INFLUENCE OF MARGINAL PREPARATION DESIGN ON MICROLEAKAGE AND MARGINAL GAP OF ENDOCROWN CEMENTED WITH ADHESIVE RESIN CEMENT

Amal Abdallah A. Abo-Elmagd * and Mohamed Abdel-Aziz *

ABSTRACT

Purpose: The aim of this in vitro study was to evaluate the microleakage and vertical marginal gap of lithium disilicate ceramic endocrown with either butt margin or shoulder finish line.

Materials and methods: Fifteen endodontically treated mandibular premolars were grouped into 3 groups (n=5) according to type of restoration. Group 1: A glass fiber post and resin core and all-ceramic crown with shoulder finish line as control group. Group 2: Endocrown with butt margin. Group 3: Endocrown with shoulder finish line (1mm wide shoulders and 2 mm axial wall heights). E-max all-ceramic restorations (IPS E-max press Ivoclar-Vivadent) were made and adhesively cemented with resin cement. A digital-microscope (Scope Capture Digital Microscope, Guangdong, China), magnification X50 was used to determine the marginal gap in (µm). Samples were sectioned and the dye penetration along the margin was assessed with the microscope at 25× magnification. The total dye penetration depth along the restoration-tooth interface was measured in (µm). Data were analyzed using one way analysis of variance (ANOVA) and post hoc significance difference tests. Difference was significant at P<0.05.

Results: Gr 1 (Fiber post and conventional crown) recorded statistically significant (p <0.05) highest vertical marginal gap mean value (73.02 ± 24.94µm), followed by Gr 3 (endocrown with shoulder F.L) (46.72±13.1 µm), then, Gr 2 (endocrown with butt margin) (44.66±10.71µm) as indicated by one way ANOVA test. Pair-wise Tukey’s post-hoc test showed non-significant difference in the vertical marginal gap mean value (P>0.05) between endocrown groups; (2) and (3). For microleakage, Gr 3 (endocrown with shoulder F.L) recorded statistically significant (p <0.05) highest marginal leakage mean value (109.76±4.4µm), followed by Gr 1 (Fiber post and conventional crown) (84.17±1.9 µm). While Gr 2 (endocrown with butt margin) recorded the lowest statistically significant (p <0.05) mean value (55.46±4.1 µm) as indicated by one way ANOVA test. Pair-wise Tukey’s post-hoc test showed significant difference (p <0.05) between all groups.

Conclusion: Within the limitations of this study, (1) Endocrown was superior to conventional crown regarding vertical marginal gap. (2) Endocrown margin design had no significant effect on vertical marginal gap. (3) Endocrown with butt joint margin resulted in less marginal leakage than that with shoulder finish line.

*Lecturer, Department of Fixed Prosthodontics, Faculty of Dental Surgery, Misr University for Science and Technology.
INTRODUCTION

With the improvements in physical and mechanical properties of ceramic materials, they have been recommended for fabrication of esthetic fixed restorations. Lithium disilicate-based ceramics are used for construction of both conventional crowns and endocrowns because they are more translucent, have high mechanical strength and can be acid etched which promote micromechanical interlocking with resin cement and bonded to the tooth interface.\(^1\)

Endocrown is a type of restoration consists of the entire core and crown as a single unit. It uses the available surface of the pulp chamber axial walls as macro-retentive resources and adhesive resin cement as a means of micromechanical retention.\(^2\) Nowadays, ceramic endocrown restoration is considered an alternative treatment to post-and-core and conventional crown in endodontically treated molar teeth. The idea of restoring the endodontically treated premolars with endocrown restoration was also reported by many researchers.\(^3,4\)

One of the main causes of failure of endodontically treated teeth is coronal leakage. Microleakage at the margins of crowns allows the passage of fluids and micro-organisms and may lead to staining at the restoration-tooth interface and pulpal irritation.\(^5\)

Ideally the cemented crown should precisely meet the finish line of the prepared tooth. However, clinical perfection is difficult to achieve. Although marginal opening alone does not directly correlate with microleakage, the accuracy of marginal adaptation is appreciated as one of the most important criteria for the clinical quality and success of prosthetic restorations.\(^6\)

The presence of marginal discrepancies in the restoration exposes the luting cement to the oral environment\(^7\) and may lead to increased dissolution of the cementing medium\(^8\) and recurrent caries of the remaining tooth structure.\(^9\) Many factors affect the marginal adaptation of a crown such as; the preparation dimensions, type of finish line, type of cement used\(^10\), type of crown material and seating force.\(^11,12\)

Luting cements have been considered as the “weak link” in fixed restorations. Therefore, they should be insoluble in oral fluids, have good mechanical properties and a good adhesion to the tooth and to the restoration in order to reduce microleakage around the restoration.\(^13,14,15\) Advances in resin cements and adhesive dentistry provide a wide chance for more conservative restoration of endodontically treated teeth than post and core and crown and better sealing the restoration/tooth interface.\(^16\) Resin cements are virtually insoluble in the oral environment. On the other hand, seating the restorations luted with resin cements has been studied and observed that cement film thickness in some situations were greater than other cement types.\(^17\)

Almost all ceramic crowns have shown inferior marginal adaptation as compared to metal-ceramic crowns.\(^18\)

Several designs of finish line have been prepared for fixed prosthodontics and their effects on microleakage and marginal gap of conventional crown have been reported in many studies.\(^19,20\) However, the number of studies that paid attention to the effect of different marginal preparation designs of ceramic endocrown on microleakage and marginal gap were very limited.

Therefore, the aim of this in vitro study was to evaluate the microleakage and marginal gap on lithium disilicate ceramic endocrown luted with resin cement using two different marginal preparation designs and compare them with a conventional fixed crown.

MATERIALS AND METHODS

Preparation of teeth

Fifteen human single rooted mandibular premolars were selected for the study with average dimensions at the level of cemento-enamel junction.
(15 mm root length, 8 mm bucco-lingual, and 5 mm mesio-distal). All the teeth samples were endodontically treated. Each root canal was prepared using rotary files (Protaper, Dentsply, Maillefer, Switzerland). After intermittent irrigation, the root canals were dried with paper points (Spident, Incheon, Korea). The canals restored with gutta-percha cones (Protaper, Dentsply, Maillefer, Switzerland) using eugenol-free root canal sealer (AH Plus, Dentsply, De tray, Germany) and stored in saline solution at room temperature. All teeth were sectioned 2 mm coronal to the cemento-enamel junction. Then, the teeth were divided into three groups (n=5) according to the type of restoration and the margin preparation design (Figure 1):

**Group 1:** Glass fiber post and composite resin core, and all-ceramic crown with shoulder finish line (control group).

**Group 2:** Endocrown with butt margin preparation

**Group 3:** Endocrown with shoulder finish line.

![Fig. (1) Prepared teeth with their heat-pressed Lithia disilicate-based ceramic crowns and endocrowns](image)

**Group (1):**

Five samples (n=5) were received glass fiber posts size no.1 (Glassix+plus, Nordin, Switzerland) and a resin composite filling core (Tetric Ceram, Ivoclar Vivadent, Liechtenstein). After coronal sectioning, a pilot reamer of the post system was used to remove the gutta-percha to the length of 12 mm from the occlusal margins. Then calibrating drill (size no.1) was used to prepare a post space. 36% phosphoric acid (Total Etch, Ivoclar Vivadent, Liechtenstein) was used to etch the canals for 15 seconds. The canals were rinsed with sterile water and dried with paper points. A light cure adhesive agent (Tetric N-Bond, Ivoclar Vivadent, Liechtenstein) was applied inside the root canal using a micro brush. The adhesive was rubbed to canal walls for 10 seconds and the excess was removed with gentle oil free compressed air for 5 seconds and light cured using a blue light curing unit (foshan coxo medical instrument co., ltd China.) for 40 seconds for each specimen.

A silane coupling agent (Silane, Ultradent, South Jordan, Utah, USA) was applied on the post surface for one minute and gently air dried for 5 seconds. Then, the post was luted with the same bonding agent using the brush, the excess was removed and the adhesive was cured for 40 seconds. Dual cure resin cement (Variolink N, Ivoclar Vivadent, Liechtenstein) was mixed properly and applied for post, the post was seated into the canal and curing light was applied at the coronal end of the post for 40 seconds.

Excess of each post more than 4 mm from the cemento-enamel margin was cut. The core was built incrementally with composite resin (Tetric N-Ceram, Ivoclar Vivadent, Liechtenstein). A transparent core build up matrix was used to standardize the samples with 3 mm core height and the same convergence of the axial walls. A rotary diamond stone was used to prepare a one mm shoulder finish line with 2 mm circumferential ferrule axial wall.5, 21

**Group (2):**

Five teeth samples (n=5) were prepared for endocrown restorations. Each tooth was sectioned 2 mm coronal to the cemento-enamel margin to
prepare a butt margin. Each pulp chamber was prepared with an oval anti-rotational shape central retention cavity with a depth of 5 mm from the cavo-surface margin and internal taper of 8-10 degrees using milling machine (NOUVAG AF30 milling machine, Switzerland).

**Group (3):**

Five teeth samples (n=5) were also prepared for endocrown restorations as in group (2). The margins of all teeth were further prepared for 1 mm shoulder finish line and 2 mm circumferential ferrule axial wall.

**Laboratory of fabrication all-ceramic crown:**

Impressions were taken to each sample using poly-vinyl siloxane impression material (Virtual, Ivoclar-vivadent) and stone dies (type IV) were poured. Either conventional crown or endocrown pattern was constructed using wax (GEO, Renfert GmbH, and Germany) with the same heights and dimensions, sprued, invested and duplicated in a hot pressed monolithic disilicate IPS e-max (Ivoclar-Vivadent) by the injection technique according to the manufacturer’s instructions.

**Cementation procedure:**

The intaglio surface of the all-ceramic crowns and endocrowns were etched with 9.5% buffered hydrofluoric acid gel (Porcelain etch, Ultradent South Jordan, Utah, USA) for one minute, then washed thoroughly and dried. The etched surface of each crown was silanized (Silane, Ultradent, South Jordan, Utah, USA) for one minute and then dried followed by adhesive agent (Tetric N-bond, Ivoclar Vivadent, Liechtenstein) and light cured for 40 seconds.

The prepared surfaces were etched with 36% phosphoric acid (Total Etch, Ivoclar Vivadent, Liechtenstein) for 20 seconds, rinsed for 30 seconds. Then, the adhesive system was applied on the prepared surface of teeth and air thinned with oil and moisture-free air for 5 seconds until the solvent is evaporated and the resin no longer flows over the surface. All crowns were cemented with their corresponding treated teeth samples using dual-cure resin cement (Variolink N, Ivoclar Vivadent, Liechtenstein). Excess cement was removed immediately with a microbrush moistened with bonding agent and light cured.

**Thermocycling**

The teeth were stored in distilled water at 37°C for 24 hours prior to thermal cycling according to the ISO (International Organization for Standardization) recommendations. The specimens were submitted to 500 cycles in water bath between 5°C and 55°C. The exposure to each bath was 30 seconds and the transfer time was 10 sec.

**Vertical marginal gap testing:**

The marginal gap along the restoration margins were assessed using a custom made holding device. Samples were positioned on a digital microscope (Scope Capture Digital Microscope, Guangdong, China) perpendicularly at 50X magnification in which the images were captured and transferred to a computer equipped with the Image analysis software program (Image J 1.43U, National Institute of Health, USA).

Within the Image J software, all limits, sizes, frames and measured parameters are expressed in pixels. Therefore, system calibration was done to convert the pixels into absolute real world units. Calibration was made by comparing an object of known size (a ruler in this study) with a scale generated by the Image J software. Then, the images of traced marginal path were overlaid and transferred to Image J software in order to calculate gap distance which measured in (µm).

**Microleakage testing:**

Each sample was covered with two layers of nail polish (except for 1 mm around the crown-tooth
interface) then vertically downward immersed in a solution of 2% methylene blue dye (SD Fine-Chem limited, Mumbai, India) for 24 hours at 37°C temperature incubator. Subsequently, samples were taken out of the dye solution, washed with water. The teeth with their coronal restorations were then embedded in acrylic resin blocks to avoid chipping of ceramic during sectioning.

Samples were sectioned with a low speed diamond saw (Top Dent, Edenta Golden, Swiss) under water spray. The specimens were rinsed in running water and then dried with tissue paper. The dye penetration along the margins was assessed with USB Digital microscope (Scope Capture Digital Microscope, Guangdong, China) at 25× magnification in which the image was captured and transferred to a computer equipped with the image analysis software program (Image J 1.43U, National Institute of Health, USA). The images of traced dye path were overlaid in order to calculate dye penetration depth. The total dye penetration depth along the restoration-tooth interface was measured in (μm).

**Statistical analysis**

Data analysis was performed by one way ANOVA followed by pair-wise Tukey’s post-hoc tests to detect significance between groups. Statistical analysis was performed using Asistat 7.6 statistics software for Windows (Campina Grande, Paraiba state, Brazil). Differences were considered significant at P<0.05.

**RESULTS**

**Vertical marginal gap:**

The recorded vertical marginal gap value at tooth/restoration margin was measured in μm (figure 2).

Mean marginal gap in μm and standard deviations (SD) of the tested groups are recorded and displayed in table (1) and graphically drawn (figure 3).

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>SD</th>
<th>Tukey’s rank</th>
<th>ANOVA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gr1</td>
<td>73.02</td>
<td>24.94</td>
<td>B</td>
<td>P value &lt;0.0001*</td>
</tr>
<tr>
<td>Gr2</td>
<td>44.66</td>
<td>10.71</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td>Gr3</td>
<td>46.72</td>
<td>13.1</td>
<td>A</td>
<td></td>
</tr>
</tbody>
</table>

Different letter indicating significance (p<0.05) *; significant (p<0.05)

![Fig. (2) Marginal gap measured in μm.](image)

**Fig. (3) A column chart of vertical marginal gap mean values for all groups**

![Table 1: Comparison of vertical marginal gap results (Mean±SD) between all groups](image)
It was found that group 1 (Fiber post and conventional crown) recorded statistically significant (p <0.05) highest mean value (73.02 ± 24.94µm), followed by group 3 (endocrown with shoulder F.L) (46.72±13.1 µm). While group 2 (endocrown with butt margin) recorded the lowest statistically significant (p <0.05) mean value (44.66±10.71µm) as indicated by one way ANOVA test. Pair-wise Tukey’s post-hoc test showed non-significant difference (P>0.05) between endocrown groups; (2) and (3).

**Marginal leakage:**

The recorded marginal leakage at tooth/restoration margin was measured in µm (figure 4).

Mean marginal leakage in µm and standard deviations (SD) of the tested groups are recorded and displayed in table (2) and graphically drawn (figure 5).

It was found that group 3 (endocrown with shoulder F.L) recorded statistically significant (p <0.05) highest marginal leakage mean value (109.76±4.4µm), followed by group 1 (Fiber post and conventional crown) (84.17±1.9 µm). While group 2 (endocrown with butt margin) recorded the lowest statistically significant (p <0.05) mean value (55.46±4.1 µm) as indicated by one way ANOVA test. Pair-wise Tukey’s post-hoc test showed significant difference (p <0.05) between all groups.

**DISCUSSION**

This study was designed to investigate the vertical marginal gap and marginal leakage of endocrowns, as function of the preparation finish lines, when cemented with adhesive resin cement. Conventional all ceramic crowns were considered the gold standard for the investigated parameters, so they were taken as a control group.

The accuracy of the ceramic material replacing the lost dental structure to the prepared tooth surface is directly related to the longevity of the prosthesis which has a great value for the scientific evidence of clinical situations.20
Marginal gap in the range of 100 μm have been reported to be clinically acceptable with regard to longevity of a restoration.23,24 All the samples tested in this study were within this range.

In this study, the vertical marginal gaps of group 1 (conventional crown with shoulder finish line) showed significantly higher mean value than the endocrown groups; 2 & 3. This may be due to the incomplete seating of the crown after cementation.25 When the conventional crown is cemented; the axial wall of the preparation approaches the axial wall of the crown fitting surface and the path for the cement escape decreases, causing the hydrostatic pressure within the crown to increase. Furthermore, Cagidiaco et al26 found that the incomplete seating of the crown is due to the increased film thickness of resin cement which accumulates at the occlusal surface of the prepared tooth.

On the other hand, the improved bonding mechanism between the resin cement and the increased bulk of lithium disilicate-based ceramic at butt joint tooth/restoration interface of endocrowns decreased the marginal discrepancies.27 Moreover, the butt joint tooth/restoration interface may permits the easy escape of resin cement. Thus, the vertical marginal gap was decreased. This explained that there was no significant difference between endocrown groups; (2) and (3) in the mean vertical marginal gaps value.

Another investigation in this study was directed to microleakage which is defined as “the diffusion of substances such as bacteria, oral fluids, molecules and/or ions, into a fluid-filled gap” 28 or “a structural defect that is naturally present or that occurs between restorative materials and tooth structure”.23

Different materials and techniques have been used for measuring microleakage with or without thermal cycling, including; scanning electron microscopy, compressed air, bacterial activity, chemical and radioactive tracers agents and radioactive isotopes.29 The color dye penetration technique used in this study is the most popular one, because it is an easy simple method and provides the ability for accurate observation by digital imaging.30,31

The results revealed that designs of finish line preparation for different lithium disilicate-based restoration of endodontically treated premolars play an important role in the degree of microleakage. The endocrowns with butt margin (group 2) showed the lowest statistically significant mean leakage value. A peripheral enamel layer might be present around the circumferential butt joint marginal preparation of the tooth and enhance such a favorable tooth/porcelain bonding which could reduce the marginal leakage.

The results of this study showed also a statistically significant higher leakage value in the endocrowns with shoulder finish line (group 3) than glass fiber post-retained crown with shoulder finish line (group 1). This result was in agreement of Forberger and Göhring 4 who concluded that marginal continuity of ceramic crowns was better and more resistant to thermal stresses when posts and cores were included in the restoration of endodontically treated teeth compared to teeth restored with ceramic crowns of the endo-crown design. The specimens in this study were artificially aged by thermal cycling. The thermal cycles could produce significant stresses on the restorations interface causing the failure of the cement interface even with the relatively low number of thermal cycles. It has been suggested that as thermal stresses act rapidly to produce microleakage, prolonged cycling is unnecessary.32

**CONCLUSION**

Within the limitations of this study, the following conclusions can be drawn:

1. Endocrown is superior to conventional crown regarding vertical marginal gap
2. Endocrown margin design has no significant effect on vertical marginal gap.
3. Endocrown with butt joint margin results in less marginal leakage than that with shoulder finish line.

REFERENCES


