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Micro CT evaluation of marginal discrepancies of endocrown restored molars with different intrapulpal depths and materials of fabrication. (in-vitro study)

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Abstract

Objective The purpose of this study was to evaluate the effect of different preparation depths (0, 2 and 4 mm) of different restoration designs (classic endocrown design versus overlay design) on marginal adaptation of restorations fabricated of two different restorative materials (lithium disilicate and PEEK).

Materials and methods Sixty mandibular natural molars were collected as abutments for the restorations of this study, and grouped in three main groups of different cavity depths (0, 2 and 4). Each group was divided into two subgroups according to material of fabrication to (L) for lithium disilicate (IPS emax CAD, Ivoclar vivadent, Switzerland) and (P) for PEEK (Bio-hpp, Bredent, Germany). CAD/CAM milling technology was used for fabrication of restorations. After cementation of restorations over abutments, hydrothermal aging was performed, and then marginal adaptation was evaluated via micro CT technology.

Results Regarding cavity depths, there was a significant difference between different groups ($p < 0.001$). The highest value was found in samples with 4 mm extension (84.35 ± 18.16), followed by samples with 2 mm extension (66.52 ± 21.86), while the lowest value was found in samples without pulpal extension (59.41 ± 22.16). Post hoc pairwise comparisons showed samples with 4 mm extension to have a significantly higher value than samples without extension ($p < 0.001$). Regarding materials of fabrication, PEEK (85.32 ± 12.37) had a significantly higher value than Emax (54.86 ± 20.86) ($p < 0.001$).

Conclusions Increasing intrapulpal cavity depths increases vertical marginal gap of lithium disilicate or PEEK restorations. Endocrowns fabricated of lithium disilicate show less marginal discrepancies than that of endocrowns fabricated of PEEK.

Keywords Mandibular molars, Endocrowns, Marginal adaptation, Micro CT, Lithium disilicate, Polyetheretherketon (PEEK)

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Introduction

Traditional ways for restoring endodontically treated teeth showed decreased clinical durability because of extensive weakening in the remaining tooth structure after endodontic treatment that increases the probability of root fracture under masticatory function [1, 2].

By release of new biomimetic and minimally invasive concepts, beside new adhesive strategies, computer aided designing / computer aided manufacturing and recent high strength restorative materials; new restoration designs have been introduced for rehabilitating endodontically treated dentition [3, 4].

Endocrown is a monolithic adhesive type of restoration that obtains its retention from pulp chamber and remaining tooth structure, with good coronal sealing and superior mechanical properties [5]. Friction with pulpal walls provides Macro-mechanical retention, whereas adhesive cementation provides micromechanical. Endocrown has Many advantages over conventional crowns such as ease of application, minimal clinical time, and proper aesthetic properties [6].

Pissis [7] was the introducer of pioneer technique of endocrown and has described it as the mono-block porcelain technique. **Bindle** and **Mörmann** [8] discribed it as adhesive endodontic porcelain crowns bonded to posterior teeth that had experienced endodontic treatment.

Endocrown preparation has no specific or defined design. 2 mm intra-radicular retentive feature was suggested by several studies to afford the sufficient retention and resistance features [9, 10], while other studies focused on the effect of the depth (shallow or deep depth) of this intra-pulpal cavity on the marginal and internal adaptation of the endocrown restorations [11, 12].

Cavity depth can influence endocrown retention and stability in function of internal cavity volume, cavity surface area, and marginal and internal discrepancy. severe attrition of the crown portion mandates shallow cavity depth preparation, while a deep cavity depth can be associated with less attrition on the coronal structure [12].

The exact dimensions of the central intra-pulpal retention cavity are not precisely determined, especially in cases of excessive loss of dental tissues, where only minimal intact tooth structure above the cemento-enamel junction is left so the need for further intra-radicular extension might be important demand. The incorporation of the available space inside the pulp chamber to the preparation design enhances the stability and retention of the restoration [13]. By increasing the depth of pulpal cavity thus increasing intracoronal extension provides greater surface area that can be utilized for adhesive retention and proper distribution of masticatory forces [14].

Many restorative materials had been prohibited for endocrown fabrication provided that it possess adhesive

capacity such as etchable ceramics containing glass (Feldspathic, Leucite or Lithium disilicate based), resin composite, reinforced glass ceramics with Zirconia, hybrid resin nanoceramics or PEEK in order to adhesively bond to tooth structure.

Lithium disilicate glass ceramics are one of the most successful restorative materials used for the fabrication of different dental restorations because of its optimum esthetics, superior strength, and excellent adhesion properties to the tooth structures [15]. It's composed of crystalline phase (approximately 70 vol %) which is incorporated in glassy matrix. In the partial crystallization process (so-called 'blue' state), platelet-shaped lithium meta-silicate crystals LiSiO_3 (40 vol %) are formed and embedded in a glassy phase. It has flexural strength of $130 + 30$ MPa, which makes the blocks easily milled. After that, tempering the milled restorations at 850°C leads to formation of lithium disilicate crystals $\text{Li}_2\text{O}_2\text{Si}_2$, so the milled restoration then has the final shade and flexural strength of $360 + 60$ MPa [16].

Polyetheretherketone (PEEK) is a synthetic type of polymer with proper biomechanical and inert chemical properties. It is reported that poly-aromatic semi-crystalline thermoplastic entity of Polyetheretherketone (PEEK) with its promising mechanical properties favor it for biomedical applications. Using polyetheretherketone (PEEK) material for endocrowns fabrication was suggested because of its mechanical properties and superior biocompatibility. Due to its opaque white color, it requires veneering to improve the esthetics [17]. Nagi et al [18]. compared the marginal fit of both peek and lithium disilicate endocrowns and concluded that both restoration-swere within the clinically acceptable range.

Because marginal adaptation affects periodontal condition in addition to acting as a barrier against microbial invasion, it is a critical criterion for the lifetime and efficacy of indirect restorations. A larger marginal gap may cause the luting material to be exposed to the oral environment more often, which could lead to its disintegration [19]. A weak cement seal invites bacterial infiltration, which causes the cement to deteriorate chemically and mechanically. This leads to repeated caries and damage to the pulp, which is crucial [20].

McLean [21] concluded that the clinically acceptable range of a marginal discrepancy is less than $120\ \mu\text{m}$ in terms of longevity of the restoration after they examined more than 1000 crowns. **Kirsch C. et al.** [22] stated that marginal gap values of ($8\text{--}206\ \mu\text{m}$) are acceptable. CAD/CAM manufacturers aim to produce restorations that provides marginal gap values of ($25\text{:}40\ \mu\text{m}$) when cemented that is considered theoretically ideal.

Micro-computed tomography, also known as X-Ray Microscopy, or micro CT, is a scale of 3D X-ray imaging that has significantly improved resolution [23]. It truly

embodies 3D microscopy, which is the non-destructive imaging of an object's incredibly fine-scale internal structure, both in vivo and in vitro [24]. A variety of user-friendly desktop and floor-standing equipment are available for micro- and nano-tomography. With a resolution of sub-microns, it creates three-dimensional photographs of the interior microstructure and morphology of the sample [25, 26].

Due to variations in the electronic densities of the materials exposed to the X-ray beams, micro-CT has been used for nondestructive investigation of the marginal fit of indirect restorations. The acquired images enable the assessment of the adaptation line in two or three dimensions in a variety of cuts and directions, providing a large number of measurement sites and making the study of crucial distances easier [27–29]. In addition to offering the identification of crucial distances with a multitude of applications, micro-CT permits an adequate number of gap measurements. For scanning, the sample is positioned in the scanning tube such that it is perpendicular to the X-ray beam. Using image analysis software, measurements on the CT scan pictures can be obtained in both 2D and 3D [30].

So, the objective of this study was to evaluate the effect of different preparation depths (0, 2 and 4 mm) of different restoration designs (classic endocrown design versus overlay design) on marginal adaptation of restorations fabricated of two different restorative materials (lithium disilicate and PEEK), the null hypothesis stated that altering cavity depths or fabrication materials has no effect on the marginal adaptation of endocrown and overlay.

Materials and methods

Materials are listed in (Table 1).

Sample size calculation

Sample size calculation was performed using G*Power statistical power analysis program (version 3.1.9.7) for sample size determination. A power analysis was designed to have adequate power to apply a statistical test of the null hypothesis that there is no difference would be found between tested groups. The minimal required sample size (n) was found to be (54) samples and this was sufficient to detect a large effect size (d) = 1.55 with an actual power (1- β error) of 0.8 (80%) and a significance level alpha (α)

of (0.05) (5%) Sample size was increased to (60) samples to account for possible failures during testing.

Samples selection and evaluation

Sixty caries free, recently extracted human mandibular first and second molar teeth were collected for the present study after having exemption from the research ethics committee of faculty of dentistry, Ain Shams University, Cairo, Egypt. This invitro study did not include any intervention with human participants or animals, however, written and oral consents were obtained from the patients to use their extracted teeth in this research. Teeth were extracted from uncontrolled diabetic patients and evaluated for intact and cracks-free surfaces. All external debris was removed with an ultrasonic scaler. A digital caliper was used to measure the dimensions of the teeth at cemento-enamel junction level with an average mean mesio-distal dimension 10.5 mm. \pm 0.5 mm. and an average mean bucco-lingual dimension 9 mm. \pm 0.5 mm. Any other discrepant dimensions were excluded from the study.

Samples were stored under distilled water in separate closed container for each till the next steps. No endodontic treatment was done for all sample teeth according to a protocol advocated by Yooseok S. et al. [30] for purpose of standardization among samples.

Samples were randomly divided into three groups (0, 2, 4) ($n=20$ each) by using a computer-generated list of random numbers (www.randomizer.org). Each group samples received different intrapulpal cavity depths; 0, 2 and 4 mm depths, then each group was subdivided equally and randomly according to the restoration material into two subgroups (L) for lithium disilicate and (P) for PEEK ($n=10$ each), all procedures performed by single operator.

Samples preparation

Reduction of coronal portion was done 2 mm. from the cemento-enamel junction using diamond rotary wheel instrument (Intensiv wheel 817, Switzerland) mounted on high speed handpiece leaving flat occlusal margin, and the margins were finished with butt joint preparation (meaning flat horizontal sidewall preparation acts as finishing line without axial preparation). Pulpal cavity preparation was done with a tapered flat end diamond rotary instrument (Intensiv inlay kit, Switzerland) mounted on high speed handpiece leaving a 5 degrees diverged axial walls with a total 10 degrees divergence. A 2 mm. circumferential occlusal band thickness; (two mm thickness of axial tooth structure) was created (Fig. 1). A paralleling device was used to mount handpiece for standardizing both flat butt reduction and occlusal divergence between samples.

Table 1 Materials used in the study with its chemical

	Material	Brand	Chemical composition
1	Lithium disilicate. (Fig. 1).	IPS emax CAD Ivoclar vivadent Switzerland	57–80% SiO ₂ , 11–19% Li ₂ O and other oxides Li ₂ O, K ₂ O, MgO, Al ₂ O ₃ , P ₂
2	Peek blank (Fig. 2).	bre.CAM Bio-hpp Bredent Germany	Repeating units of three phenyl rings, two ester groups and one keto group

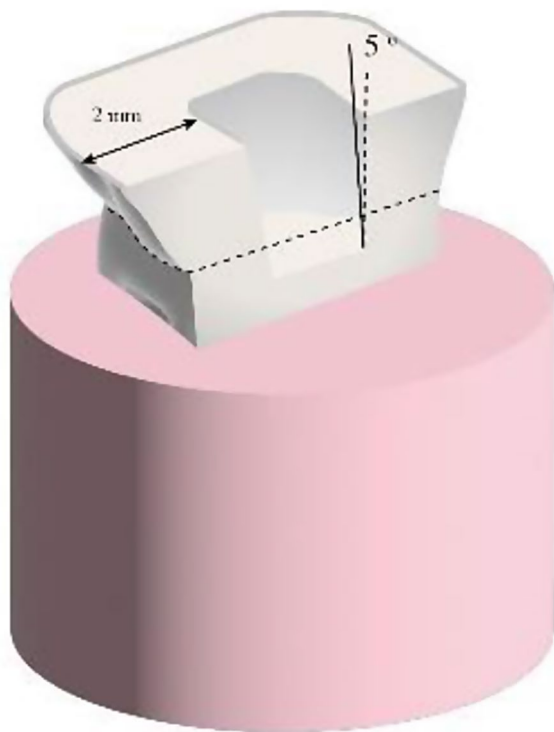


Fig. 1 Schematic diagram showing 5 degrees axial wall divergence

Preparation of different cavity depths

The preparation depths of all samples were adjusted using flowable composite according to their groups as follow: For group (0 depths) samples, obliteration of pulpal cavity to the level of occlusal margins was done leaving flat occlusal surface. For group (2 depths) samples, 2 mm pulpal cavity depth from the occlusal margins was left. For group (4 depths) samples (Fig. 2), 4 mm pulpal cavity depth from the occlusal margins was left [31, 32].

Restorations fabrication

Optical scanning of all samples was done via extra oral scanner(DS mizar; egsolutions, Italy) with the following parameters: 2×5 megapixel cameras, accuracy (ISO 12836): 10 μm and scan speed (full arch): 30 s and then Digital scans of all samples were converted to STL format in order to create virtual dies using CAD system software; Exocad in-lab designing software(exocad GmbH, America, Inc). All 3D models were checked for detection of any undercuts or sharp point angles. Automatic margin line detection was used to trace the finish-line of all preparations.The luting space and adhesive gap were set at 50 μm.

Regarding Lithium disilicate subgroup (L) a restoration of 2 mm. thicknesses was done, with anatomical occlusal aspect. The formed design was considered the final form and was ready for milling step (Fig. 3). For designing

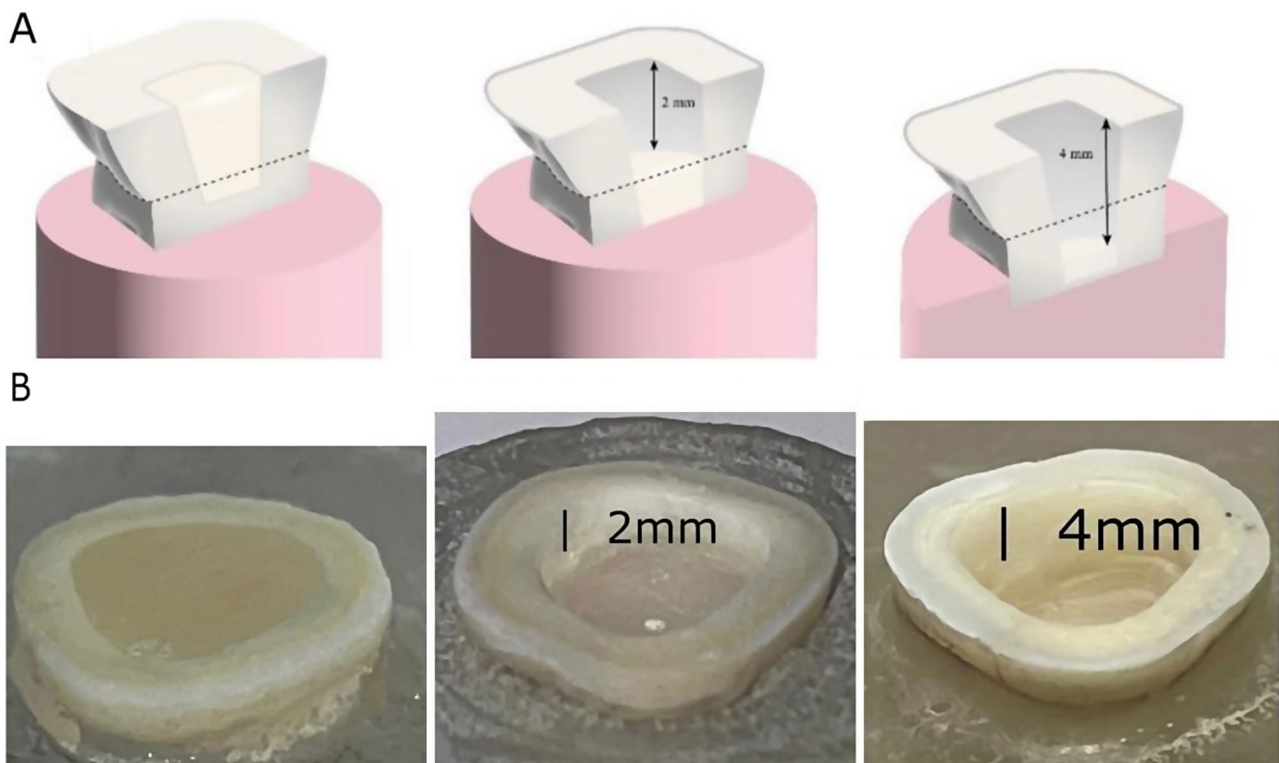


Fig. 2 A) Schematic diagram showing different intrapulpal depths(0,2,4 mm), B)Prepared samples with different intrapulpal depths (0,2,4)mm

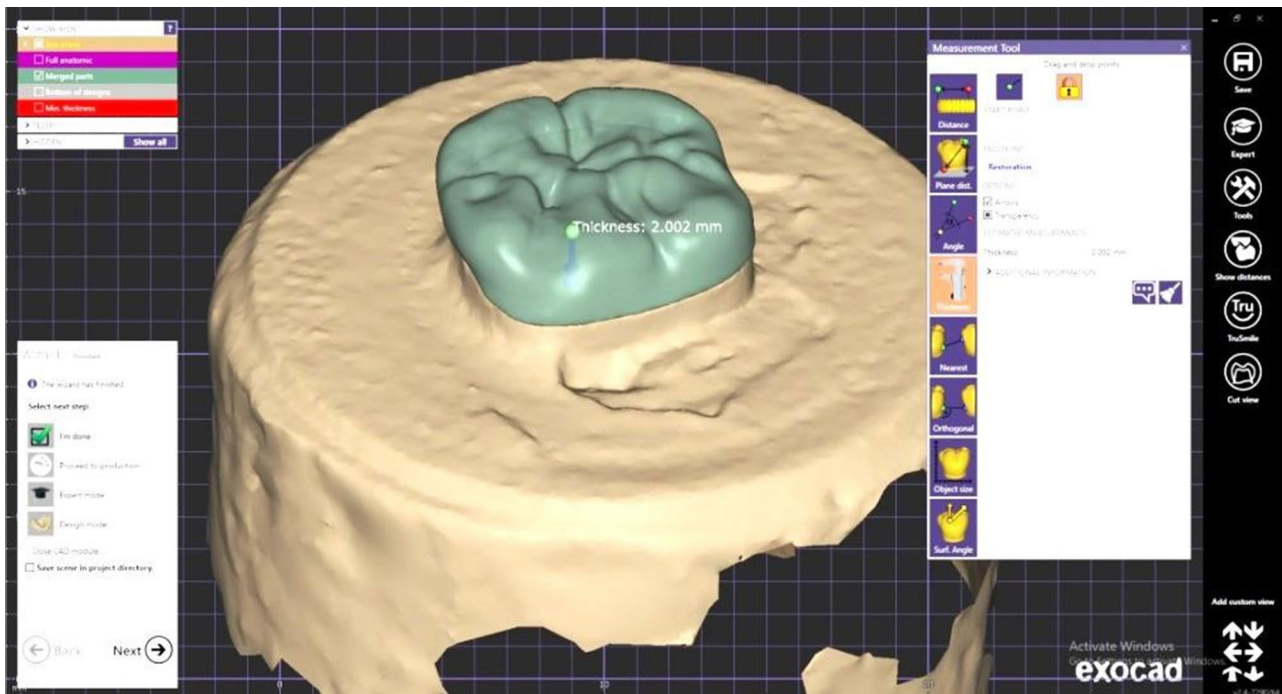


Fig. 3 Original full anatomical design for fabrication of subgroup (L) restorations

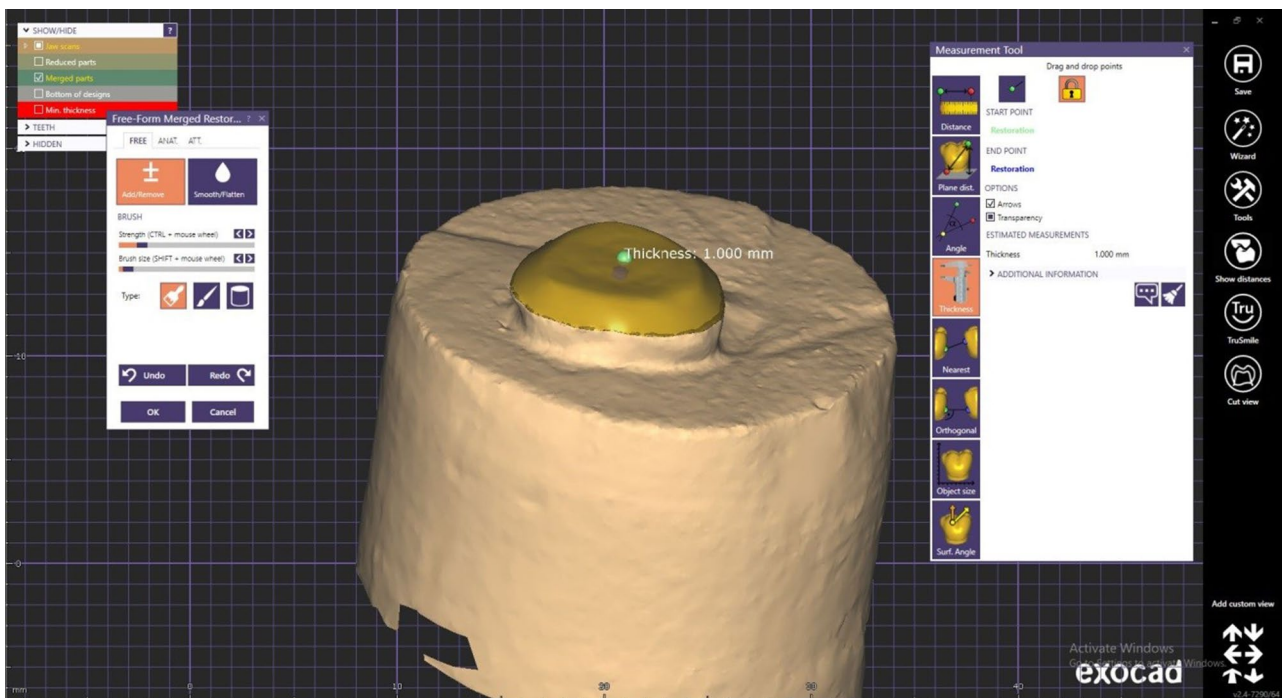


Fig. 4 1 mm cutback for PEEK core fabrication

restoration of PEEK subgroup (P), a 1 mm. cutback of the original 2 mm thickness design was done leaving a room for composite veneer fabrication. (Fig. 4) So the final restoration would be 1 mm thickness PEEK core and 1 mm thickness composite veneer.

Milling of the restorations was done using SHERA Eco-Mill 5x; Bimedis, china milling machine. The milling preview was activated to start the milling process. The milling machine dialog box allows for choosing the type and size of the material according to the type of the restoration to be milled, then the block was fixed in the



Fig. 5 Cemented composite veneers over PEEK cores **A**) 0 mm depth **b**) 2 mm depth **c**) 4 mm depth

spindle of the milling machine and the door was closed then the milling icon was clicked to start the milling process.

Regarding subgroup (L), the restorations were full anatomically milled using lithium disilicate ceramics blocks (IPS emax CAD, Ivoclar vivadent, Switzerland) of 2 mm thickness, then crystallization phase was adjusted at the furnace (programat P310). For subgroup (P), the restorations were fabricated as bi-layered structure *First*, the PEEK core of 1 mm thickness using Polyetheretherketone (Bio-hpp, Bredent, Germany). *Second*, indirect composite veneer of 1 mm thickness using composite resin veneering blank. Both components were connected with CAD-ON technique using dual cure composite resin after connected surfaces being sandblasted with 110 μ m aluminum oxide grit at a pressure of 3 bars with 45 angle of application and 3 cm distance and after conditioning with light polymerized adhesive which then cured in a light polymerization unit according to manufacturer instructions. (Fig. 5)

Restorations cementation

After restorations have been checked for marginal fit with inspection and dental explorer, cementation process was started with abutments acid etching with 37% phosphoric acid for 20 s on the enamel margin, then rinsed with water spray and dried with compressed air.

For subgroup (L), Acid etching of restorations with 9.5% hydrofluoric acid for 20 s was done, and then rinsed thoroughly for another 60 s then dried. Silane coupling agent was added and left to react for 60 s. For subgroup (P), sandblasting of the fitting surfaces was done with 110 μ m aluminum oxide grit at a pressure of 3 bars with 45° angle of application and 3 cm distance. Next, a universal MDP-containing adhesive (ALL-Bond Universal) was applied and light-polymerized for 20 s according to the manufacturer's instructions.

Cementation was done using dual-polymerized self-adhesive resin cement at room temperature (Breeze) using the automix tip to the fitting surface of the

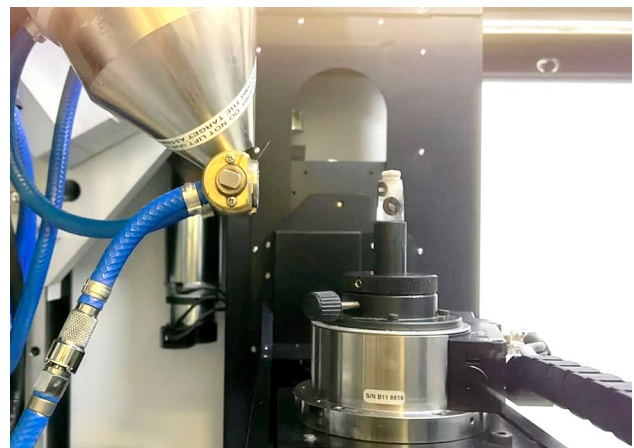


Fig. 6 mounted sample for CBCT measurement

restorations and inside the preparations. Cementation was done under constant loading via loading device with 1 kg pressure towards central fossae of the occlusal surface of the restorations, to minimize variation in pressure applied among samples during cementation.

Aging

All samples were subjected to hydrothermal aging in autoclave at 134° C and 2 MPa for five hours. This step was to mimic one year of oral conditions according to ISO standards 13,356 [33]

Marginal gap measurement

This phase was started with micro CT scanning of each sample, using Nikon XTH 225 ST system which was operated with the following parameters: 145 kV tube voltage, 145 μ A tube current, and 1440 angular projections acquired over a rotation of 360°, with an exposure time of 1.42 s. The software used is Inspect-X and the scanning session takes 70 min per tooth. (Fig. 6)

The raw files were converted into bmp files using NRecon software, and CTAn was used for designing bmp CT files and reconstructing 3D images. For each design,

six cross sections were obtained; three bucco-lingual at the X-axis (Fig. 7) and three mesio-distal at the Y-axis (Fig. 8). The distribution of cross sections at each axis (Y and X) was as follow: first cross section was through the center of the sample, and two additional cross sections were obtained bilaterally at 1 mm intervals. Six 2D Images were obtained from six cross sections of each constructed 3D design (three images from three cross sections of each axis). For calculating marginal gap of each 2D image, an average of six measurements at six reference points were obtained via 3D distance length tool value in microns (Fig. 17). To maintain a consistent position during these measurements, the pixel level in the X and Y axes were recorded using DataViewer software, and the μ CT result analysis was carried out with a fixed gray value threshold ISO 50% for all scans and used for all specimens, by a single well-trained operator. (Fig. 9)

Statistical analysis

Numerical data were presented as mean and standard deviation values. They were checked for normality using Shapiro-Wilk test. Data showed parametric distribution and were analyzed using two-way ANOVA followed by Tukey's post hoc test. Comparison of main and simple effects was done utilizing Bonferroni correction with the pooled error term from the main ANOVA model. The significance level was set at $p < 0.05$ within all tests. Statistical analysis was performed with R statistical analysis software version 4.1.3 for Windows.

Results

Effect of different variables and their interaction

Effect of different variables and their interaction on marginal gap (μm) were presented in (Table 2).

There was a significant interaction between type of material and preparation design ($p = 0.027$).

Main effects

A-Effect of material

Intergroup comparison, mean and standard deviation (SD) values of marginal gap (μm) for different materials (regardless the effect of preparation depths) were presented in (Table 3) showing that PEEK had a significantly higher value than Emax.

B-Effect of preparation design

Intergroup comparison, mean and standard deviation (SD) values of marginal gap (μm) for different preparation designs (regardless the effect of materials) were presented in (Table 4) showing that there was a significant difference between different groups Post hoc pairwise comparisons showed samples with 4 mm extension to have a significantly higher value than samples without extension ($p < 0.001$).

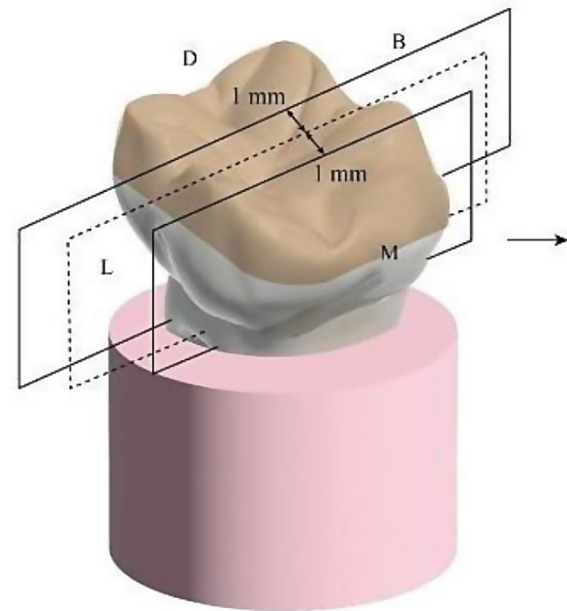


Fig. 7 X axis (bucco-lingual cross sections)

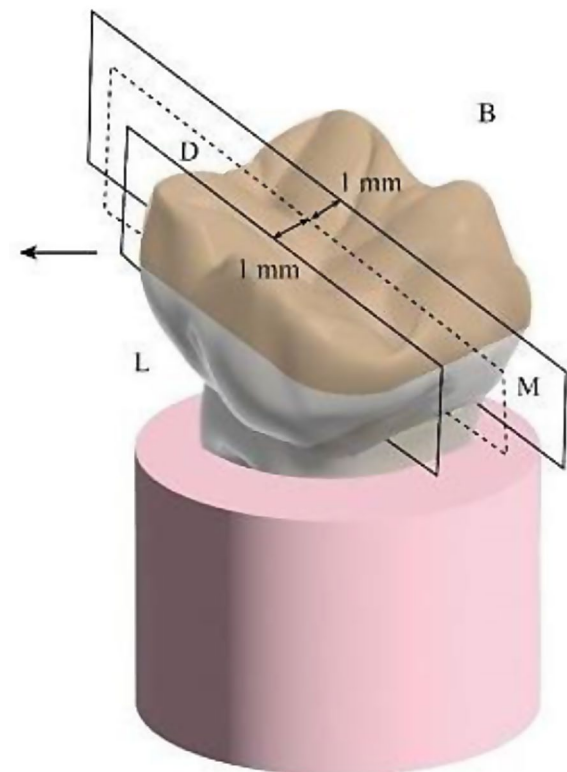


Fig. 8 Y axis (mesio-distal cross sections)

Interactions

Intergroup comparisons, mean and standard deviation (SD) values of marginal gap (μm) for different materials and preparation designs were presented in (Table 5) and.

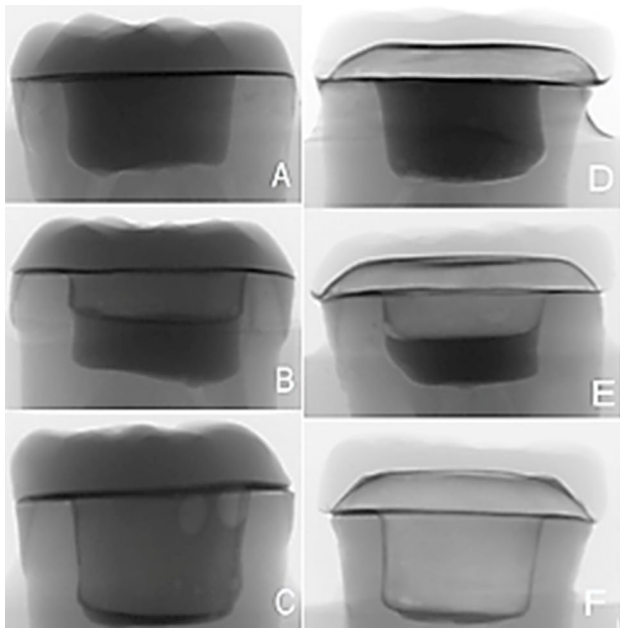


Fig. 9 2D images of Constructed 3D design of each group; (A) L0, (B) L2, (C) L4, (D) P0, (E) P2 and (F) P4

Table 2 Effect of different variables and their interactions on marginal gap (μm) (μm)

Source	Sum of squares	df	Mean square	f-value	p-value
Material	9743.36	1	9743.36	60.02	<0.001*
Preparation design	4623.02	2	2311.51	14.24	<0.001*
Material * Preparation design	1298.33	2	649.17	4.00	0.027*

df= degree of freedom*; significant ($p \leq 0.05$) ns; non-significant ($p > 0.05$)

Table 3 Intergroup comparison, mean and standard deviation (SD) values of marginal gap (μm) for different materials

Marginal gap (μm) (mean \pm SD)		p-value
Emax	PEEK	
54.86 \pm 20.86	85.32 \pm 12.37	<0.001*

*; significant ($p \leq 0.05$) ns; non-significant ($p > 0.05$)

Table 4 Intergroup comparison, mean and standard deviation (SD) values of marginal gap (μm) for different preparation designs

Marginal gap (μm) (mean \pm SD)			p-value
0 mm	2 mm	4 mm	
59.41 \pm 22.16 ^B	66.52 \pm 21.86 ^{AB}	84.35 \pm 18.16 ^A	<0.001*

Means with different superscript letters within the same horizontal row are significantly different *; significant ($p \leq 0.05$) ns; non-significant ($p > 0.05$)

A-Effect of material with each preparation design

- 0 mm:

PEEK had a significantly higher value than Emax.

- 2 mm:

Table 5 Intergroup comparisons, mean and standard deviation (SD) values of marginal gap (μm) for different materials and preparation designs

Material	Marginal gap (μm) (mean \pm SD)			p-value
	0 mm	2 mm	4 mm	
Emax	40.88 \pm 10.27 ^B	46.75 \pm 5.90 ^B	76.95 \pm 20.89 ^A	<0.001*
PEEK	77.95 \pm 12.55 ^A	86.28 \pm 9.46 ^A	91.75 \pm 12.26 ^A	0.105ns
p-value	<0.001*	<0.001*	0.132ns	

Means with different superscript letters within the same horizontal row are significantly different *; significant ($p \leq 0.05$) ns; non-significant ($p > 0.05$)

PEEK had a significantly higher value than Emax.

- 4 mm:

PEEK had a higher value than Emax yet the difference was not statistically significant.

B-Effect of preparation design within each material

- Emax:

There was a significant difference between different groups. The highest value was found in samples with 4 mm extension, followed by samples with 2 mm extension, while the lowest value was found in samples without extension. Post hoc pairwise comparisons showed samples with 4 mm extension to have a significantly higher value than other groups.

- PEEK:

There was no significant difference between different groups. The highest value was found in samples with 4 mm extension, followed by samples with 2 mm extension, while the lowest value was found in samples without extension.

Discussion

The null hypothesis was rejected as there was a statistically significant difference between the values of test groups in marginal adaptation.

Endocrowns are a possible treatment alternative for the restoration of endodontically treated teeth with severe loss of coronal tooth tissue. Today, such restorations are most likely made of plenty of restorative materials, such as pressed glass ceramics, milled glass ceramics, hybrid ceramics or even composite blocks. Polyetheretherketone (PEEK) could be a possible alternative for ceramics [34, 35].

Good marginal adaptation of endocrown restored endo-treated dentition decreases microleakage considerably and the occurrence of secondary caries. It thus improves the longevity of the fillings [36]. The depth of pulpal cavity was proved to have effect on marginal

discrepancies of endocrowns. Studies done by **Yooseok et al.** [30] and **El-damanhoury et al.** [12] proved that increasing inrapulpal cavity depth negatively affected the marginal adaptation.

The effect of material of fabrication on marginal adaptation of endocrown has been evaluated. **Godil et al.** [35] had used PEEK for fabrication of endocrown, and reported increased marginal gap compared to lithium disilicate.

The aim of this study was to evaluate the effect of different preparation depths (0, 2 and 4 mm) of different restoration designs (classic endocrown design versus overlay design) on marginal adaptation of restorations fabricated of two different restorative materials (lithium disilicate and PEEK).

Extracted human teeth were used in the present study to be similar to the clinical condition concerning the enamel and dentin bonding. In order to minimize the possible variations and to approach the desired standardization, selection of teeth of average sizes and almost similar shapes allowing maximum deviation of 10% from the determined mean was performed before testing [30]. This was done via selection of first and second mandibular molars with mean mesio-distal dimension of 10.5 mm. \pm 0.5 mm. and mean bucco-lingual dimensions of 9 mm. \pm 0.5 mm. which was measured by digital caliber.

Preparation was done via individual practiced clinician for purpose of simulation of clinical situation, so as to anticipate representable results. Standard inlay preparation diamond kit was used via a high-speed hand-piece which was connected to paralleling holding device to make sure that there was fixed tapering of preparation among samples.

Butt margin design was used because it is considered the classical approach and almost all in-vitro studies were demonstrated using that design. butt joint designs provided a stable surface that resists the compressive stresses because it is prepared parallel to the occlusal plane [12].

Flowable composite was used as a base to modify cavity depth between groups, and it was selected because of low modulus of elasticity and coefficient of thermal expansion and contraction that was too close to that of dentin [32].

For PEEKs, bonding to PEEK is still quite challenging [37]. Airborne particle abrasion improved its micro-roughness [38], while pretreatment with methyl methacrylate-based (Visio.Link) adhesives increased wetting with the veneering material and demonstrated adequate chemical bond to PEEK [39].

In the present study, priming of intaglio surface of PEEK restoration was performed via universal bond containing mdp functional group. This was agreed with Chersoni S. et al. who found that water based SE bond is suitable for adhesion of hydrophobic and chemically inert

surfaces, which quite caters to the properties of PEEK. The hydrophilic primer can penetrate into the porous surface of PEEK, thereby contributing to improved Shear Bond Strength [34].

In order to simulate the clinical conditions to which the restorations will be subjected, hydrothermal aging was carried out; All samples were subjected to autoclave at 134o C and 2 MPa for five hours, to mimic one year of oral conditions according to ISO standards 13,356 [33].

In this study, μ CT was used to detect the marginal discrepancies after cementation, a technique that was conflicted by **Yooseok et al.** [30] protocol of measuring marginal discrepancies before cementation claiming that low radiographic contrast between cement and dentin would be confusing during analysis.

The results of this study revealed that all the tested samples showed mean values within the recommended clinical range (30.26 μ m to 109.3 μ m) as in the study by **McLean** [21] who has conducted a five-year study on over one thousand restorations and determined that 120 μ m was the maximum acceptable marginal adaptation value.

This study revealed that endocrowns fabricated of lithium disilicate showed less marginal discrepancies (54.86 \pm 20.86) than done endocrowns fabricated of PEEK (85.32 \pm 12.37). This result was in agreement with **Godil et al.** [35] who found that endocrowns that were fabricated from lithium disilicate showed less marginal and internal discrepancies than those fabricated of PEEK, and they attributed their result due to the semi-crystalline structure of PEEK which contains fillers embedded in resin matrix, therefore creating differences in the milling of the two materials [40]. These differences were obvious in (Fig. 9) that showed irregular margins of subgroup P compared to more smooth milled restorations of subgroup L.

That wasn't in agreement with **Hasanzade M. et al.** [41] who concluded that there was no significant differences in marginal adaptation between tested endocrowns fabricated of (Vita Enamic, IPS Emax CAD and Vita Suprinity). and the results were (71.00 \pm 3176, 69.22 \pm 23.49 and 77.52 \pm 13.39) respectively.

A more obvious disagreement was observed by a study done by **Osman M. et al.** [39] which revealed a better marginal fit of PEEK endocrown versus endocrowns fabricated of Lithium disilicate. But these confliction may be attributed to different method of endocrown fabrication, which was pressing instead of milling technique, beside the silicon replica method of measurement used in the mentioned study instead of micro-CT analysis used in the current study.

Cavity depth affected marginal adaptation of studied restorations. Increased cavity depth caused increased vertical discrepancies with 4 mm cavity depths of

subgroup L (76.95 ± 20.89). But that increase in marginal discrepancies with increasing intra-pulpal cavity depth was not statistically significant for P subgroup with different cavity depths (0, 2 and 4) which were (77.95 ± 12.55 , 86.28 ± 9.46 and 91.75 ± 12.26) respectively.

This outcome was confirmed by a conclusion of a previous studies by **Yooseok S. et al.** [30] and **Gaintantzopoulou et al.** [12]. They concluded that increased cavity depth of endocrown preparation increased vertical marginal gap. **Yooseok et al.** [30] evaluated the effect of cavity depths on internal and marginal adaptation of endocrowns and they attributed their findings to the fact that areas farther from the scanner is less accurate and undercuts couldn't be easily detected which may interfere with restoration setting.

Another explanation of increased marginal discrepancy with increased cavity depth that increased axial length would increase surface area available for friction between fitting surface of restoration and cemented surface of the abutment, which interfere with seating of restoration compared to decreased axial length [42].

This study had some limitations as the endocrown and overlays were tested under invitro conditions which might be different from clinical conditions. further invivo studies are required.

Conclusions

Within the limitations of this study, the following conclusions were got:

- Increasing intrapulpal cavity depths increases vertical marginal gap of restorations made of lithium disilicate or PEEK.
- Endocrowns fabricated of lithium disilicate show less marginal discrepancies than that of endocrowns fabricated of PEEK.

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Author contributions

M.A. major contributor in writing the manuscript. A.M.H study design M.M. data analysis A.M. figure preparation A.T. Technical support of Micro-CT scanning S.O. drafting the article. All authors read and approved the final manuscript.

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Data availability

The datasets used and/or analyzed during the current study are available from the corresponding authors on reasonable request.

Declarations

Ethics approval and consent to participate

The Research Ethics committee, Faculty of dentistry, Ain Shams University approved all experimental methods and the study was performed in accordance with its regulations, licensing requirements and relevant guidelines. Because this study did not contain any intervention with human participants or animals and it only utilized archival teeth whose owners cannot be identified, it was exempt from ethical assessment. The approval of the ethics committee is Fdasu-RecD031819. The need for informed consent was waived by the ethical committee of the Ain Shams University, Cairo, Egypt.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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