Clinical Evaluation of The Marginal Integrity, and Internal Fit of E-Max Endocrown Restorations with Different Marginal Preparation Designs. Ex-Vivo Study

Inas A. Elalem**, Rabab M. Ibraheem†, Ahmed M. Hamdy‡

1Lecturer of Conservative and Fixed Prosthodontics at Dr.Haider A. Shafi dental college, Al-Azhar University, Gaza Strip, Palestine
2Professor of Fixed Prosthodontics, Faculty of Dentistry, Cairo University, Cairo, Egypt
3Professor of Fixed Prosthodontics, Faculty of Oral and Dental Medicine, October University Modern Science and Arts, Cairo, Egypt

*Corresponding Author: Inas A. Elalem, Dr. Haider A. Shafi dental college, Al-Azhar University, Gaza Strip, Palestine. Address, Rimal, Gaza, Gaza Strip, Palestine. Tel:00970599448344, Email: inas.alalem@gmail.com

Introduction

One of the conservative approaches that has been developed with the advances of adhesive and bonding techniques is the endocrown restoration, which is a monoblock restoration that has the ability to restore a severely destructed endodontically posterior teeth. It follows the concept of minimal invasive preparation as it gains its retention and stability from anchoring to the internal part of the pulp chamber and the cavity margins [1,2]. Endocrown restorations have two different marginal preparation designs, either with a finish line, or with a butt joint. Both designs are supra-gingival cervical margins that have the advantages of preservation of sound tooth structure, and the periodontium, as well as the facilitation of teeth preparation and impression taking [3].

Endocrown restoration approach has gained more popularity, due to its advantages in providing better esthetic, better mechanical performance, less removing of sound tooth tissues, and less clinical time [4]. Endocrown restoration has been considered as a reliable alternative to the conventional restoration of severely damaged posterior teeth [3-5]. Lithium disilicate glass ceramic has been widely used in the dental practice because it had satisfied the requirements of both dentists and patients. It is a highly aesthetic material, and can be easily and simply bond to the tooth structure with resin cement after being treated with hydrofluoric acid and silane coupling agents. Along with the surface treatment of tooth structure by acid etching and application of bonding agents [6]. It also has adequate mechanical and sufficient strength to be used in the fabrication of single and short span bridges up to premolar areas combined

Abstract

Purpose: The aim of this study was to evaluate clinically the marginal integrity, and internal fit of endodontically treated molar teeth restored with endocrown restorations with two different preparation designs.

Materials and Methods: Seventeen patients had a twenty endocrown restorations which were constructed of lithium disilicate (IPS E.max press ceramic). The endocrown restorations were randomly and equally divided into two groups regarding the marginal preparation designs; group 1: had a butt joint preparation and group 2: had a circumferential preparation with deep chamfer finish line. Evaluation of the marginal integrity and the internal fit were performed using silicon replica technique, each replica was sectioned into four segments and each segment had five reference points to be measured using digital microscope at 35X magnification. The data were analyzed using Two-way ANOVA and Post-hoc tests.

Results: The marginal gaps of both groups were within the clinical acceptable range, but group 1 (73.49±5.29µm) was statistically significantly higher than group 2 (59.81±3.42µm), meanwhile there was no significant difference regarding the internal fit of both groups as group 1(83.05±11.72 µm) had slightly higher mean value than group 2 (80.29±10.59 µm).

Conclusion: Endocrown restorations with different preparation designs showed a clinical acceptable range of marginal and internal fit.

Keywords: Endocrown Restorations, Marginal Preparation Designs, Marginal Integrity, Internal Fit.
with having acceptable clinical marginal and internal adaptation [7,8].

The two of the most important parameters that affect the longevity of any restoration and very crucial for the clinical outcome of the dental restoration are the marginal and internal fit of the restorations. Increasing the marginal and internal discrepancies will lead to dissolution of the luting cements in the oral environment which may negatively affect the longevity and increase the failure rate of the restorations [9, 10].

In response to the limited clinical evidence regarding the endocrown restorations [11], the purpose of this clinical study was to investigate the effect of different marginal preparation designs of E-max press endocrown restorations on the marginal integrity, and internal fit. The null hypothesis was that there would be no difference in the marginal integrity and internal fit between the two endocrown preparation designs.

Materials and Methods

The study received approval from the Ethics Committee of the Modern Science and Arts University. All the study participants were randomly selected and informed of the study procedures, its purpose, the benefits of the interventions and the minimal risk that might be inquired during the study. In addition to that, they were acquainted that they have the right to withdraw at any time from the research, to ask questions about the research procedures and they have the freedom of participation without coercion. The consent form was discussed and declared prior to their signatures.

The participants were recruited in the department of higher education of the Modern Science and Arts University in Cairo, Egypt and all the study procedures were conducted in the dental clinic of the higher education department of the Modern Science and Arts University. Only patients that met the inclusion criteria were chosen, meanwhile who met the exclusion criteria were excluded as shown in (Table 1).

This study included 20 endocrown restorations, which were performed in a total of 17 patients divided into 13 female and 4 male between the ages of 18 and 50 years in which the mean age of the study participants is 29 years. Three female patients had two endocrown restorations, while the others had a single endocrown restoration.

The patients were assigned randomly and equally into two groups according to the marginal preparation design of endocrown restorations either with a butt joint or with circumferential preparation with deep chamfer finish line in which each group had a ten-endocrown restorations.

The randomization method was performed by tossing a coin and all the clinical procedures were implemented by the same operator who is a master student in esthetic and conservative dentistry to ensure standardization in all the procedures. The clinical procedures of the study are briefly illustrated in (Figure 1).

Preparatory procedures and teeth preparation

All patients were motivated to keep good oral hygiene during and after treatments. Prophylactic treatment was performed. Patients who suffered from pulpal pain had received root canal treatment and for dental photography documentation, a set of at least 12 pictures were taken for each participant. The prosthodontics procedures were performed in two visits in the dental clinic of the department of higher education of Modern Science and Arts University. In the first visit before tooth preparation a silicone putty index (Zhermack, Elite® HD+ Putty soft, fast set, Italy) for a provisional restoration was made involving at least one tooth each beyond the endodontically treated tooth using a sectional tray and the shade was selected using Toothguide 3D Master (VITA Zahnfabrik, North America), also prior to tooth preparation.

Tooth preparation was performed for every patient according to the endocrown preparation parameters which were recommended by Einhorn et al (2017) [2].

The patients were randomly assigned into two groups regarding the marginal preparation designs: (group 1) had a butt joint preparation design and (group 2) had a circumferential preparation with deep chamfer finish line design.

Butt joint preparation design (Group 1)

A proper occlusal reduction in occluso-cervical direction of two mm was performed using a wheel stone bur (Mesinger diamond wheel 909 FG medium, Germany) to allow an appropriate space for the endocrown material thickness and to have a 90° butt joint margins with a minimum width of (2 ± 0.5) mm, and minimum height of (2 ± 0.5) mm to provide adequate adhesion of the endocrown restoration. Additionally, a central retentive cavity of (3 ± 0.5) mm depth that extended into the pulp chamber space was prepared to provide a proper resistance and retention features along with occlusal divergence of 8 to 10 degree as well as smooth internal wall transitions. Moreover, a flat pulpal floor was performed with sealed canal orifices with flowable composite (3M Filtek Z350XT flowable composite shade A1, USA) as shown in (Figure 2-A).

<table>
<thead>
<tr>
<th>Inclusion Criteria</th>
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<tbody>
<tr>
<td>1. Patients age range from 18 to 50 years old with healthy physical status and able to read and write.</td>
<td>1. Patients with improper physical status or who cannot read or write.</td>
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<tr>
<td>2. Patients should have an asymptomatic properly treated root canal molar with no active periodontal or apical lesions indicated for endocrown restorations.</td>
<td>2. Patients with active periodontal lesions, apical lesions involvement, or improper root canal treatment.</td>
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<tr>
<td>3. Patients having molar tooth indicated for both root canal treatment and endocrown restoration.</td>
<td>3. Sever loss of the tooth structure in which the amount of the remaining tooth structure is less than 2mm.</td>
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<tr>
<td>4. Patient with good oral hygiene and motivation.</td>
<td>4. Endodontically treated molar teeth with great variation in dimensions in all directions.</td>
</tr>
<tr>
<td>5. Patients with normal occlusal relation and casts could be assembled for bite registration.</td>
<td>5. Patients with poor oral hygiene.</td>
</tr>
<tr>
<td>6. Selected endodontically treated teeth must have nearly similar dimensions in which the mesiodistal width range from (11.5 ± 0.5) mm and the buccolingual width range from (10.5 ± 0.5) mm.</td>
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Seventeen patients were recruited in the dental clinic of higher education department and had a total of twenty endocrown restorations \((n=20)\)

Randomly and equally divided into 2 groups. According to the marginal preparation designs of endocrown restorations by tossing a coin

**Group 1:** had a butt joint preparation design \((n=10)\)

**Group 2:** had a circumferential preparation with deep chamfer finish line design \((n=10)\)

Fabrication of twenty lithium disilicate endocrown restorations

Trial placement of the restorations on the prepared teeth intra-orally to ensure proper seating

Construction of addition silicon replica samples by injecting the light-body silicon replica in the fitting surface of endocrown restorations, then inserting it over the corresponding teeth preparation intra-orally

To measure the marginal integrity and internal fit

Cementation of the endocrown restorations in the patient mouth

Figure 1: Schematic diagram illustrates briefly the clinical procedures

Circumferential preparation with deep chamfer finish line design (Group 2)

The occlusal reduction was performed as group [1]. Then the tooth was prepared with taper stone with 1 mm round end (Meisinger diamond tapered round end 856 FG medium, Germany) in which 0.8 mm finish line was made. The initial proximal preparation was made with diamond tapered point needle stone (Meisinger diamond tapered point needle 859 FG medium, Germany) to open the tooth contact mesially and distally, then proceeding with the 1 mm round end taper stone bur in which the outer axial walls had a minimum width and height of \((2 \pm 0.5)\) mm, along with occlusal convergence of 8 to 10 degree and all the gingival margins were kept
supragingival. The central retentive cavity of (3 ± 0.5) mm depth was prepared which extended into the pulp chamber space with occlusal divergence of 8 to 10 degree as well as all internal line angles were rounded and smoothened. In addition to that, a flat pulpal floor was performed similar to the group [1] as shown in (Figure 2- B).

All the teeth preparations were made by the same operator to ensure standardization of the preparation along with measuring and checking the depth of the pulp chamber cavity, the width and the height of the cavity walls using graduated periodontal probe with rubber stopper and digital caliper (Jinjiang jixiang group Co. Ltd, China) to ensure that the depth of central pulpal cavity in both groups was between (3±0.5) mm, and to verify that the width and the height of the axial walls were between (2 ± 0.5 ) mm in both groups.

Before taking the secondary impression, a putty rubber impression index was taken to ensure the proper endocrown preparation to check if there were any irregularities in the pulp chamber. Then, a secondary impression was taken using two steps (putty-wash) impression technique: in the first step, the putty impression was taken before endocrown preparation, then the excess material was removed and escape channels were cut in the putty impression using dental scalpel (International HK Co, Jiangsu, China) and scalpel blade size 11 (Huaiian Ruijie medical instruments Co., Ltd. Jiangsu, China). The second step was taken after endocrown preparation by relining the putty impression with light wash (Zhermack, Elite® HD+ Light body, fast set, Italy). The final step in the first visit of the prosthodontic procedure was fabrication of the provisional restoration by the injection of the provisional restorative material (3M, Protexm™ Plus temporization material shade A2 refill, USA) in the putty index that was taken before then seating it on the prepared tooth, with up and down movement before removing the index until it set. After finishing and polishing of the provisional restoration, a temporary cement (Cavex, temporary cement Haarlern, Netherlands) was used for the temporary cementation of the provisional restoration.

**Laboratory construction procedures**

The twenty endocrown restorations were constructed of lithium disilicate (IPS E.max press Ingots LT, Ivoclar Vivadent, Zürich, Switzerland) fabricated using CAD/CAM wax patterns by biogeneric individual mode with standard die spacer 50 μm. After fabrication, all the embrasures, contacts, and fit of the final restorations were evaluated, then adjustments were made if needed. Following the complete adjustments of endocrown restorations, lithium disilicate stains (IPS E-max Ivocolor stains, Ivoclar Vivadent, Zürich, Switzerland) were applied whenever necessary, and the restorations were glazed using lithium disilicate fluorescent glaze paste (IPS Ivoclor glaze paste, Ivoclar ivadent, Zürich, Switzerland)

**The silicon replica fabrication**

In the second visit, the provisional restoration was removed, followed by cleaning the endocrown preparation with a rubber cup and a polishing brush using a fluoride-free prophy cleaning paste (Proxat® medium fluoride- free, Ivoclar Vivadent, Zürich, Switzerland). Checking and adjustments of endocrown restoration in the patient mouth was achieved. Evaluation of the marginal integrity and the internal fit were performed by silicon replica technique, which was constructed by injecting a light-body silicon replica in the fitting surface of endocrown restoration then inserting it over the corresponding tooth preparation inside the patient mouth for 2:30 minutes then using a putty silicon to stabilize it. Each replica was sectioned buccolingually and mesiodistally into four segments named (MB, DB, ML, DL) and each segment had five reference points assigned at different positions; two points located at the pulpal floor, labeled (A, B), one midpoint of the axial wall, labeled (C), one point at the line angle, labeled (D), and one point at the cavosurface, labeled (E) in which (A, B, C) points were used to access the internal fit, while (D, E) points were used to assess the marginal integrity. An overall of twenty reference points were measured in each replica sample and measured using a digital microscope (Digimage Profi, digital microscope with up to 300x magnification, 5-million-pixel resolution, DNT) at 35X magnification. The digital microscopy was used for measuring the thickness of the light-body silicone for all the replicas which represented the distance between the preparation and the fitting surface of the restorations as well as the margin of the restoration and the finish line of the preparation in a vertical direction at 35x magnification. A digital image analysis system (Image J 1.43U, National Institute of Health, and USA) was used to measure and evaluate the gap distance. Within the digital image analysis system, all limits, sizes, frames and measured parameters are expressed in pixels. Therefore, a calibration system was done to convert the pixels into absolute real-world units. Calibration was made by comparing an object of known size which was a ruler in this study with a scale generated by the digital image analysis system. To avoid any bias, blinding was performed to mask the true nature of samples by placing stickers on each group in which a butt joint group had a number [1], and the circumferential preparation with deep chamfer finish line group had a number [2]. After that, all data was obtained and statistically analyzed.

**Cementation of the endocrown restoration**

Endocrown was cleaned using 37% phosphoric acid etching (Bisco, Schamburg, IL, USA) for 60 seconds, followed by rinsing in water and ultrasonic cleaner (COXO Dental digital ultrasonic cleaner DB-4860, China) for ten minutes after removal of the replica. Proper isolation of the teeth was performed, then the prepared tooth was etched using 37 % phosphoric acid for 15 seconds then thoroughly rinsed and air dried followed by application of the bonding agent (Adper single, bond plus adhesive 3M, USA), air thinning and light curing for 20 seconds, followed by a surface treatment of the endocrown restoration, which was carried out by application of 9.5% hydrofluoric acid ( Bisco, Schamburg, IL,USA) on the fitting surface for 90 seconds then rinsed out with copious amount of water; air dried, and silane application (Bisco, Schamburg, IL,USA) in which a single coat of silane was applied on the internal surface for 30 seconds before air drying. For cementation of endocrown restoration, a dual-cured, self-adhesive resin cement (G-Cem TM capsule, GC America) was mixed for 10 seconds according to the manufacture instructions then applied on the fitting surface of the endocrown followed by placing the restoration gently on the tooth by applying finger pressure of the operator. An initial curing for three seconds was carried on followed by removal
of the excess cement using plastic sticks with sponge end, then completing the curing procedure using LED light cure unit with 1200mW/cm² intensity (Elipar, 3M ESR Canada) for a period of 40 seconds for each surface. Post-operative periapical x-ray was taken after cementation and dental photography was taken for documentation as shown in (Figures 3-A, 3-B).

Statistical analysis

The numerical data were analyzed for normality by checking the data distribution. Two-way ANOVA test was used to study preparation designs and their interactions on marginal integrity and internal fit. Post-hoc test was used for pair-wise comparisons were performed when ANOVA test is significant. The significant level was set at P ≤ 0.05. Student t-test was done between groups.

Result

The preparation design affected the marginal integrity significantly, while it did not affect the internal fit significantly. Group [1] recorded statistically significant higher marginal gap mean value (73.49±5.29 µm) than group [2] (59.81±3.42 µm), as indicated by unpaired t-test (P<0.0001 < 0.05) meanwhile group [1] recorded higher internal gap mean value (83.05±11.72 µm) than group [2] (80.29±10.59 µm) with no significant effect (P=0.2132<0.05) as indicated by unpaired t-test as summarized in (Table 2). However, both groups regarding the marginal integrity and internal fit were within the clinical acceptable range. Regardless of the preparation designs, it was found that the pulp site recorded the highest statistically significant gap mean value (77.67±12.89 µm) followed by the axial site with intermediate gap mean value (67.19±9.28 µm), while the lowest statistically significant gap mean value was recorded with the margin site (63.19±7.65µm) as indicated by two-way ANOVA (P<0.0001 < 0.05). Pair-wise Tukey’s post-hoc test showed non-significant (p>0.05) difference between margin and axial sites as shown in (Table 3). It was found that there was a significant direct correlation between marginal gap and internal gap as revealed by Pearson correlation (r=0.8469, R²=0.7173, p<0.05) figure (4). This relation is a strong positive relation.

Discussion

The endodontically treated teeth are often susceptible for loss of structural integrity due to previous dental caries, removing of existing restoration and the performance of endodontic procedures which make them more brittle, resulting in weakening of the teeth. Therefore, a full coverage restoration was recommended for badly destructed endodontically treated teeth [12, 13]. Studies [14, 15], showed that preservation of the tooth structure by a more conservative preparation allows better performance and longevity of the endocrown restoration because of decreasing the restoration size, which decreases the stress concentration on the cement interface and root dentin. Therefore, all prepared teeth had a pulpal depth of (3 ± 0.5) mm along with a width and height of (2 ± 0.5) mm of the cavity walls for preserving the tooth structure, and to provide sufficient enamel for proper bonding, as well as to avoid any variation in the preparation which might affect the bulk thickness of the endocrown restoration that might significantly affect the marginal integrity and internal fit.

Endocrown restorations were fabricated from a heat-pressed lithium disilicate due to its excellent properties, that the material possesses including high fracture toughness (2-3 MPa), high flexural strength (360 MPa to 440 MPa), high thermal shock resistance because of its low thermal expansion, and having lithium disilicate crystals which enable minimizing the micro cracks propagation combined with its high esthetics properties and bonding availability which makes it the golden standard between all glass ceramics restorations [16, 17].

The wax pattern was fabricated using CAD/CAM technique because of it’s a critical step that might affect the internal fit of the endocrown restoration. Therefore, this technique is used to reduce human error and control all the variables to decrease the margin of errors [18, 19].

![Figure 3: Post-operative endocrown restoration cemented on tooth # 14 A: Buccal view, B: Occlusal view of endocrown restoration cemented on tooth #14](image)

![Table (2) Descriptive statistics of marginal and internal fit results in um (Mean values ± SDs) for both groups tested.](table)

<table>
<thead>
<tr>
<th>Variables</th>
<th>Mean ± SD</th>
<th>Range</th>
<th>95% CI</th>
<th>Statistics</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marginal gap</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Group 1</td>
<td>73.49±5.29</td>
<td>66.99-84.09</td>
<td>69.43-77.57</td>
<td>&lt;0.0001 significant</td>
<td>(p&lt;0.05)</td>
</tr>
<tr>
<td>Group 2</td>
<td>59.81±3.42</td>
<td>54.89-65.93</td>
<td>57.18-62.44</td>
<td></td>
<td></td>
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<tr>
<td>Internal gap</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group 1</td>
<td>83.05±11.72</td>
<td>76.71-102.82</td>
<td>74.05-92.06</td>
<td>0.2132 non-</td>
<td>(p&gt;0.05)</td>
</tr>
<tr>
<td>Group 2</td>
<td>80.29±10.59</td>
<td>65.79-100.27</td>
<td>73.73-86.85</td>
<td>significant</td>
<td></td>
</tr>
</tbody>
</table>

![Figure (4) A linear chart of correlation between total marginal gap and internal gap](chart)
The silicon replica technique was used because it is considered an accurate and reliable technique that has been used for in-vivo and in-vitro studies [20-22], and has proven its validity [23,24]. It is also a non-destructive technique that does not cause damage to the abutment tooth or the restoration.

The results regarding the marginal integrity revealed that there was a significant difference between the butt joint preparation design and the circumferential finish line preparation design. Therefore, the null hypothesis is partially rejected. This significant difference might be due to the heat-treatment combined with the pressing technique of fabrication of the endocrown restoration and the changes of the thermal temperature accompanied with the staining and glazing processes that may result in considerable stresses that can lead to margins distortion [25, 26]. The design and the width of the finish line affect the amount of marginal distortion during firing [27], with greater effect in the horizontal plane [28]. That is why the butt joint margins showed higher marginal gap than the deep chamfer finish line. In addition to that, the slight increase in the thickness of the butt joint margins (2mm) can increase the margin distortion when compared with the deep chamfer finish line (0.3mm) margin design which has a minimum thickness less than one millimeter with round base in its configuration [29].

There are only limited data evaluating the marginal and internal fit of endocrown restorations with different preparation designs of the cervical margins. Abo-Elmagd and Abdel-Aziz [30] evaluated the marginal adaptation of lithium disilicate endocrown restoring premolar teeth, with two different preparation designs at the marginal area. It was found that the mean marginal gap of the butt joint margins was (44.66 μm) lower than the shoulder finish line (46.72 μm) which is lower mean values than those reported in the present study. However, no direct comparison can be made, due to the use of premolar teeth instead of molar teeth, the use of different preparation designs and different measuring techniques between the two studies.

Both designs were within the clinical acceptable range regrading both marginal and internal fit, since it was reported that marginal discrepancies less than 120 μm were clinically acceptable [31], others considered that a marginal gap of ≤75 μm was the ideal clinical situation, [32] and some authors suggested that the internal gaps that showed an optimal clinical situation, should not exceed 100 μm [33, 34].

The results regarding the internal fit showed that there was no significant difference between the butt joint preparation design and the circumferential finish line preparation design. Therefore, the second null hypothesis is partially accepted. This non-significant difference might be due to the standardization of the pulpal depth, the axial cavity wall divergence and die spacer used, so a similar internal gap values should be expected [35, 36]. Cook and Fasbinder [37], evaluated the internal fit of CAD/CAM IPS Empress endocrown restoring premolar teeth, with different preparation designs at the marginal area and the internal line angles. The internal gap widths ranged from (139-229 μm), which is higher than those reported in the present study. It might be due to the use of premolar teeth instead of molar teeth, a different fabrication technique of the restorative material, and different measuring technique between the two studies.

Moreover, the results showed that the pulp space had the highest gap followed by the axial site and the margin site, which is similar to the results of Shin et al [1]. This might be attributed to the maximum material thickness at the pulp space, which was subjected to higher distortion during heat-treatment [26].

The limitations of the present study include the use of one restorative material fabricated with the same technique and the follow up on the endocrown restorations was not conducted. The use of other materials or other fabrication techniques might have resulted in different outcomes. Further research is proposed to investigate the effect of other materials and fabrication techniques on the marginal and internal adaptation combined with different preparation designs with long term follow up on the restorations.

Conclusions

Within the limitations of this study, regarding the marginal integrity and internal fit of the restoration, both endocrown designs could be indicated due to clinically acceptable range.

Acknowledgements

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References


