Section: Research Paper

EFFECT OF PREPARATION DESIGN OF PREMOLARS ON THE MARGINAL AND INTERNAL FIT OF HYBRID CERAMIC ENDOCROWNS AN IN VITRO STUDY

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ABSTRACT

Aim: This study was conducted to evaluate the marginal integrity and internal fit of hybrid ceramics in butt joint versus ferrule preparation designs of premolars with hybrid ceramic endocrown restorations.

Keywords: endocrown, conservatism, hybrid-ceramics, marginal integrity, internal fit endocrown-design, endodontically treated premolars

Methodology: Twenty sound maxillary premolars were endodontically treated and divided into 2 equal groups. Butt joint group received endocrown with butt joint finish line design. Ferrule group received endocrown with ferrule design finish line. All restorations were fabricated from hybrid resin nano-ceramic material (Cerasmart, GC Dental, USA) using 4-axis milling machine (CEREC MC XL, Sirona, Germany). Marginal gap was assessed using direct viewing under digital microscope, while internal gap was assessed using the replica technique.

Results: Marginal gap of ferrule group was (18.66 ± 5.99) µm, higher than butt joint group (17.44± 4.20) µm, with insignificant difference in all surfaces except mesial surface which was significantly higher in ferrule group (19.57 ± 4.65) µm, than butt joint group (15.54± 4.41) µm. Comparison

between both groups regarding internal fit revealed that ferrule group (109.99) µm was higher in internal gap than butt joint group (89.61) µm with insignificant difference between them in all areas except the mesial surface which was (130.57) µm in ferrule group and (98.03) µm in butt joint group. Pulpal area had significantly the highest internal gap.

Conclusion: Both designs were within the clinically acceptable range regrading both marginal integrity and internal fit

1. Introduction:

The absence of tooth structure is the most significant biomechanical alteration influencing its long-term prognosis. Endodontically treated teeth are more susceptible to fracture than vital teeth. These teeth are traditionally restored with full coverage crowns, which are typically built on a core that is attached to the root via post. The need for deep anchoring with a long fiber post, has increased risk of root perforation and root fracture associated with post placement.**(**22**)**

With recent innovations of ceramic materials (glass and hybrid ceramics) and bonding protocols, endocrown restorations have grown in popularity as a reliable alternative to traditional treatment modalities of endodonticaly treated teeth due to their advantages of improved aesthetics, mechanical performance, and more tooth structure preservation.(13)

Hybrid ceramics were developed as an attempt to close the gap between the versatility of composite resins and the durability and esthetic of ceramic materials.The unique composition of resin nano-ceramic allows the material to have a modulus of elasticity (12.8 GPa) similar to that of dentine. Resin nano-ceramic restorations show less crack propagations and provide better fracture resistance than some of CAD/CAM ceramics.(10,21)

In addition to their resiliency, hybrid ceramics demonstrated significantly higher flexural strength, as well as lower flexural modulus values, when compared to other glass ceramics as well as, having visibly smoother margins.(6)

The marginal integrity and internal fit are two of the most important parameters concerning the longevity and durability of any restoration affecting the clinical outcome. Poor marginal and internal fit exposes the cement content to the oral environment leading to cement dissolution, stimulating caries initiation and causing damage to an essential pulp and paradental structures resulting in restoration failure.[5,13]

Past studies revealed satisfactory results regarding marginal integrity and internal fit in different endocrown ceramic materials, but few studies were performed to test hybrid ceramic endcrowns. Consequently, this study aimed to evaluate the effect of preparation design of hybrid ceramic endocrown on the marginal integrity and internal fit of premolars.

2. Null Hypothesis:

1. There is no difference in the marginal integrity of hybrid ceramic (Cerasmart) endocrown restorations of premolars between ferrule and butt joint preparation designs
2. There is no difference in the internal fit of hybrid ceramic (Cerasmart) endocrown restorations of premolars between ferrule and butt joint preparation designs.

3. Methodology:

This study was designed to evaluate the marginal integrity and internal fit of hybrid ceramic endocrowns with ferrule design compared to butt joint design on endodontically treated premolars

Teeth selection, disinfection and storage

This study included twenty caries-free freshly extracted human maxillary premolars. Teeth were selected with a length of 12 ±1 mm. buccolingual dimension 7 +/- 1 mm and the mesiodistal dimension 5 +/- 1 mm. Measurements were done using a caliper (Durmiri caliper, Cairo, Egypt).

The selected teeth were disinfected by immersion in a 5 % sodium hypochlorite solution for 15 minutes at room temperature, followed by cleaning with an ultrasonic scaler.[14,20,26]

Endodontic treatment and Teeth mounting

The access cavity of the teeth was performed with a round bur followed by an ENDO-Z bur using high speed hand piece. The working length was determined, then the canals were cleaned and

shaped using rotary system Protaper (DENTSPLY Maillefer, Switzerland). Sodium hypochlorite 5% was used for irrigation. Canals were then dried with paper points and matched tapered single cone obturation technique was used. Excess gutta percha was removed by a heated instrument and the coronal parts were vertically compacted with a plugger, followed by injecting and curing a layer of

flowable composite (Nexocomp flow,flowable composite,Metabiomed, korea) to seal the canal orifices. (14)

All teeth were mounted in epoxy resin by the aid of a customized sample holder in a vertical direction using centralizing device. A special container was filled with epoxy (Kempoxy, epoxy resin, Egypt) then each tooth was embedded in the epoxy blocks up to 2mm below the cement-enamel junction to simulate the bone level and were held in position till complete resin polymerization.(14)

Grouping of the samples

Teeth were divided randomly into 2 main groups 10 samples each according to the design of restoration used. Group (**B**): Endodontically treated teeth restored with hybrid ceramic (CERASMART) endocrowns with butt joint design finish line. Group (**F**): Endodontically treated teeth restored with ferrule design finish line.

Preparation of teeth

The proximal surfaces of the teeth were marked at 2mm above the cemento-enamel junction and decapitation was done using a diamond disc (Frios MicroSaw Diamond Discs, DENTSPLY Maillefer, Switzerland) under water coolant.

Endocrowns preparation of group B:

After decapitation, the preparation was standardized such that the pulp chamber was 3 mm in depth. Axial walls were prepared with 10^{o} divergence adjusted with the angle of 10^{0} taper stone mounted on straight hand piece. All internal line angles were smoothened and rounded (fig.1). (11)

Endocrowns preparation Group F:

Group F were prepared the same as group B then a ferrule finish design have been prepared. Preparations of teeth were adjusted to prepare the teeth with 2mm circumferential ferrule axial wall heights and with 10^{o} axial convergence (Intensiv SA, Switzerland). All axial walls had circumferential shoulder finish line 1mm wide with rounded internal line angle (fig.2).

Figure (1): Butt joint preparation

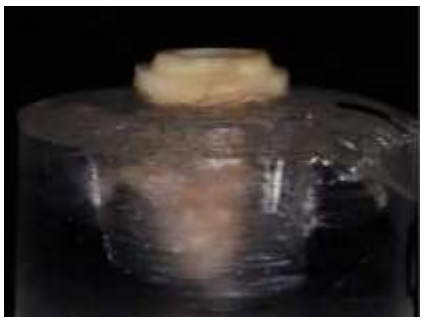

Figure (2): Ferrule preparation

Construction of Hybrid Ceramic CAD/CAM Endocrowns

Marks were made on the epoxy resin blocks corresponding to buccal and mesial surfaces of the premolars by a high-speed stone under water coolant to facilitate the recognition of these surfaces during scanning (fig.3).

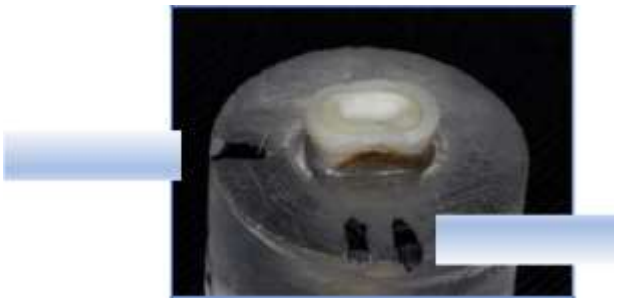

Figure (3): Marks on the epoxy

A Cerec Primescan scanner (Sirona Dental System, Germany) was used to obtain a 3D image of each prepared tooth on the Cerec CAD/CAM software (version 5.1) system. With the aid of Cerec software, the prepared scanned teeth were correlated to a virtual endocrown restoration with 5.5mm

buccal cusp and 5mm lingual cusp height for standardization of the tooth form and die-spacer thickness of endocrown was set at (80 μm) (fig 4,5).[9]

All endocrowns were produced by wet grinding using 4-axis milling machine (CEREC MC XL)

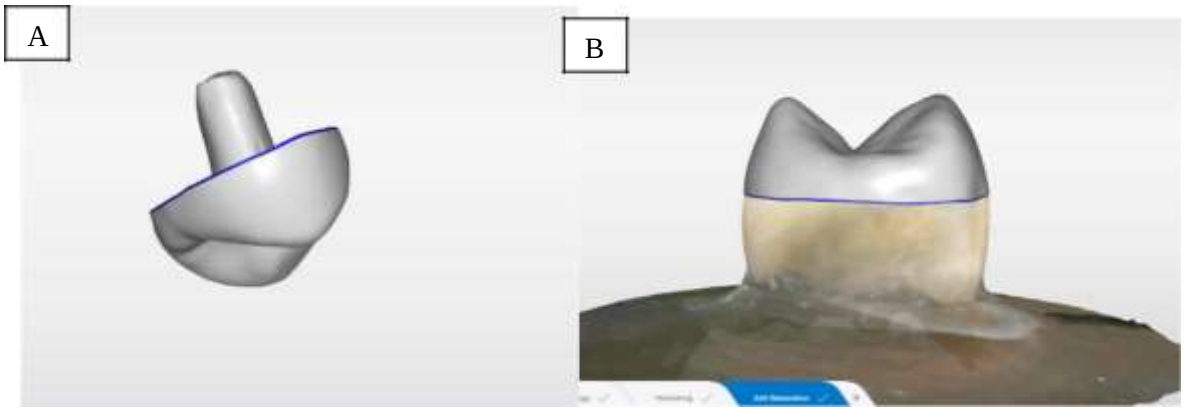

Figure (4): Virtual model for endocrown restoration of a butt joint

A: Fitting surface, B: Side view

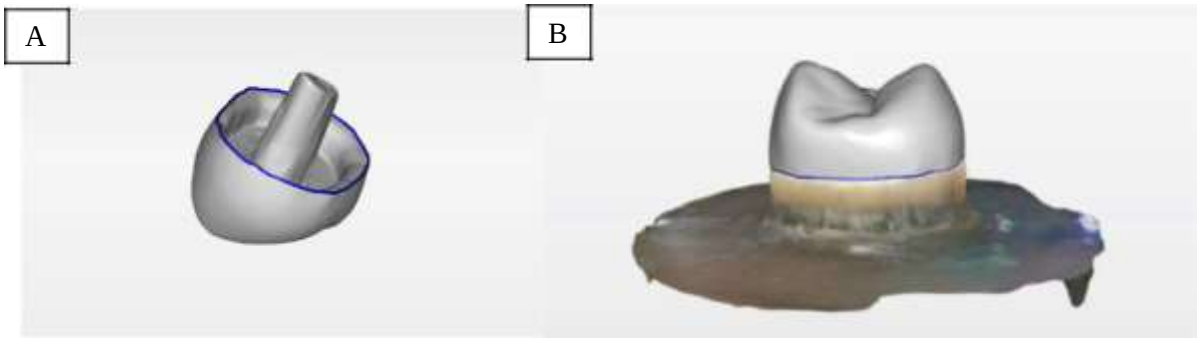

Figure (5): Virtual model for endocrown restoration of ferrule

A: Fitting surface, B: Side view

Finishing and polishing

Finishing and polishing was done using silicone finishing points in addition to diapolisher paste (Diapolisher paste, GC America, Tokyo, Japan). The paste was applied with Robinson brush (Robinson brush, Keystone ind., USA.) on a low speed hand piece as recommended by the manufacturer. uster The lappeared immediately as the restorations were being polished.

Vertical marginal gap measurment

Each tooth was photographed using USB Digital microscope with a built-in camera . The photos were captured at their highest resolution (2272 x 1704 pixels) and connected to an IBM compatible personal computer at a fixed magnification of 40X. The gap was measured and evaluated using digital image analysis system. A specially manufactured holding device was used to keep the teeth in place while photography.

Each tooth had its margins photographed. Then, for each image, morphometric measures were taken [5 equidistant landmarks throughout the circumference for each surface, for a total of 20 points]. (Fig.6).[16]

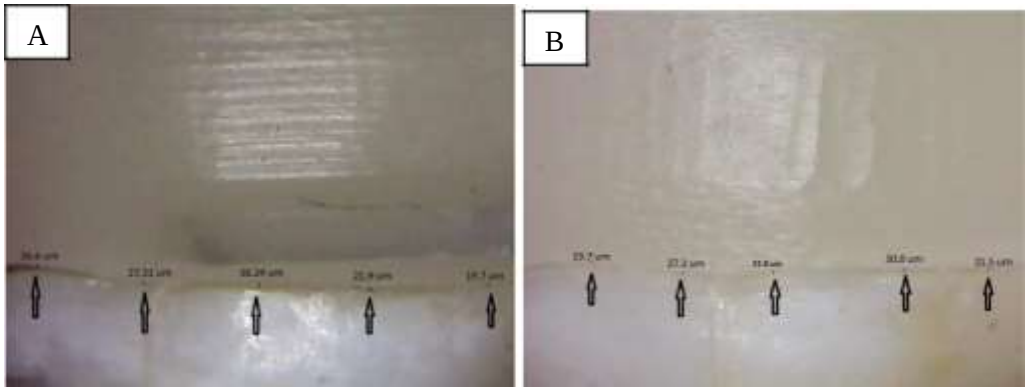

Figure (6): Marginal gap evaluation at 5 equidistant points. A: Butt joint. B: Ferrule.

Internal fit measurement

Internal fit was measured using the replica technique. A thin layer of light-body addition silicone (Elite HD +, addition silicone (light),Zhermack, Italy.) was applied to the tooth preparation, and the endocrown was placed under a load of 50 N using the holding device. The endocrown was removed once the impression material had been set, leaving a thin film of silicone adhering to the preparation, reflecting the space between the endocrown and the tooth cavity.

For the purpose of stabilization, a heavy body material (Elite HD +, addition silicone (putty),Zhermack, Italy.) was placed in the space previously occupied by the endocrown, which adhered

to the light-body film. With this procedure, it was possible to remove the replica of the light-body material. The replica was then cut mesio-distally.

The measurements were performed using digital microscope. The average cement thickness of the pulpal, external margin and axial walls of each tooth (seven points per tooth) was used in the statistical analysis (Fig. 7**)**.[7]

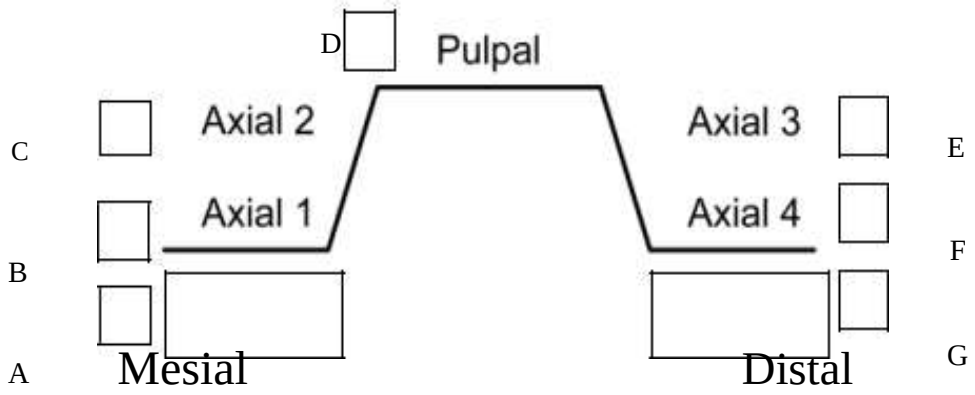

Figure (7): Diagram showing seven points on each replica that were measured A: Mesial. B: Axial 1, C: Axial 2, D: Pulpal; E: Axial 3, F: Axial 4, G: Distal.

4. Results

The collected data were statistically analyzed using SPSS 20®, Graph Pad Prism® and Microsoft Excel 2016. All quantitative data were explored for normality by using Shapiro Wilk Normality test and presented as means and standard deviation (SD) values.

Marginal integrity:

1. **Group B (Butt joint):**

Means ± standard deviation of marginal gap for each surface was as follows: buccal (19.42± 5.09) µm, distal surface was (16.06± 3.47) µm, lingual surface was (18.73±3.82) µm, mesial surface was (15.54± 4.41) µm, while in overall was (17.44± 4.20) µm.

Comparison between different surfaces was performed by using One Way ANOVA test which revealed insignificant difference between them as $P > 0.05$, followed by Tukey`s Post Hoc test for

multiple comparisons which revealed insignificant difference between all surfaces.

2. **Group F (Ferrule):**

Mean ± standard deviation of marginal gap for each surface was as follows: buccal (17.51 ± 3.72) µm, distal surface was (17.44 ± 7.03) µm, lingual surface was (20.13 ±8.58) µm, mesial surface was (19.57 ± 4.65) µm, while in overall was (18.66 ± 5.99) µm.

Comparison between different surfaces was performed by using One Way ANOVA test which revealed insignificant difference between them as P > 0.05, followed by Tukey`s Post Hoc test for multiple comparisons which revealed insignificant difference between all surfaces.

3. **Comparison between Group F & B:**

Comparison between both groups was performed by using Independent t-test which revealed insignificant difference in all surfaces as P > 0.05 except mesial surface as group F (19.57 ± 4.65) µm was significantly higher than group B (15.54 ± 4.41) µm as P < 0.05, as presented in table (1) and (fig.8).

Table (1): Comparison between Group F & B regarding buccal, distal, lingual, mesial & overall

	Marginal integrity				
Side	Group F (Ferrule)		Group B (Butt joint)		P value
	M µm	SD µm	M µm	SD µm	
Buccal	17.51	3.72	19.42	5.09	0.35
Distal	17.44	7.03	16.06	3.47	0.58
Lingual	20.13	8.58	18.73	3.82	0.64
Mesial	19.57	4.65	15.54	4.41	0.05*
Overall	18.66	5.99	17.44	4.20	0.61

M: mean SD: standard deviation

P: probability level which is significant at P ≤ 0.05

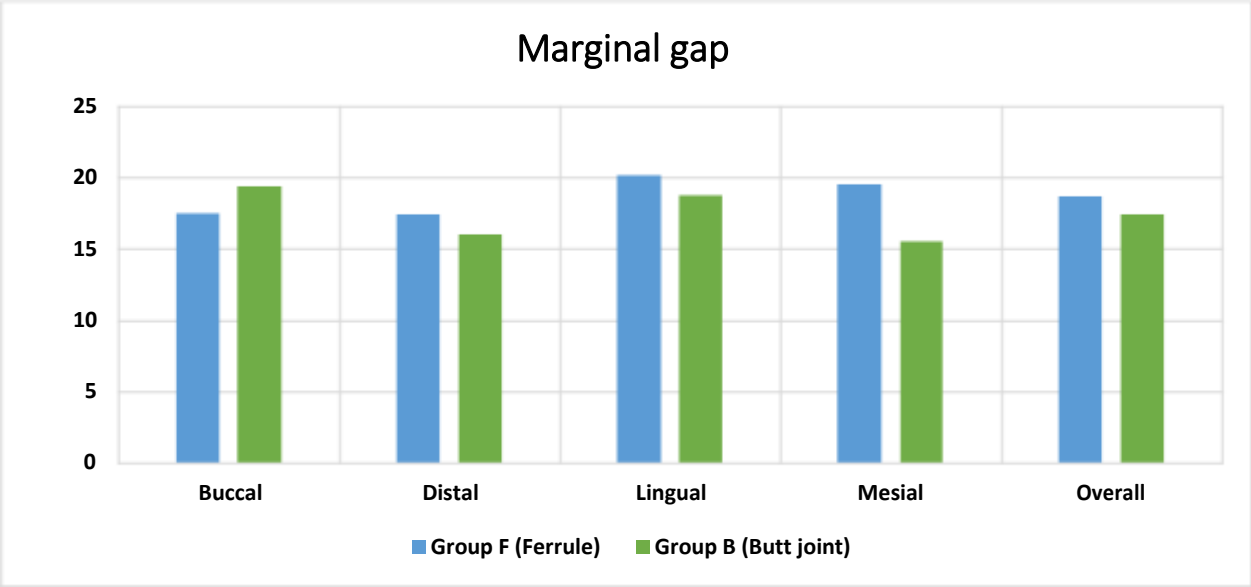

Figure (8): Column chart showing Comparison between Group F & B regarding marginal gap.

Internal fit:

1. Group B (Butt joint):

Comparison between different areas was performed by using One Way ANOVA test which revealed significant difference between all areas as $P < 0.05$, followed by Tukey`s Post Hoc test which revealed significant difference in means with different superscript letters as $P < 0.05$ while revealed insignificant difference in means with the same superscript letters as $P > 0.05$.

- Pulpal was significantly the highest internal gap, followed by axial 2, mesial, axial 1 with insignificant difference between them followed by axial 3, axial 4 with insignificant difference between them.
- Distal was significantly the lowest internal gap.

Table (2): Mean ± standard deviation of internal fit in group B (Butt joint) regarding mesial, axial1, axial2, pulpal, axial3, axial 4, distal and overall:

	Group B		
	M µm	SD µm	P value
Mesial	98.03 ^{ac}	21.91	0.0003*
Axial1	95.28 ^{ab}	23.39	
Axial2	100.68 ^{ac}	28.43	

Pulpal	116.08 [a]	44.61	
Axial3	91.43 [ac]	29.14	
Axial4	68.77 [c]	23.63	
Distal	56.99 [b]	20.93	
Overall	89.61	20.12	

- M: mean SD: standard deviation
- P: probability level which is significant at $P \leq 0.05$
- Counts with the same superscript letters were insignificantly different as $P > 0.05$
- Counts with different superscript letters were significantly different as $P < .05$

2. Group F (Ferrule):

In internal fit of group F, comparison between different areas was performed by using One Way ANOVA test which revealed significant difference between all areas as $P < 0.05$, followed by Tukey`s Post Hoc test which revealed significant difference in means with different superscript letters as $P < 0.05$ while revealed insignificant difference in means with the same superscript letters as $P > 0.05$

- Pulpal was significantly the highest internal gap followed by mesial.
- There was insignificant difference between axial1, axial2, pulpal, axial3 and axial4.
- Distal was significantly the lowest internal gap.

Table (3): Mean ± standard deviation of internal fit in Group F (Ferrule) regarding mesial, axial1, axial2, pulpal, axial3, axial 4, distal and overall:

Group F (Ferrule)			
	M µm	SD µm	P value
Mesial	130.57 [a]	28.46	0.002*
Axial1	110.98 [ab]	24.61	
Axial2	106.09 [ab]	40.50	
Pulpal	147.41 [a]	56.30	
Axial3	114.83 [ab]	48.04	
Axial4	95.97 [ab]	58.16	
Distal	64.08 [b]	23.28	
Overall	109.99	26.36	

- M: mean SD: standard deviation
- P: probability level which is significant at $P \leq 0.05$
- Counts with the same superscript letters were insignificantly different as $P > 0.05$
- Counts with different superscript letters were significantly different as $P < .005$

3. Comparison between Group F & B:

Comparison between group F & B was performed by using Independent t-test which revealed insignificant difference between them in all areas as P> 0.05, except mesial as group F(130.57 ± 28.46) µm was significantly higher than group B (98.03 ± 21.91) µm as P < 0.05, as presented in (fig. 9).

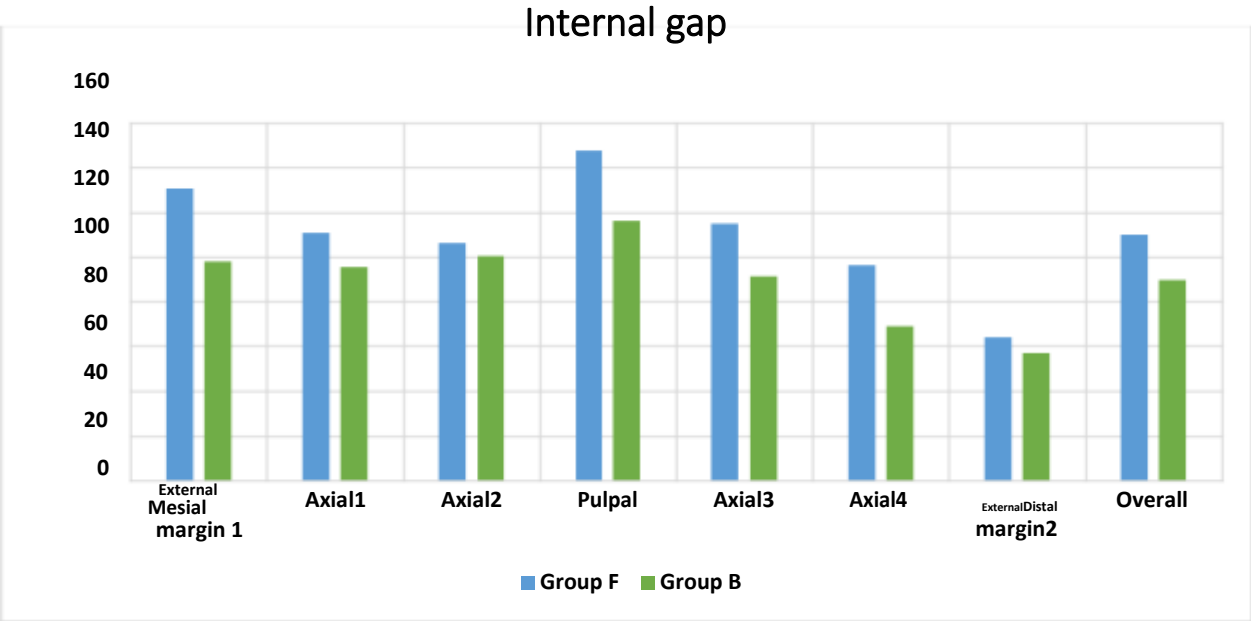

Figure (9): Column chart showing Comparison regarding internal gap between Group F (Ferrule) and group B (butt joint).

5. Discussion

Endocrowns have been identified as more conservative treatment option for restoring endodontically treated teeth.[(4)]

Endocrowns are very successful in molars while in premolars they are still questionable due to the reduced surface area of adhesive bonding compared to molars. Moreover, premolars present higher leverage than molars, due to their higher cuspal height and deep occlusal fissures owing to this fact, we chose hybrid ceramic material (Cerasmart). It has been observed that hybrid materials are

less brittle and more flexible than standard ceramics. Their elastic modulus is identical to dentine, allowing stress absorption and improving restorative system reliability. (12,25)

It has also been found that hybrid resin ceramics are materials that combine the advantages of ceramics and composites. They can be manipulated in a single step, unlike certain partially sintered CAD/CAM materials, which require extra firing cycle. This results in final restoration with greater dimensional accuracy. It also guards against excessive wear on the opposing teeth as well as its superior edge stability.(4,6)

Decapitation of the stored teeth 2mm coronal to the CEJ was done by one operator to imitate the compromised position of highly damaged endodontically treated teeth. (24)

The preparation of endocrowns in all teeth followed the principle of minimally invasive preparation by anchoring the inner portion of the pulp chamber for retention and stability, a pulpal depth of 3mm was performed along with width and height of 2mm, preserving the remaining tooth structure and standardizing the preparation.(13)

Axial divergence was selected to be 10 degrees per wall following **Hajimahmoudi et al., 2021(17)** who evaluated different cavity taper (5 and 10 degrees) of endocrown restorations and concluded that endocrowns with a 10 degree taper adapted better, with reduced frictional interferences and were easily scanned and milled.

The butt joint design was selected as it is the gold standard of endocrown preparation, offering a band of peripheral enamel that aids in bonding and resisting compressive forces by preparing the occlusal surface parallel to the occlusal plane to ensure stress resistance along the major axis of the tooth.(12)

Ferrule preparation design on the other hand introduced the benefit of increasing the available surface area for bonding, minimizing bonding failures associated with premolar endocrowns, increasing retention and stability. This design also would decrease the overall cement thickness with subsequent reduction in polymerization shrinkage, increasing the fracture resistance of ferrule design compared to butt joint design. Moreover, the addition of short axial walls with shoulder finish line

would result in resisting the shear stresses through the walls and better load distribution through the margin.[4,12,25]

Optical impressions are a viable alternative to traditional impression techniques. The benefits include precise models, simplifying the traditional procedures, the ability to create and update a database of the samples for future interventions, the ability to simulate interventions, clean impression procedures, and reduction of the operative time, thus eliminating manual errors. [1]

In the current study, for the aim of simulating the procedure of production of chair-side restorations, each prepared premolar was scanned by intra-oral scanner (prime scan, Sirona) followed by designing of endocrowns with the aid of Cerec software. A prime scan CAD/CAM scanner has the advantage that it doesn't need a reflective medium to scan. Reflective medium could alter the cement space later specified tampering the results of the internal fit. Also, it has high depth of field.[19]

The cement space employed in this investigation was 80 µm to ensure a good marginal seal and to allow the restoration to be seated more accurately. According to **AL-Zomur et al., 2021[5]**, reducing the cement space less than 40 µm would raise the seating forces. On the other hand increasing the cement space would decrease the fracture resistance of the restoration and increase cement shrinkage. As a result, they recommended the cement thickness of endocrown to be 80-100 µm.[7,8,18]

Finally, the restoration was fabricated from hybrid ceramic material (Cerasmart) by CAD/CAM (CEREC MC XL) milling machine. CEREC MC XL is a 4-axis milling machine that has the advantage of moving linearly up and down through X, Y, and Z axes as well as block rotation around the X-axis, milling sharp angles and under cuts and increased accuracy.[2]

An ideal fit promotes periodontal health and prevents cement dissolution. A poor fit, on the other hand, has a negative impact on the periodontium, making long-term oral health maintenance difficult. For these reasons the objective of our study was to evaluate the marginal integrity and internal fit of endocrowns.[18]

Direct viewing using a digital microscope was used to evaluate the marginal fit. The technique measures the outer distance between the endocrown and the preparation margin. This approach has

the advantage of not being invasive as it does not require any sectioning before measuring the gap, making it less expensive and less time consuming than other techniques and decreasing the possibility of error accumulation that may occur as a result of numerous procedures and ultimately impair the accuracy of results.[25]

In group B (Butt) the mean standard deviation of marginal integrity was (19.42 µm ± 5.09) in the buccal surface, (16.06 µm ± 3.47) in the distal surface, (18.73 µm ±3.82) in the lingual surface, (15.54 µm ± 4.41) in the mesial surface, while in overall was (17.44 µm ± 4.20)**.**

In group F (Ferrule), the mean standard deviation of marginal integrity was (17.51 µm ± 3.72) in the buccal surface, (17.44 µm ± 7.03) in the distal surface, (20.13 µm ±8.58) in the lingual surface, (19.57 µm ± 4.65) in the mesial surface, while in overall was (18.66 µm ± 5.99)

Ferrule group recorded insignificantly higher marginal gap compared to butt joint group in all surfaces, except mesial surface as group F was significantly higher than group B. So, the first null hypothesis was partially accepted.

Both designs fell within the clinically acceptable range of marginal fit. Since it was claimed that marginal disparities less than 100 µm were clinically acceptable.[13]

Better marginal integrity of butt group was explained by **Taha et al., 2018[25]** who noted that the type and curvature of the finish line are elements that may affect the vertical marginal gap. The butt joint margin design provides a configuration with little complexity or narrow margins, which contributed to good endocrown seating while avoiding vertical marginal gaps.

The most closely linked characteristic to a restoration's lifetime is its fitting accuracy. Furthermore, an excellent internal fit improves prosthesis retention and fracture resistance. The silicone replica approach was used in our study as it is considered simple, dependable, non-invasive, and non-destructive.[5]

The second hypothesis was also partially accepted. Comparison between both groups regarding the internal fit revealed insignificant difference between them in all areas, except mesial as ferrule group was significantly higher than butt joint group and comparison between surfaces within the same group showed that pulpal surface was significantly the highest internal gap.

Both designs' results were accepted regarding the internal fit according to **Elghoul et al., 2020[(11)]** who stated that the accepted internal gap of endocrowns ranges between 75-160 μm.

Insignificant difference in the internal gap values could be anticipated to the uniformity and standardization of the pulpal depth, the axial cavity wall divergence, and the cement space utilized.[(13)]

Regarding the mesial surface that was significantly higher in both marginal and internal gap in ferrule group. This could be attributed to the distal shadow phenomenon when an illuminated object casts a shadow away from the scanner (cerec camera) at a specified angle with respect to the recording axis. The tooth structure is reversed with an endocrown, therefore this shadow only manifests on the mesial cavity surface. This could theoretically result in the mesial shadow phenomena.[(23)]

The increased pulpal internal gap in both groups might be attributed to the silicone replica material thickness at the pulpal site which was the highest, that was subjected to higher distortion during setting.[(13)] This was in consistent with the findings of **Gaintantzopoulouthat and Damanhoury, 2016[(15)]**, who concluded that internal gap values of endocrowns increased significantly on the axial and pulpal walls. Also, **Zimmermann et al., 2018[(27)]** determined that, due to the size of milling equipment, flat surfaces such as pulpal areas for endocrowns may be over-milled. As well as the presence of hydrostatic pressure within the restoration which accumulates the replica material at the pulpal floor of the prepared tooth.[(3)]

Within the limitations of the present study the following conclusions could be drawn:

- Both designs fell within the clinically acceptable ranges of marginal and internal gap.
- Mesial surface of endocrown prepration in both groups had the highest marginal and internal gap.
- Pulpal area had the highest internal gap in both groups compared to other measured areas.

RECOMMENDATIONS

- Further studies are needed to calculate the absolute marginal gap and compare between different cement spaces as altering spacer thickness, may have an impact on internal fit.

- Clinical recommendations: Conducting the same study in clinical trials could give further information about the clinical behavior of endocrowns.

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Data availability statement: not applicable

Conflict of interest: the authors declare no conflict of interest

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