EGYPTIAN
DENTAL JOURNAL

Vol. 67, 3491:3500, October, 2021

Print ISSN 0070-9484 • Online ISSN 2090-2360

Fixed Prosthodontics and Dental Materials

www.eda-egypt.org • Codex : 88/21.10 • DOI : 10.21608/edj.2021.85048.1710

INFLUENCE OF DIFFERENT MARGINAL PREPARATION DESIGNS AND MATERIALS ON THE MARGINAL INTEGRITY AND INTERNAL ADAPTATION OF ENDOCROWN RESTORATIONS

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ABSTRACT

Objective: This in vitro study was performed to assess the marginal accuracy and internal adaptation of CAD/CAM fabricated endocrowns restoring endodontically treated molars with two different designs and materials.

Materials and methods: Forty extracted maxillary first molar teeth were divided into two main groups (n=20) according to the preparation designs: group B: (Butt joint) & group S (Shoulder finish line): and each group was subdivided into two subgroups (n=10) according to materials: group E: lithium disilicate glass-ceramic (IPS e.max CAD; Ivoclar Vivadent AG) & group C: hybrid nanoceramic (Cerasmart; GC Corp). A digital scan was made with a digital scanner (Identica Hybrid Scanner; Germany) and virtual endocrowns were milled with a 5-axis milling machine (Imes-Icore; CORiTEC250i; Germany). The silicone replica technique and a stereomicroscope (25X) were used to measure the marginal and internal gaps of endocrowns at different points. All data were statistically analyzed using three-way ANOVA test with Post Hoc Tukey test to detect pair-wise comparison. Student's t-test also was used.

Results: There was a statistically significant difference between the preparation designs on the marginal integrity and internal adaptation ($p<0.05$), but restorative materials significantly affected on the internal adaptation ($p<0.05$) and showed no significant effect on the marginal integrity ($p>0.05$).

Conclusions: All tested groups showed acceptable marginal and internal mean value gaps. Butt joint design showed a better effect than shoulder finish line design on the marginal integrity and internal adaptation. Cerasmart showed a better effect than IPS e.max CAD on the internal adaptation.

KEY WORDS: Endocrown Restorations, Marginal Integrity, Internal Adaptation, IPS e.max CAD, Cerasmart.

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INTRODUCTION

In everyday clinical practice, deciding on the final coronal restoration for root canal treated teeth continues to be a significant challenge. The efficiency of the coronal restoration is critical for long-term performance of endodontically treated teeth, not just in terms of restoring function but also in terms of protecting the remaining tooth structure and maintaining a good marginal quality.[1]

A shift in treatment options toward more conservative modalities has been observed recently with the advances in adhesive systems, dental materials, and computer-aided design/computer- aided manufacturing (CAD/CAM) systems. These technologies reduced the need of posts to restore the endodontically treated teeth (ETT) and have resulted in new restoration design, which is minimally invasive preparations that's considered the gold standard for this type of restoration and is called endocrown.[2, 3]

The precursor of the endocrown approach was the Pissis[4] who is in 1995 identified it as the monoblock porcelain technique. Bindle and Mormann[5] discussed the endocrown for the first time as "an adhesive endodontic restorations" or "a full porcelain restoration" attached to posterior root canal treated teeth, anchored to the internal portion of the pulp chamber and to the cavity margins.

The endocrown prosthetic material is considered to be an important point of concern. As an adhesive bonding affects endocrown retention, so the use of prosthetic material that is bonded to tooth tissues is important, therefore IPS e.max CAD (Glass-matrix ceramics) was used in this study.

The high similarity between mechanical properties for both the selected material and sound tooth structure has favorable effect on restorative system reliability, therefore Cerasmart material (Resin Nanoceramic) was used in this study for its mechanical properties such as less brittle, more flexible compared to conventional ceramics and more accurate margins. [6]

The key factor for the long-term performance in fixed prosthesis is good marginal integrity. Poor marginal fitness exposes the cement content to the oral environment that leads to dissolution of cement, stimulating caries initiation and causes damage to an essential pulp and paradental structures resulting in restoration failure.[7]

The fitting accuracy of CAD/CAM fabricated restorations is crucial for clinical long-term success. Presently, there are limited data available about the marginal integrity and internal adaptation of endocrown restorations and no enough information about the effect of preparation designs and materials on the fit of endocrown restorations. Therefore, the purpose of this study was to evaluate the effect of marginal preparation designs on the marginal integrity and internal adaptation of ceramic-based (IPS e.max CAD) and resin-based (Cerasmart) CAD/CAM endocrown restorations.

The null hypotheses were that there would be an effect of different designs and materials on the marginal integrity and internal adaptation of endocrown restorations.

MATERIALS AND METHODS

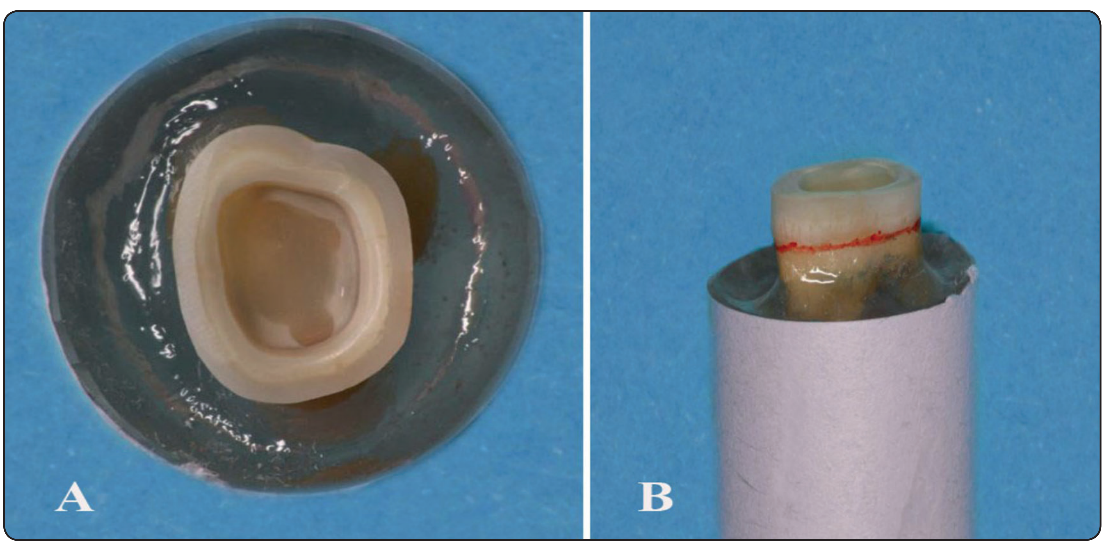
This study was approved by the Ethical Research Committee of the Faculty of Dentistry, Mansoura University (2020.A22110220). Forty extracted human maxillary right and left first molars (n=40) with completed roots, free of cracks or fractures were collected from oral surgery department, Faculty of Dentistry, Mansoura University, from patients seek for complete denture or diabetic patient. Teeth were hopeless, mobile and periodontally compromised. The average bucco-palatal and mesio-distal dimension widths were 10.73±0.64 mm and 9.31±0.52 mm respectively, with a maximum deviation of 10%, estimated at the cemento-enamel junction (CEJ) as determined with a digital caliper. The teeth were cleaned with an ultrasonic scaler and kept at room temperature in 0.9% normal saline solution till use.

Endodontic treatment was performed using crown-down procedure. Each tooth was fixed at an upright position in a plastic ring of centralizing device which filled with an epoxy resin below the CEJ by 2 mm to simulate the normal biological width. All endodontically treated teeth (n=40) were randomly divided into two main groups (n=20) according to the preparation designs: Group (B): Preparations with butt joint design and group (S): Preparations with 90^{o} shoulder finish line design. After root canal treatment of all the teeth, the gutta percha was removed till canals entrance using a round bur with water cooling system. A thin layer of flowable composite material (Te-Econom Flow, Ivoclar Vivadent) was bonded to seal the canal entrance to enhance the bonding.

A dental surveyor machine; Bredent; Germany) was used for preparing all teeth to standardize the preparation dimensions. The preparation was performed according to endocrown preparation parameters which were recommended by Marwa Elagra. [8] A super coarse diamond disc (Transflex-T; Bredent; Germany) was used for horizontally decoronated of all teeth leaving 3mm above cemento-enamel junction (CEJ) to achieve the badly destructed root canal treated teeth. All teeth were prepared according to its own group preparation criteria. For butt joint design, the axial access cavity was prepared using a tungsten carbide conical bur with round end (F200 2H 40; Bredent; Germany). Coronal divergence was 8^{o} [9] and the pulp chamber depth was 4 mm[10] from coronal tooth structure to the flowable composite on the pulpal floor. All internal line angles were rounded and smoothened, and the remaining thickness of dentin walls was (2±0.5 mm) which measured by digital caliper (Fig 1).

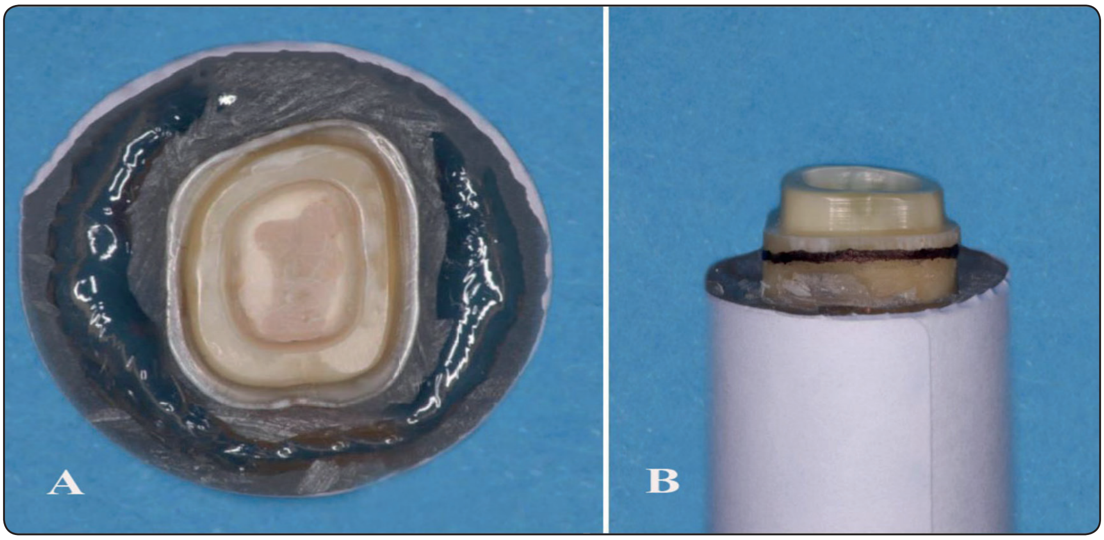
On other hand, the shoulder finish line design has the same preparation as butt joint design intracoronally, but extracoronally, the remaining vertical portion of the tooth was prepared using a tungsten carbide conical bur with flat end (F186 2H 40; Bredent; Germany) to create a circumferential 90^{o} shoulder finish line 1mm width located on sound tooth structure leaving a 2mm ferrule and with 8^{o} [9] coronal convergence (Fig 2).

Each group was subdivided into two subgroups (n=10) according to material used: Subgroup (E): Teeth received IPS e.max CAD material and subgroup (C): Teeth received Cerasmart material.



A: Occlusal view. B: Lateral view.

Fig. (1) Endocrown preparation with butt joint design.



A: Occlusal view. B: Lateral view.

Fig. (2): Endocrown preparation with shoulder finish line design.

All prepared specimens were scanned with a digital scanner (Identica Hybrid Scanner; Germany). Exocad chairside software, version 2.2 (Valetta; exocad; GmbH; Germany) was used to design the endocrown on virtual model. The technician was determined the design parameters according to the type of tooth (16,26) and the restoration. Automatic margin finder was used for detecting the Preparation margins and the path of insertion. The luting space was set to be 50 μm as standard.[11] The virtual endocrowns were milled with a 5-axis milling machine (Imes-Icore; CORiTEC250i; Germany) under wet processing using T21, T22 and T23 diamond grinding tools. After milling was completed, the remaining part of the sprue was finished using a finishing diamond wheel. Crystallization process was applied to specimens in group E (IPS e.max CAD) (post milling firing) and glazed using additional glaze firing (Add on Technique) as glaze paste material (IPS e.max Ceram glaze; Ivoclar Vivadent). The specimens in group C (Cerasmart) don't need any crystallization firing and were finished utilizing EVE finishing kit (EVE Diapol, EVE Ernst Vetter GmbH, Pforzheim, Germany) and polished utilizing dental polish paste (Pearl Surface Z paste; Kuraray Noritake Dental Inc; Japan). All specimens were subjected for checking adaptation at their margins using sharp explorer instrument.

The marginal and internal gaps of endocrown restorations in the 4 studied groups were evaluated using silicone replica technique (SRT) with the light-body vinyl Polysiloxane impression material (VPS)[10,11] (Imflex, Metabiomed, Korea) as the following steps: Each endocrown has been filled with an orange light-body vinyl Polysiloxane impression material (VPS) which seated for five minutes under finger pressure along the long axis of the corresponding tooth. After five minutes, an endocrown was removed from its corresponding tooth and a layer of light body was attached to the internal side of the tooth. A customized plastic syringe was used to stabilize the light-body using the purple heavy-body vinyl Polysiloxane impression material (Imflex, Metabiomed, Korea) which was injected into the tooth and into the plastic syringe to adhere and stabilize the light-body material. The tooth was put inside the syringe until the material get setting and then the tooth removed from the syringe leaving the light body replica adhered to the heavy body impression material. Every replica was cut from the center in bucco-palatal and mesio-distal directions into four slices named (MB, MP, DB, DP) using a sharp surgical blade no.11 (HuaiAn TianDa Medical Instruments Co, Ltd, China). To obtain a perpendicular view on the stereomicroscopic stage. A slice of each replica was segmented with parallel walls. The gap between the endocrown and the tooth was represented by an orange-colored light layer, which was examined at 25X magnification using a digital stereomicroscope (Olympus Model SZ2-ILST, Japan). For butt joint design, nine measurements were selected on each slice. 3 measurements on the marginal area, 3 measurements on the pulpal wall and 3 measurements on the pulpal floor. So, each replica has 36 measurements.

On other hand, for shoulder finish line design, fifteen measurements were selected on each slice. 3 measurements on the marginal area, 3 measurements on the axial wall, 3 measurements on the occlusal area, 3 measurements on the pulpal wall and 3 measurements on the pulpal floor. So, each replica has 60 measurements.

The data were tabulated, coded then statistically analyzed using IBM SPSS (Statistical package for social science) computer software 2013, version 22.0, Armonk, NY, IBM corp. Three-way ANOVA test was used to compare more than 2 independent groups on the marginal integrity and internal adaptation with Post Hoc Tukey test to detect pair-wise comparison. Student's t-test (Unpaired) was used to compare 2 independent groups.

RESULTS

Three-way ANOVA test was used to assess the effect of different designs and materials with different surfaces on the marginal integrity. It was indicated that only the designs have significant difference on the marginal integrity ($P<0.05$), while the materials and surfaces have no significant difference ($P>0.05$). The interaction between them showed no significant difference on the marginal integrity ($P>0.05$) as shown in (Table 1).

Three-way ANOVA test was used to assess the effect of different designs and materials with

TABLE (1): Multiple Way ANOVA (Three-way ANOVA test) of the combined effect of designs & materials and surfaces in prediction of marginal integrity.

Source	Type III Sum of Squares	df	Mean Square	F	P value
Corrected Model	9938.194[a]	15	662.546	1.577	.089
Intercept	746784.028	1	746784.028	1777.469	<0.001*
Design	7950.694	1	7950.694	18.924	<0.001*
Material	6.250	1	6.250	.015	.903
Surface	879.861	3	293.287	.698	.555
Design*Material	250.694	1	250.694	.597	.441
Design * Surface	124.306	3	41.435	.099	.961
Material * Surface	290.972	3	96.991	.231	.875
Design*Material *Surface	435.417	3	145.139	.345	.792
Error	53777.778	128	420.139		
Total	810500.000	144			
Corrected Total	63715.972	143			
a. R Squared = .156 (Adjusted R Squared = .057)					

Materials (IPS e.max CAD & Cerasmart) Designs (Butt & shoulder) Surfaces (Mesial & Distal & Buccal & Palatal)

TABLE (2): Multiple Way ANOVA (Three-way ANOVA test) of the combined effect of designs & materials and surfaces in prediction of internal adaptation.

Source	Type III Sum of Squares	df	Mean Square	F	P-Value
Corrected Model	45565.104[a]	15	3037.674	6.694	<0.001*
Intercept	1176321.007	1	1176321.007	2592.046	<0.001*
Design	31064.063	1	31064.063	68.450	<0.001*
Material	4064.063	1	4064.063	8.955	0.003*
Surface	3724.132	3	1241.377	2.735	.06
Design*Material	416.840	1	416.840	.919	.340
Design * Surface	2208.854	3	736.285	1.622	.187
Material * Surface	2569.965	3	856.655	1.888	.135
Design*Material *Surface	1517.188	3	505.729	1.114	.346
Error	58088.889	128	453.819		
Total	1279975.000	144			
Corrected Total	103653.993	143			
a. R Squared = .440 (Adjusted R Squared = .374)					

Materials (IPS e.max CAD & Cerasmart) ***Designs (Butt & shoulder)*** ***Surfaces (Mesial & Distal & Buccal & Palatal)***

different surfaces on the internal adaptation (pulpal wall and pulpal floor for BE & BC groups, while axial wall, occlusal area, pulpal wall and pulpal floor for SE & SC groups). It was indicated that the designs and materials have significant difference on the internal adaptation ($P<0.05$), while the surfaces have no significant difference ($P>0.05$). The interaction between them showed no significant difference on the internal adaptation ($P>0.05$) as shown in (Table 2).

To compare between different designs within the same material (IPS e.max CAD): Student's *t*-test was used and it was found that, butt joint design group (B) recorded lower marginal and internal mean value gaps than shoulder finish line design group (S) and showed there was statistically significant difference ($P<0.05$).

To compare between different designs within the same material (Cerasmart): Student's t-test was used and it was found that, butt joint design group (B) recorded lower marginal and internal mean value gaps than shoulder finish line design group (S) and showed there was statistically significant difference ($P<0.05$).

To compare between different materials within the same design (Butt joint design): Student's t-test was used and it was found that, there was statistically significant difference between materials in internal fit ($P<0.05$). For marginal integrity there was no statistically significant difference between materials ($P>0.05$). IPS e.max CAD recorded lower marginal mean value gaps ($63.06\pm10.64\mu m$) than Cerasmart ($66.11\pm18.71\mu m$).

To compare between different materials within the same design (Shoulder finish line design): Student's t-test was used and it was found that, there was statistically significant difference between materials in internal fit ($P<0.05$). For marginal integrity there was no statistically significant difference between materials ($P>0.05$). IPS e.max CAD recorded higher marginal mean value gaps ($80.55\pm25.63\mu m$) than Cerasmart ($78.33\pm21.58\ \mu m$).

DISCUSSION

The endocrown is a single-unit restoration that combines the crown and core. It includes each cusp and extends to the pulpal floor. Endocrowns use the available surface provided by the pulp chamber's axial walls as macromechanical retention, while the resin cement serves as micromechanical retention. [4,5]

Endocrown was selected in this study as a satisfying option for endodontically treated teeth restoration, because it does not need additional tooth structure removal, which is an unavoidable process in post and core restoration. Since it is a minimally invasive procedure, so it inherently protects established tooth structure. [12]

To ensure uniformity of location, all specimens were vertically inserted in the center of a standard ring filled with an epoxy resin using a special centralizing system. Self-cured epoxy resin was chosen because it has a modulus of elasticity (12GPa) comparable to that of human bone (18GPa), simulating the teeth in the alveolar bone.

Different factors such as; preparation design, material type, scanner type, milling machine type, cement space and measuring method have been shown to influence marginal and internal discrepancies, so the aim of this study, to test the effect of marginal preparation designs (butt joint, shoulder finish line) and materials (IPS e.max CAD, Cerasmart) by considering all other factors equal in all specimens.

The teeth that have been chosen were of the same size. The specimens were prepared by one operator using 1 type of diamond rotary instrument on a dental surveyor and were decapitated 3mm coronal to the CEJ to simulate the compromised situation of severely damaged endodontically treated teeth. To eliminate manual errors, a precise CAD/CAM scanner and milling machine were used, and each replica was sectioned in the same position to examine the differences from a perpendicular perspective.

In this study, the cement space that used was 50 μm [11] to ensure a good marginal seal and to allow the restoration to set more precisely. Differences of marginal discrepancy in the vitro studies are directly related to the space given to the cementing agent. Since, according to Anadioti et al [13,14] the choice of spacing less than 40 μm prevents the crown from settling, resulting in increased marginal discrepancy.

Ceramic material (IPS e.max CAD) and resin nanoceramics (Cerasmart) were selected in this study. IPS e.max CAD is widely used in the fabrication of restorations as reported with high flexural strength, favorable esthetics and translucency. The restorations need to pass through a crystallization stage in a ceramic oven. This crystallization step has been indicated as one of the factors responsible for the discrepancies in both marginal and internal adaptation. [15]

Furthermore, resin nanoceramics have the ability to modify and repair the surface easily and their stress absorbing properties. The structures of the Cerasmart endocrown restorations have a modulus of elasticity similar to that of dentin (18 ± 2 GPa), less crack propagation and higher fracture resistance than conventional ceramics, which are more prone to fracture due to their brittle nature. [16]

The silicone replica technique was used in this study because it is straight forward, an accurate, reliable technique that has been used for in-vivo and in-vitro studies, less costly, noninvasive and can be repated quickly without loss of precision. It is also a non-destructive technique that does not cause damage to the abutment tooth or the restoration. Colpani et al [17], Oka et al [18] and Ariganello et al [19] reported that, the silicone replica technique recorded higher reliability than the other methods.

In the present study, the effect of different preparation designs and materials were tested for marginal integrity and internal fit of endocrown restorations. In the current study, the results regarding both the marginal integrity and internal adaptation according to designs revealed that, there was a significant difference between the butt joint design and the shoulder finish line design (P<0.05), therefore the null hypotheses were accepted.

Inas Elalem et al [11] evaluated clinically the marginal integrity and internal adaptation of IPS e.max press endocrown with two different marginal preparation designs (butt joint design & deep chamfer finish line design). They were resulted that, for marginal gap there was a significant difference between two groups. The endocrown with deep chamfer design has less marginal gap than those with butt joint design. For internal gap there was no significant difference between two groups and the endocrown with deep chamfer design has less internal gap than those with butt joint design. These results are in dis agreement with our results in which the butt design has less marginal gap than those with shoulder design. The difference between both studies may be related to the difference in the material of restoration (IPS e.max press rather than IPS e.max CAD), different designs (deep chamfer design rather than shoulder design) and the difference in the teeth (mandibular molars rather than maxillary molars).

These results are in dis agreement with Abo-Elmagd and Abdel-Aziz [20] who studied the influence of two different marginal preparation designs on the marginal gap of endocrown restorations and restored with IPS e.max press. They found that, endocrown marginal designs had no significant effect on marginal gap (P>0.05). The difference between both studies may be related to the difference in the material of restoration (IPS e.max press rather than IPS e.max CAD) and to the difference in the teeth (mandibular premolars rather than maxillary molars).

Other study of Kholoud Soliman et al [21] evaluated the effect of different marginal designs (butt, shoulder) and cavity depths (2mm, 4mm) on the marginal integrity of IPS e.max Press endocrowns. They reported that, there was no significant effect between designs on marginal gap (P>0.05) with 4mm, but with 2 mm had significant effect. These results are in dis agreement with our results in case of 4mm depth used. The difference between both studies may be related to the difference in the material of restoration (IPS e.max press rather than IPS e.max CAD) and to the difference in the teeth (mandibular first molars rather than maxillary first molars).

In the current study, the results regarding the marginal integrity and internal adaptation according to materials revealed that, there was no significant difference between IPS e.max CAD and Cerasmart material (P>0.05) according to the marginal integrity, but there was a significant difference between IPS e.max CAD and Cerasmart material (P<0.05) according to the internal adaptation, therefore the null hypotheses were partially accepted.

These results are in agreement with Doaa Taha et al [22] assessed the marginal integrity of endocrown restorations utilizing different machinable blocks of endodontically treated forty mandibular molars which prepared with a butt design. They were reported that, the marginal gaps values of the tested materials were statistically insignificant (P>0.05).

Moritz Zimmermann et al [23] studied the impact of different CAD/CAM materials (Celtra Duo, Lava Ultimate and Empress CAD) on the fitting accuracy (marginal integrity and internal adaptation) of the endocrown restorations. They were reported that, for marginal area (marginal gap) and axial area (internal gap), the endocrown restorstions fabricated from Lava Ultimate were performed statistically significant better than Celtra Duo. These results are in agreement with our result according to internal adaptation (P<0.05), but in dis agreement with our result according to marginal integrity (P>0.05). The difference between both studies may be related to the difference in the material of restoration (Celtra

Duo rather than IPS e.max CAD and Lava Ultimate rather than Cerasmart).

These results are in agreement with Saglam et al [24] evaluated the marginal integrity of twenty extracted human permanent maxillary premolars fibricated from feldspathic (CEREC) and PICN (Vita Enamic) to receive endocrown restorations. They were reported that, there were no significant differences in the marginal gap values between two groups (P>0.05).

Mahya Hasanzade et al [25] compared the marginal integrity and internal adaptations of CAD/ CAM endocrowns and crowns fabricated from three different materials (IPS e.max CAD, VITA Enamic and VITA Suprinity). They reported that, a type of material had no significant effect on any kind of discrepancy (P>0.05). These results are in agreement with our result according to marginal integrity (P>0.05), but dis agreement with our result according to internal adaptation (P<0.05). The difference between both studies may be related to the difference in the teeth (dental model molars rather than natural molars).

Another study of Wiam El-Ghoul et al [10] studied the influence of resin-based: Cerasmart (C), Trilor (T), and ceramic-based materials: IPS e.max CAD (E), Vita Suprinity (V) on the marginal integrity and internal adaptation of endocrowns. They were reported that, there were significant differences among the studied groups (P<0.05). Resin-based groups had higher discrepancies than ceramic-based groups. These results are in dis agreement with our results. The difference between both studies may be related to test more than two materials and to the difference in the teeth (mandibular molars rather than maxillary molars. Only butt joint design tested rather than both butt joint design and shoulder finish line design).

These results are in agreemenet with Heba Darwish et al [9] evaluated the effect of different central cavity designs (cavity depth, axial wall divergence) on the internal adaptation of IPS e.max CAD and Lava Ultimate. They were reported that, Lava Ultimate endocrowns presented better internal adaptation compared to those restored with IPS e.max CAD endocrowns, regardless of the central cavity design.

The limitations of this study were that include: No simulating of oral conditions through thermocycling and cycling loading. In addition, cementation procedures were not applicated because specimens were subjected to other test with another student.

CONCLUSIONS

Under the limitations of the current study, the following conclusions were drawn;

1. Butt joint design showed a better effect than shoulder finish line design on the marginal integrity and internal adaptation.
2. Cerasmart showed a better effect than IPS e.max CAD on the internal adaptation.
3. All tested groups showed acceptable marginal and internal gaps mean values.
4. The largest gap was observed at the pulpal floor for all butt joint design groups. The shoulder finish line design groups showed the pulpal wall was the largest gap for IPS e.max CAD group, while the axial wall was the largest gap for Cerasmart group.

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