MARGINAL ADAPTATION AND INTERNAL FIT EVALUATION OF DIFFERENT PREPARATION DESIGNS OF ENDOCROWNS USING LITHIUM DISILICATE (E-MAX) (RANDOMIZED CLINICAL TRIAL)

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Abstract

Aim: The present study was done to evaluate marginal adaptation and internal fit of different preparations of endocrowns using the replica technique; two types of preparation were evaluated, one with ferrule preparation design compared to that prepared with butt joint preparation design, manufactured by heat-pressed lithium disilicate.

Materials and methods: Twenty-six healthy patients were chosen according to inclusion and exclusion criteria and randomly distributed into two groups (n=13) according to the preparation design of endocrowns. The first group received butt joint-prepared Endocrowns over posterior teeth (molars). The second group received circumferential ferrule-prepared Endocrowns. Both groups were fabricated using heat-pressed lithium disilicate (IPS e-max Press).

Results: The marginal and internal gaps of both groups were within the clinical acceptable range, but the **ferrule group**, recorded statistically significant higher internal gap mean than the **butt joint group**.

Conclusions: Endocrowns restoration designed with butt joint preparation revealed better internal fit than those designed with circumferential ferrule. The marginal and internal fit of both butt joint and circumferential ferrule preparation designs of endocrowns shows a clinically acceptable range.
Keywords: Endocrowns, Lithium disilicate, Marginal adaptation, internal fit, Marginal discrepancy, preparation design, e-max.

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INTRODUCTION

The selection of an ideal restoration for endodontically treated teeth has been widely and controversially discussed in the literature. The coronal seal of an endodotically treated tooth is a must; to avoid contamination with saliva and other debris from the oral cavity, otherwise what is called; a coronal leakage or coronal microleakage will occur that may result in the failure of the endodontic treatment. The amount of remaining tooth structure will control in somehow the selection of ideal restoration; this may be as simple as a composite restoration or a full coverage supported restoration with a post and core system. If the final restoration is not constructed quickly at a reasonable time, the prognosis will decrease significantly, and tooth fracture is one of the most essential causes of treatment failure. [1-3]To fabricate a full-coverage crown, a lot of tooth structure should be removed to make space for the final crown; this may decrease the strength of the remaining tooth structure, which is not following the guidelines of conservatism in teeth reduction.[2] Post and cores followed by a crown have been the gold standard for treating endodontically treated teeth to protect them from a fracture as the removal of the pulp and pulp tissues will decrease the strength of the teeth following the vitality loss; unfortunately, it has many drawbacks, especially for the radicular dentin; drilling for the post will remove a lot of the radicular dentin and possibilities of perforation is available during preparing the canals to receive a post that only will retain the core to support the final crown rather than strengthening the tooth.[3]

Adhesive dentistry has become more advanced, which helps conservative treatments be more effective; the endocrowns became an option to restore endodontically treated teeth with very high rates of success in comparison to full coverage restorations.[4] Endocrowns were introduced by Pissis in 1995 as an alternative to full coverage restorations after RCT depending on the remaining tooth structure.[5] The endocrown is a monolithic ceramic restoration restoring endodontically treated teeth anchored to the internal part of the pulp chamber and cavity margins; to gain macro-mechanical retention from the pulpal walls and micro-retention using an adhesive resin cement.[6]

The choice of materials with high bond-ability and high mechanical strength had been documented in lithium disilicates, as well as remarkable aesthetics that closely resemble natural tooth look.[7] The effect of the marginal integrity of the restorations has always been a crucial factor in the longevity of the restoration.[8] The preparation design will always have a role in determining a restoration with good margins; hence a successful restoration is achieved. Some studies recommended endocrowns with butt joint finish line, and others recommended another modification claiming that the preparation design may affect the marginal adaptation of the endocrowns and their fracture resistance.[9,10] However, few clinical studies studied the effect of the endocrown preparation design on the marginal adaptation.

Consequently this study aimed to investigate the marginal adaptation and internal fit of different preparation designs of endocrowns using lithium disilicate (e-max press).

MATERIALS AND METHODS

Sample size calculation

The aim of this study was to assess the marginal adaptation and internal fit of different preparation designs of endocrown. Based on a previous study by Elalem et al. (2019). A sample size of 11 restorations in each group will be needed. This number will be increased to a sample size of 13 restorations in each group to compensate for losses during follow-up. Sample size calculation was achieved using PS: Power and Sample Size Calculation Software Version 3.1.2 (Vanderbilt University, Nashville, Tennessee, USA).

Research ethics approval

This study and the template informed consent form reviewed by the Ethics Committee of Scientific Research - Faculty of Dentistry – Cairo University, and approved in July 2019.

Recruitment

The patients were recruited from the diagnosis clinic of the Fixed Prosthodontics Department– Cairo University.

Study design

This study was performed at Fixed Prosthodontics Department clinics of the Faculty of Dentistry, Cairo University, Cairo, Egypt. A total of 26 endocrowns were fabricated in this study. They were divided equally into two groups (n=13). All procedures starting from diagnosis to delivery, were carried out by the same investigator who followed a meticulous clinical procedure for standardization. The endocrowns were fabricated by the same dental technician to eliminate any variations.

1-Patient selection and randomization

1.1 Inclusion and exclusion criteria:

Twenty-six patients having endodontically treated molars without any active periodontal or periapical lesions, with the presence of teeth in opposite arch with normal occlusal relation, which are indicated for endocrowns restorations were chosen for this study after the clinical and radiographic examination. Having age ranges from 21-50 years old medical free, with the physical and psychological ability to tolerate conventional restorations and willing to return for follow-up examinations. Patients suffering from parafunctional habits, bad oral hygiene and pregnant women were excluded from the study. The participants were assigned informed consent.

1.2 Randomization

To avoid selection bias in our study, the participants were randomly divided into 2 groups with a 1:1 allocation ratio by using random sequence generator of web site (WWW.RANDOM.ORG).

1.3 Allocation concealment

The patients were numbered from (1-26) on folded papers placed in opaque sealed envelopes.

1.4 Blinding

This clinical trial was double blinded to avoid risk of any bias the assessors and the statistician were blind throughout the whole procedures and follow-up visits.

2-Treatment phases

2.1 Diagnostic phase: Intra-oral examination, photographs, diagnostic casts, diagnostic wax up, scaling and polishing, and shade selection were done.

2.2 Tooth preparation phase:

For the control group with butt-joint design, a proper occlusal reduction of (2±0.5) mm [9-12] was performed using a wheel stone bur to have enough room for the endocrown material thickness and to obtain a 90° butt joint margins that can minimize the complexity of the design. The minimum width and height of the axial walls were (2±0.5) mm to properly bond the endocrown restoration and ensure enough strength for the remaining tooth structure. A central retentive cavity with a depth of at least (3±0.5) mm that extended into the pulp chamber space was also created to ensure sufficient resistance and retention, along with occlusal divergence of 8 to 10 degrees. All internal wall transitions were smoothed, as shown in (Figures 1, 2). In order to decrease stresses, a smooth flat pulpal floor preparation design was obtained with the help of a flowable composite (3M Filtek Z350XT flowable composite, USA).

For the intervention group with ferrule design, after preparing the tooth with butt joint, a circumferential chamfer finish line will be formed all over the tooth with a 1.6 mm thickness tapered round diamond stone to obtain a 0.8 mm depth finish line, the initial preparation was started using a diamond tapered fine needle stone to open the contact before creating the finish line, and a 2+/- 0.5 mm ferrule height, as shown in (Figures 3, 4).

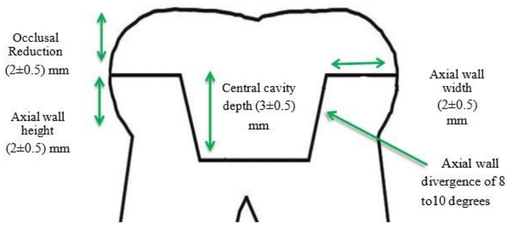

Figure (1): Schematic diagram for endocrown with Butt-joint preparation dimensions.

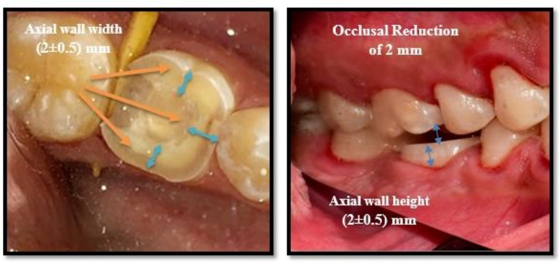

Figure (2): Intra-oral photos for endocrown with butt joint preparation dimensions in occlusal and lateral views

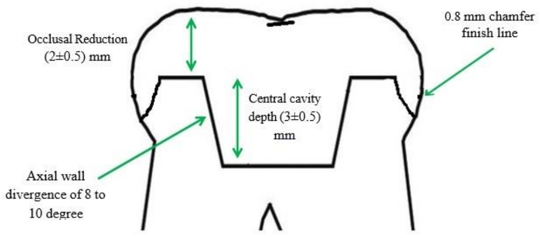

Figure (3): Schematic diagram for endocrown with ferrule preparation dimensions.

Figure (4): Intraoral photos for the endocrown with ferrule preparation in occlusal and lateral views

2.3 Impression-making phase: Final impressions were taken using the addition silicon (Panasil, Kettenbach GmbH Germany) in two-step impression technique. [13]

2.4. Provisionalization: Using bis acrylate composite resin material (Charmtemp Dentkist, Korea).

2.5. Master cast construction: The final impression was poured with a type IV dental stone. (GC FUJIROCK EP, GC, America.)

2.6. Scanning and designing phase:

The master cast was scanned using Ceramill map400 (Ceamill map 400, Amann Girbach, America inc); 3 Dimensional images were created and extracted as an 'STL' file for use by the Exocad software. Designing was done using Exocad software. Using a 5-axis milling machine (Ceramill motion 2, Amann Girrbach AG, Kobach, Austria), all teeth received the try-in endocrowns milled from the PMMA blocks. After try-in approval, the CAD/CAM wax patterns were designed and milled; to full anatomical endocrowns.

2.7. Lithium disilicate endocrown fabrication:

Lithium Disilicate (IPS Press e-max, Ivoclar Vivadent, Germany) ceramic was provided as an ingot to fabricate tooth shape endocrown restorations. IPS Investment Ring System and the IPS Press VEST premium were selected. The sprue was joined to the milled wax patterns in the direction of the ceramic's flow and at the thickest section of the wax-up, allowing the material to flow freely during pressing. Between the waxed-up items and the silicone ring, a 10 mm gap was kept. Preheating and wax elimination were done using the Programat EP3010 system (Programat EP 3010 Ivoclar Vivadent Liechtenstein). After that, the investment was loaded with emax press ingot. Plunger was inserted, and pressing started. After pressing, the divesting were done followed by finishing and polishing; staining and glazing were done by Cendres Metaux Soprano10 Kit for stains and Glaze.

2.8. Silicon replica fabrication

Before the final cementation of the restoration, a silicon replica was fabricated by injecting a light-body silicon replica in the fitting surface of endocrown restoration and then inserting it over its corresponding preparation inside the patient's mouth for 2-3 minutes. After removal, putty silicon was applied over it to stabilize it. Each replica was then sectioned buccolingually and mesiodistally into four segments using a sharp surgical blade no.11 (HuaiAn TianDa Medical Instruments Co, Ltd, China). The digital microscope was used for measuring the thickness of the light-body silicone for all replicas at five reference points: Two points located at the pulpal floor (A, B), one midpoint of the axial wall (C), one point at the line angle (D), and one point at the cavosurface angle (E), in which (A, B, C) points were used to assess 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 (U500x Digital Microscope, Guangdong, China). The digital microscope 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 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.

2.9. Intra-oral bonding for endocrowns:

Before bonding, a prophylaxis paste and polishing brush placed in a low-speed contra angle were used to clean the tooth surfaces to eliminate residues of temporary cement that might cause a considerable decrease in the luting agent's bond strength. Then, with the help of a rubber dam, isolation was achieved. The internal surfaces of the E-Max endocrowns were etched for 20 seconds with 9.5% hydrofluoric acid (Ceramic Etchant 9.5%, Bisco, USA). After etching, they were rinsed with water for another 60 seconds, then air dried, giving the chalky white appearance. Afterwards, a single coat of the ceramic primer (porcelain primer hydrolyzed Silane, Bisco, USA) was applied to the endocrowns and left for 1 minute, then air thinned.

Finally, the teeth' surfaces were gently dried for 5 seconds. The endocrowns fitting internal surfaces were coated with luting resin cement (BisCem Self-adhesive resin cement. Bisco, USA). Using finger pressure, the endocrowns were placed on their respective teeth until they were seated entirely. A sharp explorer was used to remove any excess cement. Interdental dental floss was used to remove all extra cement from between the endocrowns and surrounding teeth. In addition, articulating sheets were utilized to look for occlusal interferences, Post-operative periapical x-ray was taken after cementation and dental photography was taken for documentation as shown in (Figure 5 A, B).

Figure (5): Post-operative endocrowns restorations (A) Lateral view Butt-joint design (B) lateral view ferrule design

3-Postoperative instructions and care

The patients were instructed that Brushing and flossing should be done on a regular basis using a non-abrasive fluoride toothpaste and a soft brush.

4-Statistical methods

All Data was collected, checked, revised, tabulated and entered into the computer. The results were analyzed using Graph Pad Instat (Graph Pad, Inc.) software for Windows. A value of $P < 0.05$ was considered statistically significant. For numerical quantitative data (marginal and internal gap), Continuous variables were expressed as the mean and standard deviation. After the homogeneity of variance and normal distribution of errors had been confirmed, a one-way analysis of variance was performed, followed by Tukey's post-hoc test if it showed significance. Student t-test was done for compared pairs. Correlation between internal and marginal gaps was detected by Pearson correlation. The sample size (n=13) was large enough to detect large effect sizes for main effects and pair-wise comparisons, with the satisfactory level of power set at 80% and a 95% confidence level.

RESULTS

Results of marginal and internal gap using replica technique:

For Butt joint group, it was found that the highest gap mean value was recorded at pulpal site(65.76 µm) followed by axial site (53.29 µm) while the lowest gap mean value was recorded at marginal site (57.58 µm) and this was statistically significant as designated by ANOVA test ($P=0.02 < 0.05$). Pair-wise Tukey's post-hoc test showed non-significant ($p > 0.05$) difference between (axial and marginal) sites as shown in **table (1) and**

figure (6) Totally it was found that within butt joint group the internal gap (pulpal + axial) was statistically non-significantly higher than marginal one as proven by paired t-test (p =0.1652 > 0.05)

For ferrule group, it was found that the highest gap mean value was recorded at pulpal site (84.51 µm) followed by axial site (75.91 µm) while the lowest gap mean value was recorded at marginal site (51.35 µm) and this was statistically significant as proved by ANOVA test (P=0.0015< 0.05). Pair-wise Tukey's post-hoc test showed non-significant difference between (axial and pulpal) sites as shown in table **(1) and figure (6).** Totally it was found that within ferrule group the internal gap (pulpal + axial) was statistically significant higher than marginal one as confirmed by paired t-test (p =0.003 < 0.05)

Table (1) Descriptive statistics of gap results in microns (Mean values SDs) for both groups at different sites

Variables		*Mean*	*± SD*	*Min.*	*Max.*	*95% CI*		*Statistics*
						Low	*High*	*P value*
Butt-Joint	*Pulpal*	65.76^{B}	15.41	40.331	101.56	59.18	75.94	0.02*
	Axial	53.29^{C}	17.52	15.625	93.75	43.47	62.51	
	Marginal	57.58^{BC}	15.63	26.674	90.74	50.29	67.27	
Ferrule	*Pulpal*	84.51^{A}	21.83	51.606	118.15	76.54	100.27	0.0015*
	Axial	75.91^{AB}	19.65	31.25	110.49	65.93	87.29	
	Marginal	51.35^{C}	14.61	23.438	111.56	43.59	59.48	
Statistics	*P value*	<0.0001*						

Different Large letter in the same column indicating statistically significant difference (Tukey's p < 0.05)
*; significant (p<0.05) ns; non-significant (p>0.05)

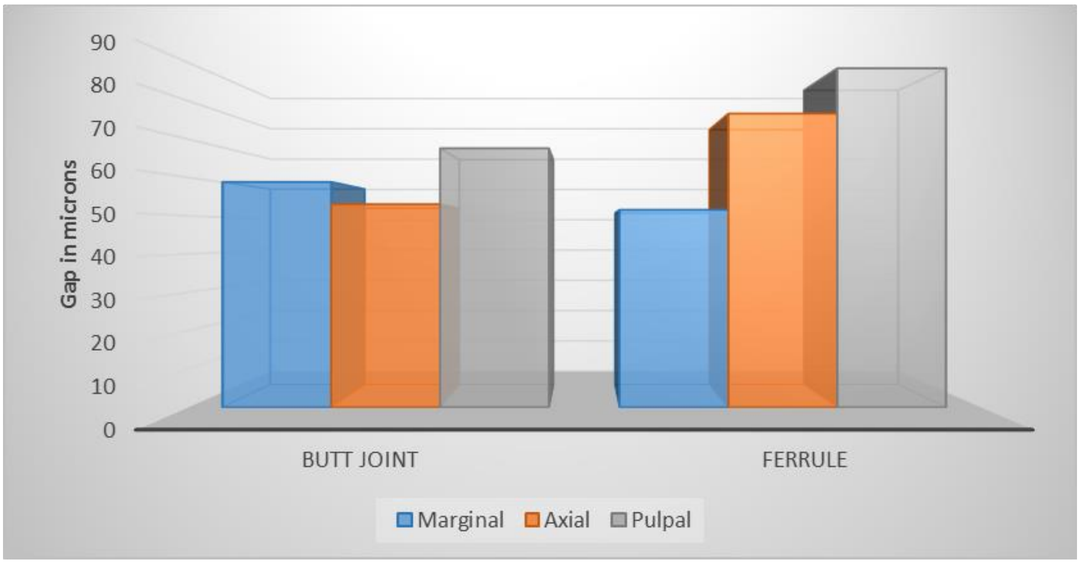

Figure (6) Column chart showing gap mean values for both groups at different measurement sites

Marginal adaptation:

Marginal site, it was found that butt joint group recorded statistically *non-significant* higher marginal gap mean value (57.58 µm) than ferrule group (51.35 µm) as indicated by student t-test (P=0.2338 > 0.05) as shown in **table (2)** and **figure (7).**

Table (2) Comparison of marginal gap results in microns (Mean values SDs) between both groups

Variable		*Mean*	*± SD*	*95% CI*		*Statistics*
				Low	*High*	*P value*
Marginal	***Butt joint group***	57.58	15.63	50.29	67.27	0.2338 n
	Ferrule group	51.35	14.61	43.59	59.48	

*; significant (p<0.05)   ns; non-significant (p>0.05)

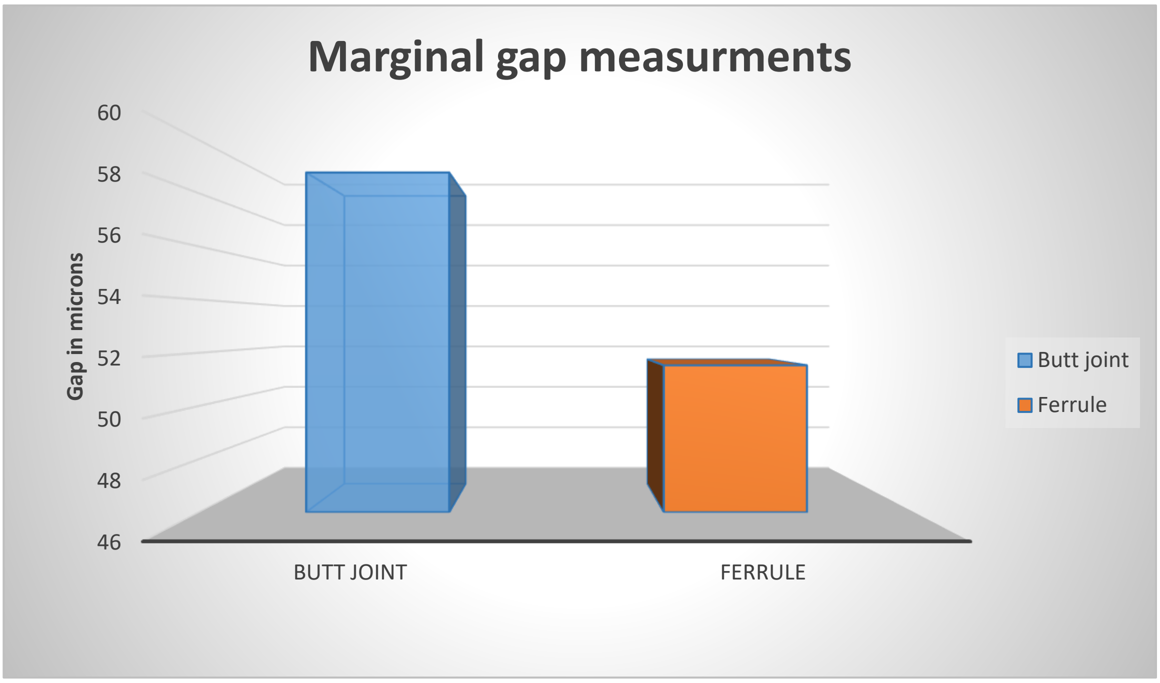

Figure (7) Column chart comparing gap mean values between both groups as function of marginal measurement site

Internal fit:

Pulpal site, it was found that ferrule group recorded statistically *significant* higher internal gap mean value (84.51 µm) than butt joint group (65.76 µm) as indicated by student t-test (P=0.0096 < 0.05) as shown in **table (3)** and **figure (7).**

Axial site, it was found that ferrule group recorded statistically *significant* higher internal gap mean value (75.91 µm) than butt joint group (53.29 µm) as showed by student t-test (P=0.0035 < 0.05) as shown in **table (3)** and **figure (7).**

Table (3) Comparison of internal gap results in microns (Mean values SDs) between both groups as function of measurement sites

Variables		*Mean*	*± SD*	*95% CI*		*Statistics*
				Low	*High*	*P value*
	Butt joint group	65.76	15.41	59.18	75.94	

Pulpal	***Ferrule group***	84.51	21.83	76.54	100.27	0.0096*
Axial	***Butt joint group***	53.29	17.52	43.47	62.51	0.0035*
	Ferrule group	75.91	19.65	65.93	87.29	

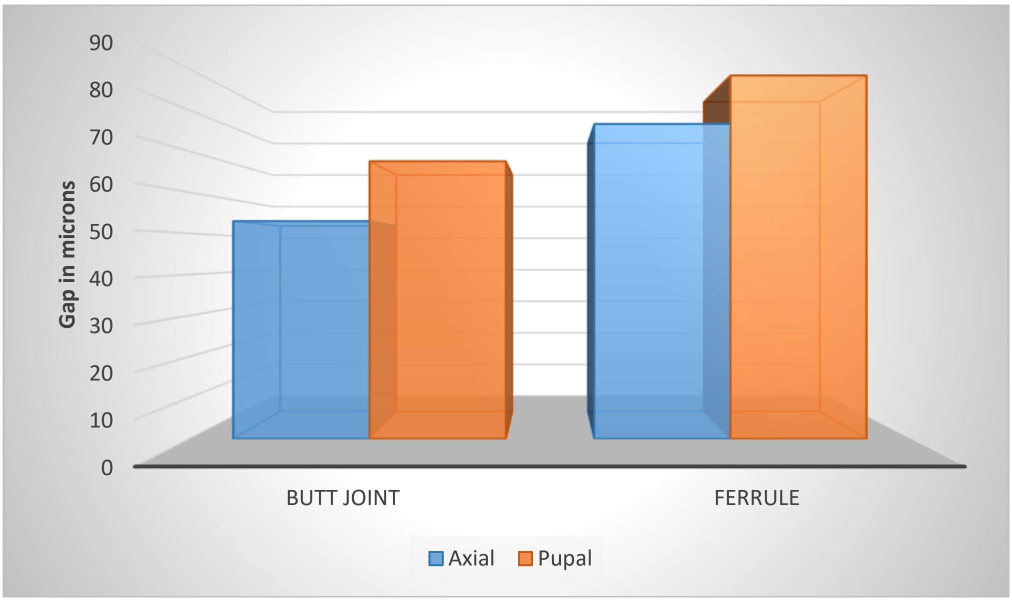

Figure (7) Column chart comparing internal gap mean values between both groups as function of measurement sites

Correlation between internal and marginal gap:

There was non-significant direct correlation between internal and marginal gap as revealed by Pearson correlation ($r=0.3088$, $r^2=0.095$, $p>0.05$), as shown in **table (4) and Figure (8)**

Parameter	Correlation coefficient (r)	(r^2)	p value
Internal gap	0.3088	0.095	0.2125 ns
Marginal gap			

Table (4) Correlation between internal and marginal gap

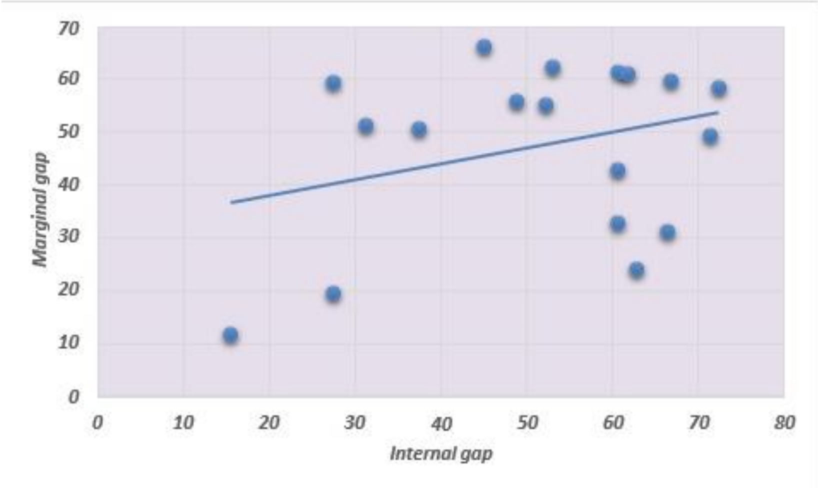

Figure (8): A linear chart of correlation between total internal and marginal gap

DISCUSSION

This study was a randomized, double-blinded clinical trial where randomization was carried out through the website (www.random.org) to eliminate the risk of selection bias among the included patients. This study is considered the second type in the hierarchy of evidence-based studies due to its strength and importance in the clinical field. [14]

Since the main researcher performed all the procedures during this study, the outcomes had to be evaluated by two experienced evaluators who were blinded and did not know which restorations belonged to which group; the assessors and the statistician were blinded throughout the whole study.

In the present study, all teeth included were posterior teeth. It was restricted to endodontically treated molars. Molar teeth were mainly selected because the endocrown restorations in molar teeth had been proven to owe a high success rate by having a larger pulp chamber, so more surface area is available for bonding. Also, molar teeth had a more favourable stress distribution in relation to premolar teeth that could contribute to lateral movements in cases having group function occlusion. [11, 15]

Scaling and polishing of the teeth were performed a few days before tooth preparation to remove any calculus and deposits to avoid having poor gingival health that might affect the accuracy of secondary impressions and consequently affect the restoration outcome.

Shade selection was taken visually using the Vita 3D-Master shade guide, being the most commonly used shade guide by clinicians nowadays. This was justified by several studies mentioning that the shade tabs are properly and evenly distributed, allowing accurate shade matching.[16]. It is acceptable to determine the shade of the tooth using Vita 3D Master and then convert it, through a table, into the Vita Classical shade guide, without variations when compared to the direct shade matching using the Vita Classical guide.[17]

In order to standardize our preparation, a graduated periodontal probe was used to measure and check the depth of the pulp chamber cavity, as well as the width and height of the cavity walls to ensure that the depth of the central pulpal cavity in both groups was between (3±0.5) mm, and the width and height of the axial walls in both groups were between (2±0.5) mm. For more standardization, the same operator performed the whole preparations in the two groups. To eliminate any irregularities in the pulp chamber, a smooth flat pulpal floor preparation design was obtained with the help of flowable composite and checked by a putty rubber impression index that was taken before the secondary impression.[10]

The choice of butt joint margins as a control group was used to minimize the complexity of designing and therefore less marginal and internal discrepancies. Also butt joint preparation design is more conservative. [9] The ferrule preparation as a comparator was chosen according to ElAlem et al (2019) as it was stated that the ferrule will increase the surface area for bonding than the butt joint margins and will decrease the marginal gap as the thickness of finish line is minimal so minimal distortion may occur.

The final impression was taken with addition silicon impression material since it has low dimensional change, relatively short setting time and with its high accuracy to record fine details due to its hydrophilic nature. Soft putty consistency was chosen to support the light consistency impression material, taken in a stock tray. [18].

The two-step putty/wash impression technique was used as it is more accurate than the one-step impression technique [13] because, in the two-step technique, the fine details are registered by the light body material at the second step of the technique, which has better flow characteristics owing to its lower viscosity and decreased filler content, while in the one-step impression technique, the tray material (putty) tends to push the syringe material (light) of the prepared tooth, so it is impossible to control which material records the details of the margin of the preparation. Thus, critical areas such as the finish line might be captured by the tray material rather than the syringe material, which cannot record the fine details to a satisfactory level because of its higher volume of filler content that causes less elasticity and fluidity and results in lower accuracy.

Moreover, in the one-step impression technique, when mixing the tray material at the same time as the syringe material, the setting distortion of the tray material is included in the overall impression distortion. In other words, in the one-step technique, the volume of the material subjected to distortion is increased as compared with the two-step technique in which the distortion of the tray material occurs during the first step of the technique and the final distortion is limited to the thin film of the light body material.[19, 20]

Temporization was an essential part of the treatment process to restore the shape and contour of the tooth to avoid any change in the position of the abutment or super eruption of the opposing tooth and also to protect the weak tooth structure till delivery of the final restoration. Although a short time was required from the preparation procedure to bonding, two provisional restorations were done. The first one was fabricated chairside using self-cured bis acrylate composite resin material, while the second one was the polymethyl-methacrylate (PMMA) endocrown fabricated for try-in in the lab. The latter had replaced the first provisional one as it was found to have a superior marginal fit and smoother appearance.[21]. The restorations were temporarily cemented using non-eugenol, acrylic-urethane polymer-based temporary cement.

In the present study, the master cast was poured using type IV dental stone, followed by scanning with an extraoral scanner. A highly accurate scanner was chosen to record all the details needed for the following design step. The material used for the fabrication of the final restoration in both groups of this study was lithium disilicate glass-ceramic. Lithium disilicate glass ceramic is one of the most popular materials in dentistry for the time being. It showed outstanding performance in terms of adjustable shade and esthetic outcomes. Also, it has good mechanical properties to withstand occlusal forces for the fabrication of single restorations and short fixed dental prostheses.[22]

Lithium disilicate ceramics showed high survival rates over the years in many clinical studies.[23,24,25] Moreover, being one of the etchable ceramics, they could achieve the high bonding strength needed in endocrown restorations.[26] Heat-pressed lithium disilicate had been chosen 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 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. According to previous studies, the use of Heat-Pressed Ceramics had the advantage of reducing sintering shrinkage during ceramic firing and hence improving the marginal adaptation; hence e-Max Press showed better results in terms of marginal and internal fit than E- Max CAD. [27-29] Although there were great debates within studies regarding the mechanical properties superiority of E-Max press over E-Max CAD. [30, 31] Yet, due to the larger and longer crystals in E-Max press and the avoidance of micro-cracks produced by milling machines, it was believed that E-Max press restorations were very slightly superior to that of E-Max CAD, and were reported to offer better internal fit and mechanical performances compared to CAD-CAM pre-crystallized blocks.[29]

Lithium disilicate material can be used as a monolithic restoration as it has high optical properties on its own[32]; it could also be veneered with Lithium Disilicate Ceram of appropriate shade for superior esthetic results. [22] In our study, teeth received monolithic lithium disilicate restorations due to the fact that they were in the posterior region. However, good esthetics was still required, yet we believed that the esthetic properties of lithium disilicate restorations were good enough and that there was no need for veneering in those restorations. Moreover, our restorations were in a high-stress posterior zone, and the veneering material may add the risk of being chipped, especially in such brittle restorations. Also, in clinical practice, it is more common to use lithium disilicate endocrowns as monolithic restorations.

The wax pattern used for the lost wax technique was fabricated using CAD/CAM technique; to ensure its accuracy, as it was a critical step that might affect the internal fit of the endocrown restoration. Therefore, this technique was used to reduce human error and control all the variables to decrease the margin of error. [10] Also, it was found that the wax pattern fabricated using CAD/CAM technique was considered reliable in production within a clinically acceptable range regarding internal fit. [33]

The choice of accurate scanners to create precise digital scans combined with the 5-axis milling machines results in an accurate fit between the restoration and the preparation. [34] The restorations were designed on Exocad software which gives easy and proper designing of the restorations with a large built-in library available with different outlines to choose from.[35] The cement space was set to 50 microns to achieve proper gap and intimate fit at the same time between the tooth and the restoration, as the choice of spacing less than 40 µm prevents the crown from settling, resulting in increased marginal discrepancy.[10, 36, 37] The sizes of milling burs used were (2.5 mm, 2mm, 1mm, and 0.5mm); as the diameter of the bur used for machining the internal surface is critical and can affect the internal gaps. [38]

Before bonding, remnants of provisional cement were removed by a polishing paste applied with a bristle brush and rubber cup under water irrigation to ensure that the tooth surface was completely cleaned from provisional cement and contaminations, which might affect the accuracy of the replica technique as well as the bond strength after cementation of the final restorations.

The two most important parameters that affect the longevity of any restoration and are very crucial for the clinical outcome of dental restoration are the marginal adaptation and internal fit of the restorations. Increasing the marginal and internal discrepancies will lead to the dissolution of the luting cement in the oral environment, which may negatively affect the longevity and increase the failure rate of the restorations. [29, 39]

Evaluation of the marginal and internal fit was performed by silicon replica technique, which was constructed by injecting a light-body silicon replica in the fitting surface of endocrown restoration and then inserting it over its corresponding tooth preparation inside the patient's mouth for 2-3 minutes. Then putty silicon was applied over it to stabilize it. Although Putty silicon is not an injectable material and is harder to apply than heavy silicon, we preferred to follow a technique that was in agreement with previous studies evaluating the marginal and internal fit of endocrowns.[10, 29]

The silicon replica technique was chosen as it is the most widely used and well-validated for evaluation of marginal integrity and internal fit, as stated by Son, et al. (2019) [40] 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, labelled (A, B), one midpoint of the axial wall, labelled (C), one point at the line angle, labelled (D), and one point at the cavosurface, labelled (E) in which (A, B, C) points were used to assess the internal fit, while (D, E) points were used to assess the marginal integrity. An overall of twenty reference points that could accurately represent the marginal and internal fit of the restorations were measured in each replica sample and was measured using a digital microscope in order to guarantee the most accurate results. The digital microscope 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 butt joint/ferrule margin 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.[10]

After the restorations had been tried and adjustments made, they were re-polished and cleaned to remove saliva remnants which could affect the bond strength to the tooth structure. Lithium disilicate endocrowns were cleaned with 37% phosphoric acid, according to Lapinska et al. (2019**)** [41]**,** in order to obtain the durable adhesion and clinical performance of the ceramic restoration.

Adequate adhesion could strengthen the restorative system, allowing the dissipation of the occlusal forces on the entire intaglio surface of the restorations, tooth and supporting structures. On the other hand, improper adhesion results in voids which could negatively affect the durability of the adhesive bond. [42]

The protocol for the surface conditioning of glass ceramics was followed for the treatment of E- Max endocrowns, according to the manufacturer's instructions, starting with the application of hydrofluoric acid, which partially dissolves the glassy matrix to create micro-irregularities. This gives a chance for the next layer of silane coupling agent, as a ceramic primer, to increase surface energy and increase the bond strength between ceramic and resin cement by forming chemical bonds between the inorganic phase of the ceramic and the organic phase of the resin. [43]

IPS E-Max press endocrowns were cemented using dual-cure self-adhesive resin cement to reach optimum bond strength with dentin.[44] Several studies suggested that the resin cement provides chemical and micromechanical bonding to the tooth structure and that resin cement bonding decreases the marginal discrepancy and provides high retention.[45]

Dual-cured resin cement was chosen as the thickness of some areas might be more than 2 mm which ensures complete polymerization in these areas. It was applied to the fitting surface of the restorations and then seated intra-orally with finger pressure. Excess cement was removed completely to avoid any post-operative complications. [46] The abutment tooth required no etching, priming or bonding agents for bonding to the endocrown restorations since a self-adhesive resin cement was used for bonding. The resin cement was chosen in this study based on its many advantages, such as low solubility, low risk of microleakage and chemical adhesion with the underlying structure to achieve the monoblock effect.[46]

The marginal adaptation was evaluated based on the junction between restoration and the tooth. The more accurately the restoration is adapted to the tooth, the bigger the chances for long-term clinical success. [22] Any marginal discrepancy present after cementation will indicate a high risk of failure of the restoration. [47]

The marginal adaptation may be influenced by multiple factors, including the preparation design, the optical scanner, the interface parameters defined in the design software, the manufacturing process, and the type of material used to fabricate the restoration.[48] Therefore, in this study, meticulous attention to all the previously mentioned details was done to reach the best results and have standardization, with the only variable being the preparation design.

The null hypothesis that there would be no difference in the marginal adaptation and internal fit was partially accepted as there were no significant differences between both groups in marginal adaptation. At the same time, there was a statistically significant difference between both groups regarding internal fit.

Concerning the material, although E-Max is widely used to fabricate endocrowns and is considered the material of choice in most cases, yet in most studies, lithium disilicate endocrown restorations were fabricated by the CAD/CAM production method leaving very limited data for endocrown restorations pressing technology.

The marginal gap mean value for the Butt-joint group in our study was (57.58 ± 15.63µm). This was in agreement with a study held by Elalem et al. (2019) [10] that showed the marginal gap in the butt joint design of the E-Max press endocrowns group was within the clinically acceptable range (73.49±5.29 µm).

Our study results were also in agreement with AL-Zomur et al. (2021)[49] and Hasanzade et al. (2020)[50], where the IPS E-Max recorded marginal mean value gaps (63.06±10.64µm) and (69.22±23.49 µm) respectively. Although they used IPS E-Max CAD instead of E-Max press yet the near results might be explained as the wax pattern used for pressing in our study was also fabricated by the CAD-CAM technology.

The low marginal gap value of E- Max endocrowns might be explained as the lithium disilicate crystals allow for good compressibility and flowability of the material during pressing. [51] Moreover, the heat-Pressing technique could reduce the sintering shrinkage during ceramic firing and hence improve the marginal adaptation. [22, 29]

While our study results were against Soliman, et al (2019) [52] that showed smaller marginal gaps. Yet the reason for the difference in results might be due to difference in construction and measurement techniques.

Our study results were also against Sağlam, et al. (2021)[53] who recorded that the marginal gap of E-Max press endocrowns was 122.49 ± 28.37 µm. The difference in results might be due to the manual technique of fabrication of wax patterns which might be prone to human errors as improper handling.

Our study results were also against El Ghoul, et al. (2020)[54] who recorded the marginal gap of E-Max CAD at marginal line angle was 104.8 ±14.1 µm while at cavosurface angle and mid marginal were 83.8 ±11.7 µm. The difference in results might be due to different technique of scanning, different spacer thickness and different technique of construction.

Concerning circumferential ferrule marginal fit results, the marginal gap mean value for the *ferrule group* in our study was (51.35± 14.61 µm). This was in agreement with a study held by ElAlem et al (2019) [10] where the marginal gap regarding ferrule group were near to our results (59.81±3.42), this may be attributed to use of heat pressed lithium disilicate and the use of CAD wax patterns.

The results of this study regarding the marginal fit in both groups showed that both groups had marginal gap within the acceptable clinical range (less than 120 µm) as defined by Meshreky, et al. (2020) [55] with the Butt joint group recorded statistically non-significant higher marginal gap mean value (57.58 µm) than Ferrule group (51.35 µm) as indicated by student t-test (P=0.2338 > 0.05).

Concerning internal fit, there are only limited data evaluating the internal fit using the silicon replica technique of endocrown restorations fabricated from lithium disilicate using the pressing technology.

The internal gap mean value for the Butt joint group it was (65.76±15.41 µm) at the pulpal site, and (53.29±17.52 µm) at axial site, while for the Ferrule group in our study was (84.51± 21.83µm) at pulpal site, and (75.61± 19.65µm) at axial site, this was in agreement with a study held by Elalem, et al. (2019) [10] that showed the internal gap in the butt joint and ferrule design of E- Max press Endocrowns respectively were within the clinical acceptable range (83.05±11.72 µm) , (80.29±10.59µm). Also our results were in disagreement concerning the statically significant difference that there were a significant difference between the internal fit of both groups as indicated by students t- test (P=0.003 < 0.05). This difference may be due to complexity of the ferrule design that may affect the internal fit of the restorations.

Our study was also partially in agreement with El Ghoul, et al. (2020)[54] and Hasanzade, et al.

(2020)[50] where E- Max CAD endocrowns internal gaps at the axial sites were 90.5 ±18.9 µm, and 70.18±14.03 µm respectively while internal gaps at the pulpal sites were 141.6 ±20.1 µm and 102.62 ±26.3 µm respectively. The difference in results at the pulpal site might be due to the difference between milling the restoration in comparison with pressing it where the later had lesser sintering shrinkage, moreover, they used intra oral scanner that might have lower accuracy in comparison of extra oral scanner used in our study.

While our study results were against Godil et al. (2021) [56] where the mean values of internal gap of lithium disilicate endocrowns was 158.2 ± 11.1 µm. However the difference in results might be explained as their study was in vitro that differ from the clinical situations also due to difference in construction and measurement techniques.

CONCLUSIONS

Within the limitations of this study, the following conclusions could be drawn as follows:

1. Endocrown restoration designed with butt joint preparation revealed better internal fit than those designed with circumferential ferrule.

2. The marginal and internal fit of both butt joint and circumferential ferrule preparation designs of endocrown, shows clinically acceptable range.

RECOMMENDATIONS

1 .Further long-term randomized clinical trials, on a larger population, are recommended to confirm the results of this study.

2. Further long-term randomized clinical trials are recommended to evaluate the circumferential ferrule preparation design for endocrown restorations for longer period up to 10 years.

3. Further studies for the clinical performance of both preparation designs are needed.

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