, h, i, j, k & l on proximal surface of heat-pressed ceramic inlays

2.5 Statistical analysis

The data collected in the form of micrometers were entered in excel sheets and analyzed statistically employing SPSS software (Version 22.0, IBM, Armonk, NY). The Kolmogorov Smirnov test analyzed the normality of the marginal gap in the two groups. The marginal gap values between the two groups were compared using parametric
independent t-test. The statistical analysis was performed at 95% confidence level, with the significance level established at p≤0.05.

3. Results

Marginal gaps, z value, and p-value of groups A and B are depicted in Table 1.

Table 1: Grouping and statistical analysis (Kolmogorov Smirnov test)

<table>
<thead>
<tr>
<th>Group</th>
<th>Fabrication technique</th>
<th>Mean (µm)</th>
<th>Z-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group A - Lithium disilicate</td>
<td>CAD-CAM technology using 3Shape intra oral scanner andimesicorescanning machine</td>
<td>83.27</td>
<td>0.6720</td>
<td>0.750</td>
</tr>
<tr>
<td>CAM (n=15) (IPS e.max CAD)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group B - Lithium disilicate</td>
<td>Heat-pressed technique using manual impression making and Programat EP 3010 furnace</td>
<td>87.11</td>
<td>0.4660</td>
<td>0.9820</td>
</tr>
<tr>
<td>heat-pressed (n=15)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(IPS e.max PRESS)</td>
<td></td>
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</tr>
</tbody>
</table>

For the statistical analysis, the Kolmogorov Smirnov test was used. The mean marginal gap in µm, standard deviation (SD), and standard error (SE) are depicted in Table 2 for two groups A and B.

Table 2: Intergroup comparison of marginal gaps (Independent t test)

<table>
<thead>
<tr>
<th>Groups</th>
<th>Mean (µm)</th>
<th>SD</th>
<th>SE</th>
<th>t-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group A (CAD-CAM)</td>
<td>83.27</td>
<td>24.00</td>
<td>5.66</td>
<td>0.4796</td>
<td>0.6346</td>
</tr>
<tr>
<td>Group B (Heat-pressed)</td>
<td>87.11</td>
<td>25.27</td>
<td>5.64</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Marginal gap values in two groups (A and B) follow a normal distribution. Hence, the parametric independent t-test was employed to analyze statistically (Table 2). The mean marginal gap in CAD-CAM group (83.27µm) is less than the mean marginal gap in the heat-pressed group (87.11µm), but the difference was insignificant (p=0.6346). The standard deviation of group A is fractionally higher than that of group B.

4. Discussion

In the past few decades in dentistry, there has been a wide array of materials like metal alloys, ceramics, and composites, for the fabrication of indirect restorations. Ceramic in dentistry is becoming popular, which has not only good mechanical properties but also excellent esthetics [9].

Several factors are to be considered while selecting the suitable restorative material for the procedure to provide optimal longevity [10]. The survival of the restorations depends upon various material factors. They are the marginal integrity of the material at the restorative-tooth interface, wear resistance, fracture resistance, modulus of elasticity, strength, dimensional stability, thermal conductivity, and biocompatibility of restorative material [11]. Adequate marginal adaptation is necessary to prevent microleakage, recurrent caries, and failure of the restoration. Direct and indirect restorations with inadequate marginal adaptation cause exposure of the dentin or base cement to the oral fluids and microbes. Eventually, the restoration may be vulnerable to microleakage and plaque accumulation that may lead to postoperative sensitivity, secondary caries, pulpal disease, and restoration failure. [12],[13] The horizon of CAD-CAM techniques modernized the indirect restorative procedures drastically. This reduced the chances of manual error and imperfections during the fabrication of restorations [14].

The study results revealed that the marginal adaptation of the CAD-CAM ceramic inlays was superior to that of heat pressed inlays. The difference was not significant statistically. Thus, the null hypothesis was accepted. The results were like earlier studies by Addi S et al. [5] who determined the marginal adaptation of lithium disilicate inlays. Another study [15] reported similar results while assessing the marginal adaptation of crowns. The improved marginal adaptation in CAD-CAM ceramic inlays was due to a reduced number of steps. Less number of steps decreases the risk of manual errors and imperfections during fabrication. Another reason was dimensional stability of material as there were no temperature changes. During fabrication of heat-pressed ceramic inlays temperature changes may result in dimensional changes during heating and cooling of ceramic.

Few earlier studies [4],[7] reported better marginal integrity with CAD-CAM fabricated ceramic inlays, and the difference was statistically significant. This difference could be due to the different study methodologies. One study [4] compared leucite reinforced ceramic with lithium disilicate ceramic inlays manufactured by CAD-CAM and heat-pressed technique. Another study [7] compared the two techniques using leucite reinforced ceramic material. Both studies employed a stereomicroscope for the determination of the marginal gap. In the present study, a scanning electron microscope was employed for its accuracy and a wider range of magnification.

On the contrary, Alajaji et al. [6] observed significantly better marginal adaptation with heat-pressed lithium disilicate ceramic material. The difference in the results could be due to the difference in fabrication and evaluation methods. In their study E4D dentist system scanner was employed for digital impression whereas 3Shape TRIOS was used in this study. Milling machine used in the current study was icore milling device whereas in the previous study E4D three-axis milling device whereas in the previous study E4D three-axis milling device and Tizian cut five-axis milling machine were used. The evaluation method employed in their study was micro-CT for internalfit and marginal fit whereas, in the present study, SEM was employed for marginal adaptation.

Apart from a reduced number of steps in CAD-CAM inlays, fabricated restorations can be luted in the same visit. Existing literature reported contradictory evidence regarding marginal adaptation achieved by both the techniques [16]. This could be due to differences in scanners, milling machines, and evaluation methods. As per existing evidence[17], video scanners are better than image scanners.
Thus, the 3Shape TRIOS scanner was employed in this study, which is a video scanner. Scanning electron microscopy allows direct examination of the specimens, but it requires the processing of specimens, which may result in irreversible changes in the specimens. Thus, marginal adaptation could not be studied after luting the restorations.

The acceptable clinical width of the marginal gap is controversial. Few authors [18],[19] reported that a marginal gap ranging from 100 to 120 µm is clinically acceptable to prevent degradation or dissolution of luting cement. According to many other studies, the marginal gap widths of 100 to 200 µm are considered clinically acceptable for indirect restorations [20] – [22]. Significant measures were taken to eliminate observer bias by randomly coding the specimens during scanning electron microscopy. Another important measure taken for accuracy was measurement of marginal gaps at 12 specified points. These gap widths were averaged for each specimen. The study’s limitation is that the scanning electron microscopy required sputter coating of the specimens which may result in desiccation of the specimens.

5. Conclusion

The method of fabrication did not significantly influence the marginal gap values of lithium disilicate ceramic inlays. The CAD-CAM ceramic inlays exhibited better marginal adaptation than heat-pressed ceramic inlays, though they did not differ significantly. All the ceramic inlays presented clinically acceptable marginal adaptation.

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b) Declaration

Conflict of Interest: Nil

Funding: None

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References


