

Original Research Paper

# Microleakage Assessment of CAD/CAM Endo Crown Restorations (an *in vitro* Study)

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**Abstract:** The preservation of tooth structure is an important factor in the successful restoration of endodontically treated teeth. The loss of structural integrity increases the occurrence of crown fractures and microleakage at the margins of restorations in endodontically treated teeth compared with vital teeth. A total of twenty endocrowns were fabricated in this study and the endocrown was divided into two main groups. Each subgroup was tested after cementation for (marginal gap and fracture strength). To simulate a frequent clinical situation then accept a different type of end crown restoration (IPS E-max cad, IPS E-max press). IPS E-max comprises highly esthetic, high strength materials for both the press and CAD/CAM technology subgroup recorded statistically significant ( $p < 0.05$ ) highest marginal gap mean value ( $54.85 \pm 2.5 \mu\text{m}$ ) followed by O group P subgroup ( $52.00 \pm 4.3 \mu\text{m}$ ) then N group P subgroup ( $49.47 \pm 1.3 \mu\text{m}$ ). CAD/CAM endocrown restoration is better in marginal fit. Microleakage is directly affected by the type of cement of CAD/CAM endocrown. Ceramic endocrown is considered a recent approach in the treatment of endodontically treated teeth with the advantage of the reduction in the amount of loss of tooth structure in comparison to the classical crown with post and core.

**Keywords:** Ceramic Endocrown, CAD/CAM Endocrown, Fracture Resistance

## Introduction

The reconstruction of endodontically treated teeth with microleakage is a common problem associated with CAD/CAM endo crown restorations (Lin *et al.*, 2020). It occurs when bacteria and other debris from the oral cavity seep into the restoration, leading to decay and other complications. To assess microleakage, a dye penetration test can be used. This involves placing a dye solution around the restoration and then observing it under a microscope to see if any of the dye has penetrated the restoration other than the vital teeth (Gomes de Carvalho *et al.*, 2021). If there is any evidence of dye penetration, then microleakage has occurred. Other methods for assessing microleakage include using a scanning electron microscope or an atomic force microscope to look for signs of leakage at the interface between the restoration and tooth structure (Haralur *et al.*, 2020).

CAD/CAM marginal accuracy may be affected with the selection of materials and the radicular extension. The design of both hybrid ceramic resin and lithium silicate materials may exhibit a questionable marginal fit (Soliman *et al.*, 2022).

Ceramic materials have several advantages over other dental materials, such as being biocompatible, esthetically pleasing, and highly durable. They also have excellent wear resistance and can be polished to a high gloss finish. Additionally, they are resistant to staining and discoloration from food and beverages (Ghajghouj and Taşar-Faruk, 2019). The reconstruction of endodontically treated teeth had a great challenge with decreased inter arch spaces. The insufficient inter occlusal space for a tooth can cause degradation of the ceramic material by different problems such as a ceramic fracture or tooth fracture. Debonding, which is more susceptible, can lead to a decrease in strength and an increase in further degradation of the ceramic material (El-Damamhoury *et al.*, 2015).

Endocrowns manufactured by CAD/CAM is a great option for restoring endodontically treated teeth. They provide a strong and durable restoration that is designed to match the natural shape and color of the tooth restoration (Zimmermann *et al.*, 2019). Endocrowns are made from high quality materials, such as zirconia or porcelain, and are milled to fit perfectly within the existing tooth structure. This ensures that the restoration is secure and aesthetically pleasing. Additionally,

CAD/CAM technology allows for precise measurements and designs, which can help reduce the risk of complications during the treatment (Rocca *et al.*, 2016).

The marginal gap of CAD/CAM milling machines and fracture resistance of restoration are affected by the construction technique used and the remaining tooth structure. The technique used to create the restoration provides how well it fits into the prepared cavity, and affects function and esthetic which ultimately determine its marginal gap. The remaining tooth structure even with the compromised tooth integrity of non-vital also affects the marginal gap and fracture resistance of restoration, as it provides support for the restoration and helps to prevent fractures (Samran *et al.*, 2015). The hypothesis of this study was that the marginal gap and fracture resistance will be affected by the construction technique and remaining tooth structure.

## Materials and Methods

The materials used in this study are listed in Table 1. Twenty human intact caries free mandibular first premolars were collected from the orthodontic clinic, faculty of dental medicine, Al Azhar University; the teeth were selected with approximate anatomic crown length, mesiodistal width, and fac-io-lingual thickness with complete root growth.

The bucco-lingual and mesio-distal dimensions were measured in millimeters at the level of cement enamel junction using digital metal gauge1 that was accurate to within 0.01 mm. The endocrowns were divided into two main groups (N and O), with ten endocrowns for each group according to the type of preparation design. Then each group is divided into two subgroups (C and P), with five endocrowns for each subgroup according to the ceramic type. All teeth are prepared by transverse section above the highest point of the cemento-enamel junction by 3 mm with a disc attached to the milling machine. By using the prefabricated small stainless steel 1.5 mm mold to act as a ruler make a transverse section to the height of 1.5 mm so the retention cavity will be by 3.5 mm. By using the prefabricated small stainless steel 1.5 mm mold to act as a ruler make a transverse section to the height of 1.5 mm so the retention cavity will be by 3.5 mm. Then by transverse section above the finish line is 1.5 mm by

using the prefabricated small stainless steel (1.5 mm) to 3 walls leaving only the buccal wall (O group).

The selected ceramic block of the required size and dimensions was inserted in the spindle of the milling chamber of the system and fastened with the set screw.

### Construction of IPS E-Max CAD Endocrown

A cylinder diamond of 1.6 mm was attached to the right side of the chamber, while a cone shaped diamond stone was attached to the left side of the chamber.

Scanner optical camera which terminated in 2 min the scanned model appeared on the screen and was subsequently rotated on the screen via the menu item (design/insertion axis) and is ready for the design step. The restoration was checked for any corrections on the outer surface, if necessary, were made with the drop and shape free forming tools, any faulty was removed.

The selected ceramic block of the required size and dimensions was inserted. The milling process ran fully automated without any interference with the two diamond stones acting together simultaneously in the shaping process with copious water coolant sprayed from two directions, it took about 15 min to terminate the entire milling process for each restoration.

### Construction of IPS Emax Press Endocrown

Fabrication of E-max press is done to the other 5 prepared teeth from (O group) and 5 prepared teeth from (N group). Making duplication to the E-max cad crown 10 times by Dupli flex duplicating material to standardize the external surface of mandibular first premolar.

### Cementation

All preparations were cleaned with pumice and water without any conditioning. The fitting surface of all ceramic restorations was etched using hydrofluoric acid porcelain etch for 1 min. The restoration was rinsed thoroughly with water for 15 sec and then dried with air free water and oil. The silane coupling agent was then applied for 1 min followed by air dryness so that the solvent evaporates completely. Rely X Unicem Aplicap (self-adhesive universal resin cement) was used for the cementation of all endocrown.

**Table 1:** The materials used in the study

	Materials type	Composition	Manufacturer name	Batch number
IPS E-max cad	Lithium disilicate Glass ceramic blocks	SiO <sub>2</sub> , LiO <sub>2</sub> , K <sub>2</sub> O, P <sub>2</sub> O <sub>5</sub> , MgO, ZnO and other coloring oxides	Ivoclar Vivadent, Schaan, Liechtenstein, Switzerland	S30202
IPS E-max press ingots	Lithium disilicate glass ceramic Ingots	SiO <sub>2</sub> , LiO <sub>2</sub> , K <sub>2</sub> O, P <sub>2</sub> O <sub>5</sub> , MgO, ZnO and other coloring oxides	Ivoclar Vivadent, Schaan, Liechtenstein, Switzerland	R67566
Rely X Unicem Aplicap	Ivoclar Vivadent, Schaan, Self-adhesive universal resin cement	Powder: Glass powder, initiator silica, substituted pyrimidine, stabilizer calcium hydroxide peroxy compound, pigment, Liquid: Methacrylated phosphoric ester, dimetha crylate, acetate, initiator D-82229 see feld Germany	3M ESPE AG, dental products	364090

### Microleakage Evaluation

Magnification X 50 with a digital microscope, the captured image was transferred to a computer in the system IBM analysis of the image. The premolars are measured with size and frames, and the transcript is into pixels. After calibration, the pixels are converted into absolute real-world units. On software, a comparison was done by the analysis of the dimension on a scale, after that, the marginal gap was revealed in microns.

### Results

SPSS statistical version 21 (statistical procedures companion, Chicago, IL, USA) was used for statistical analysis. One-way ANOVA test between the two materials and post hoc Tukey test at a set p-value  $\leq 0.05$  to a significant level.

The mean values and standard deviation of the marginal gap ( $\mu\text{m}$ ) as a function of the processing technique, and remaining walls are summarized in (Table 2).

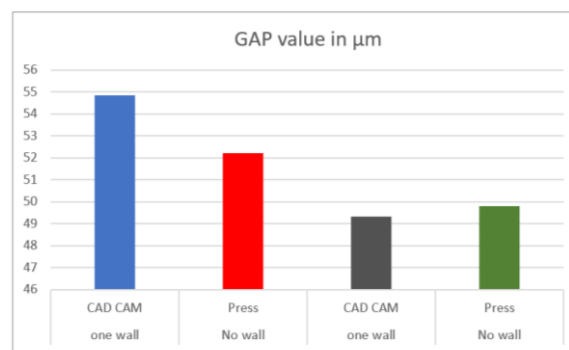
Regarding the effect of material on the marginal gap regardless of the preparation design, it was found that the O group C subgroup recorded statistically significant ( $p < 0.05$ ) highest marginal gap mean value ( $54.85 \pm 2.5 \mu\text{m}$ ) followed by the O group P subgroup ( $52.00 \pm 4.3 \mu\text{m}$ ) then N group P subgroup ( $49.47 \pm 1.3 \mu\text{m}$ ) while N group C subgroup recorded statistically significant ( $p < 0.05$ ) lowest marginal gap mean value ( $49.31 \pm 5.4 \mu\text{m}$ ) as indicated by one way ANOVA test.

The mean marginal gap of the feldspathic ceramic block was  $0.17 \pm 0.07 \text{ mm}$ , while the mean marginal gap of the polymer infiltrated ceramic network block was  $0.12 \pm 0.06 \text{ mm}$ . This difference was statistically significant ( $p < 0.001$ ).

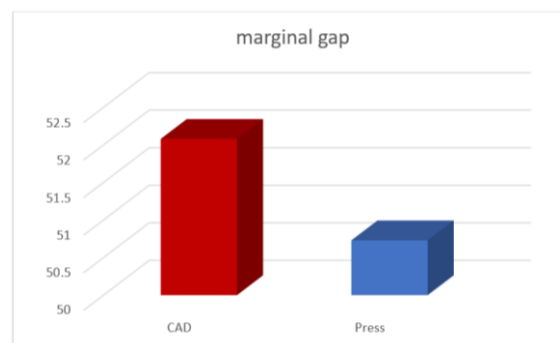
Regarding the effect of preparation design on the marginal gap regardless of the material used, a statistically significant difference was observed between the two tested preparation designs, pairwise Tukey's post-hoc test showed that there was no significant ( $p > 0.05$ ) difference between (O group C subgroup and O group P subgroup) and (O group P subgroup and N group P subgroup) and (N group C subgroup wall and N group P subgroup) that summarized in (Table 3) Fig. 1.

### Effect of Remaining Walls

Regardless of processing technique or cementation, totally it was found that the O group recorded a statistically significant ( $p < 0.05$ ) higher marginal gap mean value ( $53.425 \pm 2.36 \mu\text{m}$ ) than the N group ( $49.39 \pm 2.026 \mu\text{m}$ ) as indicated by two-way ANOVA followed by pairwise Tukey's post-hoc tests Fig. 2.



**Fig. 1:** A column chart comparing marginal gap mean values as a function of processing technique and remaining walls ranked from higher to lower



**Fig. 2:** A column chart of total marginal gap means values as a function of the processing technique

**Table 2:** Marginal gap results (mean values  $\pm$  SDs) as a function of processing technique and remaining walls

Variable	E-max processing technique	
	CAD	Press
Remaining walls	No wall	49.31 $\pm$ 5.4
	One wall	54.85 $\pm$ 2.5
		49.47 $\pm$ 1.3
		52.00 $\pm$ 4.3

**Table 3:** Marginal gap results (mean values  $\pm$  SDs) as a function of processing technique, remaining walls, and cementation ranked from higher to lower remaining walls

	Processing technique	Mean $\pm$ SDs	p-value
One wall	CAD	54.85 $\pm$ 2.5	0.00500
	Press	52.00 $\pm$ 4.3	0.00025
No wall	Press	49.47 $\pm$ 1.3	0.00400
	CAD	49.31 $\pm$ 5.4	0.00030

## Discussion

The preservation of tooth structure is essential in successfully restoring endodontically treated teeth. The endocrown technique decreases the crown fracture which is a minimally invasive and esthetic restoration that preserves the remaining endodontically tooth structure while providing adequate strength and support to the restored tooth (Chrepa *et al.*, 2014).

Crown fractures and microleakage at the margins of restorations are more common in endodontically treated teeth than in vital teeth due to the loss of structural integrity. This is because endodontic treatment removes a significant amount of tooth structure, which weakens the tooth and makes it more susceptible to fractures and microleakage. Additionally, endodontic treatment can cause changes in the tooth's root canal system, which can lead to changes in the tooth's anatomy that further weaken it. As a result, crown fractures and microleakage are more likely to occur in endodontically treated teeth than in vital teeth (Barallat *et al.*, 2022).

The choice of premolars was due to resembling the clinical situation regarding the presence of enamel and dentin architecture and contours of pulp chambers and root canals.

It is important to note that the success of endocrown restorations depends on the proper preparation of the tooth, as well as the careful selection of materials and techniques. Premolars may undergo to microleakage or fracture (Kassis *et al.*, 2021).

This is with the agreement that the endocrown is a full coverage restoration that is designed to preserve the remaining tooth structure and provide an esthetic restoration. The endocrown is made of a ceramic material that is bonded to the remaining tooth structure. This restoration can be used to restore teeth with large restorations, fractured cusps, or teeth with extensive caries. The endocrown provides a conservative approach to restoring endodontically treated teeth and can help to improve fracture resistance (Salamoni Sinhori *et al.*, 2019).

The use of appropriate materials and techniques can help to ensure a successful outcome for endocrown restorations.

In this study the teeth independent of periodontal ligament space formation to the samples as it is not a standardized method that it may be bulky in some areas and thin in other areas, the teeth may have some mobility which affects the results also there is no evidence of differences in the resistance to fracture with or without application (Abou-Elnaga *et al.*, 2019).

The choice of remaining one wall and no wall design is considered a novel approach to endocrown, an interesting research point to be investigated, dental prosthetic treatments currently follow principles based on preserving sound tissue that requires removal of the limited amount of tooth structure, modern adhesive technologies and high strength ceramic materials with enhanced fracture toughness may

facilitate the development of minimally invasive preparation techniques (Dartora *et al.*, 2019).

The choice of 1.5 mm ferrule length follows the agreement that the teeth with 1.5 and 2 mm were found to be significantly better than the teeth with 0.5 and 1 mm ferrules in resistance to preliminary failure. The authors concluded that 1.5 mm should be the minimum ferrule length when restoring a root-filled tooth with a post and core-retained crown (Shin *et al.*, 2017).

The IPS E-max press and CAD/CAM materials are available in a wide range of shades, translucencies, and opacities to match the patient's natural dentition. The system also includes a variety of tools and accessories for the easy fabrication of endocrowns (Lise *et al.*, 2017).

Two techniques were demonstrated to produce ceramic endo crowns in many studies the single visit as IPS E-max CAD of CEREC 3D CAD/CAM technique and multiple visit techniques as IPS E-max press of pressed ceramic technique (Chaudhary *et al.*, 2016).

The milling machine was used in this study to give a more standardized preparation with the elimination of human errors and mistakes as much as possible.

In this study the use of duplicating material to make the E-max press ceramic external shape exactly like the anatomical shape of the external surface of E-max CAD ceramic fabricated by CAD/CAM for more standardization.

In this study, the application of two brushes of die spacer in the die of press subgroups was to compensate the die space in the CAD/CAM machine as the single brush equals twenty microns while the CAD subgroups die spacer has forty microns (Al-Qahtani *et al.*, 2017).

The luting cement must provide a durable bond between the tooth and restoration surfaces, while, degradation, ionic dissolution, and release of alkaline lithium and aluminum ions, which are less stable in the glassy phase than in the crystalline phases with an acceptable film thickness and viscosity to ensure complete seating, be resistant to disintegration in the oral cavity, be tissue compatible and demonstrate adequate working and set times (Mondelli *et al.*, 2019).

In this study, self-adhesive universal resin cement (Rely X Unicom) without any conditioning or pre-treatment was used. The use of self-etch is when more dentin is available for bonding while total etch is when more enamel is present so that the endocrown has more dentine exposed so the use of self-etch (Panitiwat and Salimee, 2017).

Many sealers cement used in endodontic contains eugenol, however, which has been shown to inhibit the polymerization of resins so the use of eugenol free sealers to prevent this inhibition (Gaintantzopoulou and El-Damanhoury, 2016).

It was found that press subgroups recorded a statistically non-significant marginal gap mean value with cad subgroups, the statistically non-significant marginal gap between the press and CAD subgroups was follow the agreement that the

margins were within the acceptable range. The marginal fit was neither affected by the heat press techniques NOR/CAD/CAM techniques (Dalloul *et al.*, 2016).

Also, the marginal gap was found that one wall group recorded a statistically significant higher marginal gap mean value than no wall group regardless of processing technique. The pressing techniques wax patterns are built directly on the no wall group giving the operator more control during shaping, carving, and sealing around the margins and fitting surface to reduce leakage (Grassi *et al.*, 2022).

Elalem *et al.* (2019) tested the marginal fit of E-max endocrown restorations with different preparation designs of monolithic ceramics is dependent on the type of ceramic being used. Generally, HCL will cause a lightening of color and an increase in translucency. However, some types of ceramics may be more resistant to this change than others. Additionally, the amount of HCL used and the length of time it is exposed to the ceramic can also affect the results as group 1 had a preparation with a butt joint and group 2 with a circumferential preparation and a chamfer finish line. The marginal gaps of both groups were within the clinically acceptable range, but group 1 with butt joint preparation was statistically significantly higher than group 2 with a circumferential preparation and a chamfer finish line. Meanwhile, there was no significant difference regarding the internal fit of both groups (Barallat *et al.*, 2022).

Sağlam *et al.* (2020) reported different clinical marginal gaps between CAD/CAM fabricated endocrowns the clinical marginal gaps of CAD/CAM fabricated endocrowns from feldspathic ceramic block and polymer infiltrated ceramic network block was found to be significantly different. Final ceramic surface with a smoother finish than glaze fired ceramic surfaces the results indicate that CAD/CAM fabricated any imperfections and irregularities from the surface, resulting in a smooth and glossy finish. Depending on the type of polishing method used, the final surface can be highly reflective or matte (Zimmermann *et al.*, 2019). Additionally, polishing methods can be used to create intricate designs and patterns on the ceramic surface. Endocrowns from Polymer infiltrated ceramic network blocks have a better marginal fit than those from Feldspathic ceramic blocks.

From feldspathic ceramic block and polymer infiltrated ceramic network block. CAD/CAM fabricated endocrowns are an option for the restoration of endodontically treated teeth but their use on premolars must be evaluated carefully because mesio distal furcation and right-angled occlusal anatomy between the cusps make these teeth susceptible to vertical fractures in the mesio distal direction (Haralur *et al.*, 2020).

From the limitation of this study, although the *in vitro* studies cannot represent the clinical situation of the oral

environment, however, it is considered an acceptable method for comparing between groups. For future studies, we recommend examining the fatigue resistance on ceramic endocrown restoration.

## Conclusion

Within the limitation of this study, we come to the following conclusion:

1. CAD/CAM construction technique gives a good marginal fit
2. The technique of endocrown restoration construction adversely affects the marginal adaptation
3. The remaining tooth structure of endocrown preparation has a positive role in the marginal adaptation

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## Author's Contributions

**Mohamed Ahmed Wakwak:** Participated in all experiments, coordinated the data analyzed, and contributed to the written of the manuscript.

**Karim Sherif Adly:** Methodology and result.

**Abdallah Ahmed Ahmed Abd Elhady:** Concept and discussion and reviewed of the manuscript.

**Ahmed Ramdan Elmanakhly:** Aim, methodology, data analyzed and written.

## Ethics

Authors address no ethical issues that may arise after the publication of this manuscript.

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