THE EFFICACY OF HYBRID-CERAMIC ENDOCROWN DESIGN ON PREMOLARS IN TERMS OF RETENTION: AN IN-VITRO STUDY

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Abstract

Aim: The purpose of this study is to evaluate the efficacy of hybrid-ceramic endocrown design on premolars in terms of retention

Keywords: endocrown, conservatism, ceramics, hybrid-ceramics, retention, endocrown-design, endodontically treated premolars

Methodology: Twenty-four sound maxillary premolars were endodontically treated. Group (B) received endocrown, with butt joint finish line fabricated from (CERASMART, GC Dental, USA). Group (F) received endocrown, with ferrule finish line fabricated from (CERASMART, GC Dental, USA). All restorations were fabricated using (CEREC MC XL SW 5.0) and cemented using self-adhesive dual cure resin cement (DUO-LINK UNIVERSAL, Bisco Inc, Schaumburg, IL, USA). All samples were subjected to thermocycling. To test the retention, a universal testing machine was used, the endocrowns were pulled out along the path of insertion by double orthodontic wire loops through lateral projections made during designing and production of the restorations. The forces required for dislodgment of the crowns were recorded in Newtons.

Results: Retention test showed that endocrown with ferrule design have statistically significant higher values of retention than endocrown with butt-joint design

Conclusion: All obtained retention values lie within the clinically accepted ranges. Endocrown with 2 mm ferrule has superior retention than those without ferrule (butt joint) on premolars.

1. Introduction

Endodontically treated premolars could be restored using various methods, including direct and indirect restorations, with indirect full-coverage methods being preferred by many clinicians. Post and core procedures could also be required in situations involving severe loss of coronal hard tissue, but may decrease tooth fracture resistance as a result of the additional required dentin removal while also increasing root perforation risk. The endocrown is described as a full coverage restoration with a circumferential butt-joint margin and a central retentive feature that extends into the pulp chamber space. Several studies suggest a 3 mm central retentive feature to afford the optimal retention and resistance features. (1,2)

Hybrid ceramic CAD/CAM milling blocks have been introduced for the fabrication of fixed restorations instead of glass ceramic blocks. From a biomimetic perspective, these less brittle hybrid ceramic CAD/CAM blocks have mechanical properties that are approximately close to those of human dentin. Some in vitro studies reported a higher fracture resistance and more favorable fracture mode of hybrid ceramics in molars, in this way they were also suggested to have great potential for endocrown restorations. (3)

The addition of ferrule features to the endocrown preparation for maxillary premolars has not been thoroughly investigated. Most of the failures associated with endocrown restorations on premolars are due to fracture and de-bonding. Achieving a ferrule design in restoring endodontically treated premolars with endocrown restorations to gain better retention form, is still a matter of question. The aim of this study was to determine the effect of incorporation of ferrule features to the endocrown preparation on hybrid ceramic endocrown restoration retention.

2. Materials & method:

This study was designed to evaluate the retention of Cerasmart endocrowns with ferrule design compared to control group Cerasmart endocrowns with butt design on endodontically treated premolars

Teeth selection, disinfection and storage

Twenty-four caries free recently extracted human maxillary premolars were selected for this study. To standardize procedures and materials, all teeth used in this study had two root canals with a curvature of less than 5°, a length of 19 ±1 mm. Specimens ranged 7 +/- 2 mm in size, measured at the widest buccolingual dimension while the mesiodistal dimension ranged 5 +/- 2 mm. The selected teeth were disinfected by immersion in 5% sodium hypochlorite solution for 15 minutes followed by cleaning using an ultrasonic scaler. The teeth were then kept hydrated at room temperature in saline solution.

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). NaClO 5% was used for irrigation. Canals were then dried with paper points and matched tapered single cone obturation technique was used. A heated instrument was used to remove the excess gutta purcha and the coronal parts were vertically compacted with a plunger.

All teeth were mounted in epoxy resin blocks by the aid of a custom-made round Teflon shape sample holder in a vertical direction using centralizing device. The teeth were 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 of the resin. (4)

For the scanning camera to recognize the buccal and mesial surfaces, marks were made on the epoxy resin blocks by a high-speed stone under water coolant.

Grouping of the samples

Teeth were divided randomly into 2 main groups (n=12) according to the design of restoration used. Group (B) Endodontically treated teeth restored with hybrid ceramic (CERASMART) endocrowns with butt joint design. Group (F) Endodontically treated teeth restored with hybrid ceramic (CERASMART) endocrowns with ferrule design.

Preparation of teeth

The crowns of the collected teeth were cut horizontally 2mm below the occlusal surface from the proximal surfaces using a diamond disc under water coolant (Figure 1).

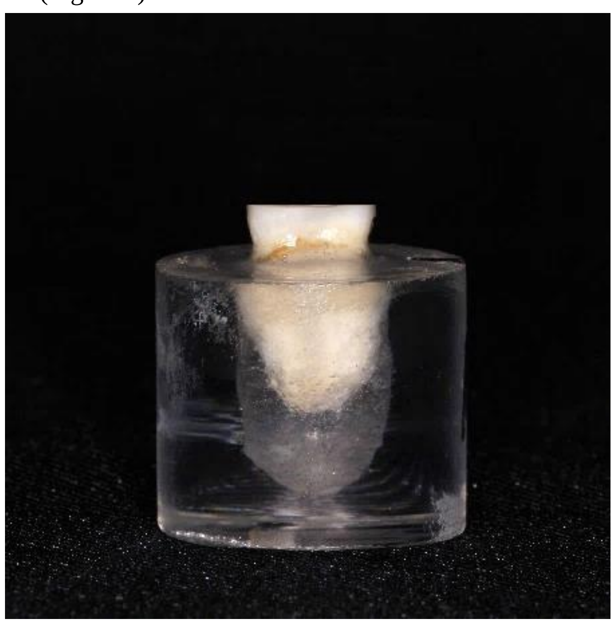


Figure (1): Tooth in epoxy following decapitation

Endocrowns preparation of group B:

After decapitation of the premolars creating a circular butt margin, the gutta percha was removed till the canal orifices. For the tooth preparation, a layer of flowable composite of 1 mm depth was injected and cured. Then the pulp chamber was measured with a periodontal probe to insure the height was 3 mm in depth. The walls of the preparation were prepared with 80 taper stone mounted on a high-speed contra to ensure an 8o divergence angle. All internal line angles were smoothed and rounded.

Endocrowns preparation Group F:

The twelve teeth of group F have been prepared as the same steps of group B then a ferrule design was prepared.

Preparations of teeth were performed using a Computerized Numerical Control milling machine. It was adjusted to prepare the teeth with 2mm circumferential ferrule axial wall heights and with 10o convergence. All axial walls had circumferential shoulder finish line 1mm wide with rounded internal line angle. The height of the prepared teeth was adjusted to be 2mm from the finished line to the occlusal surface to produce a 2mm ferrule. Pulp chamber height was maintained 3 mm in depth. All internal and external line angles were smoothed and rounded.

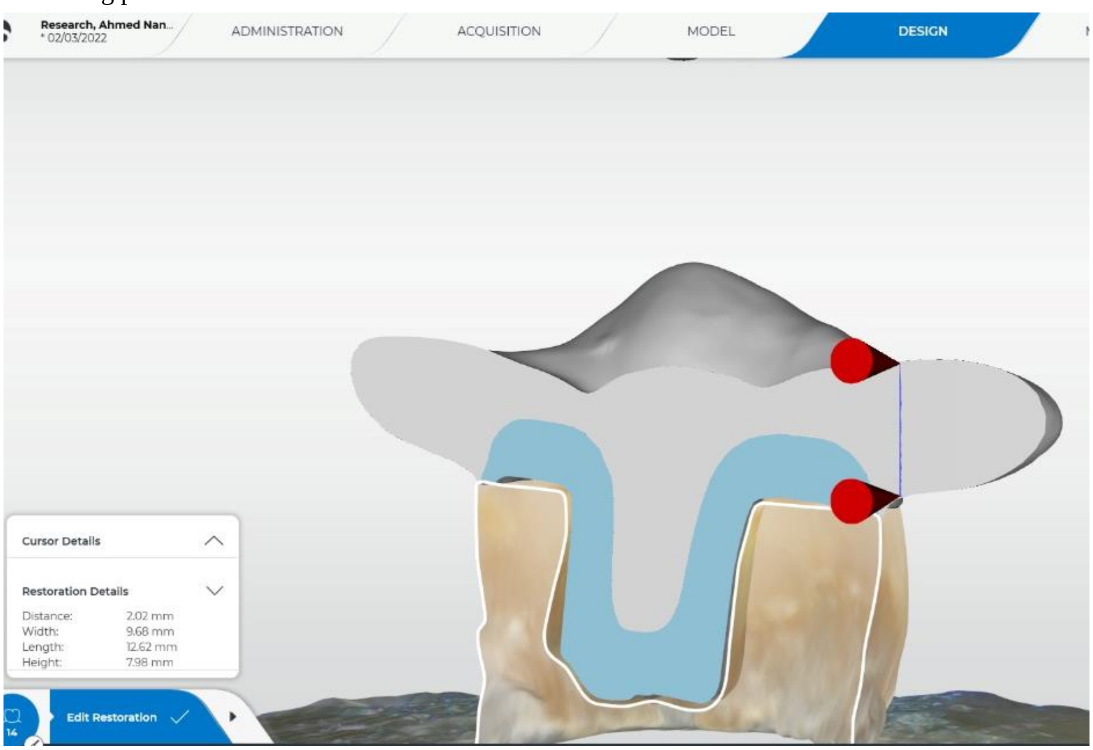
Construction of Hybrid Ceramic CAD/CAM Endocrowns

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 5.2) system. The captured picture was then saved in preparation catalogue of the software. A virtual model was calculated by the software from the scanned pictures and preparation margin detection was done by manual margin finder. 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. Die-spacer thickness of endocrown was set at (80 µm) (5)

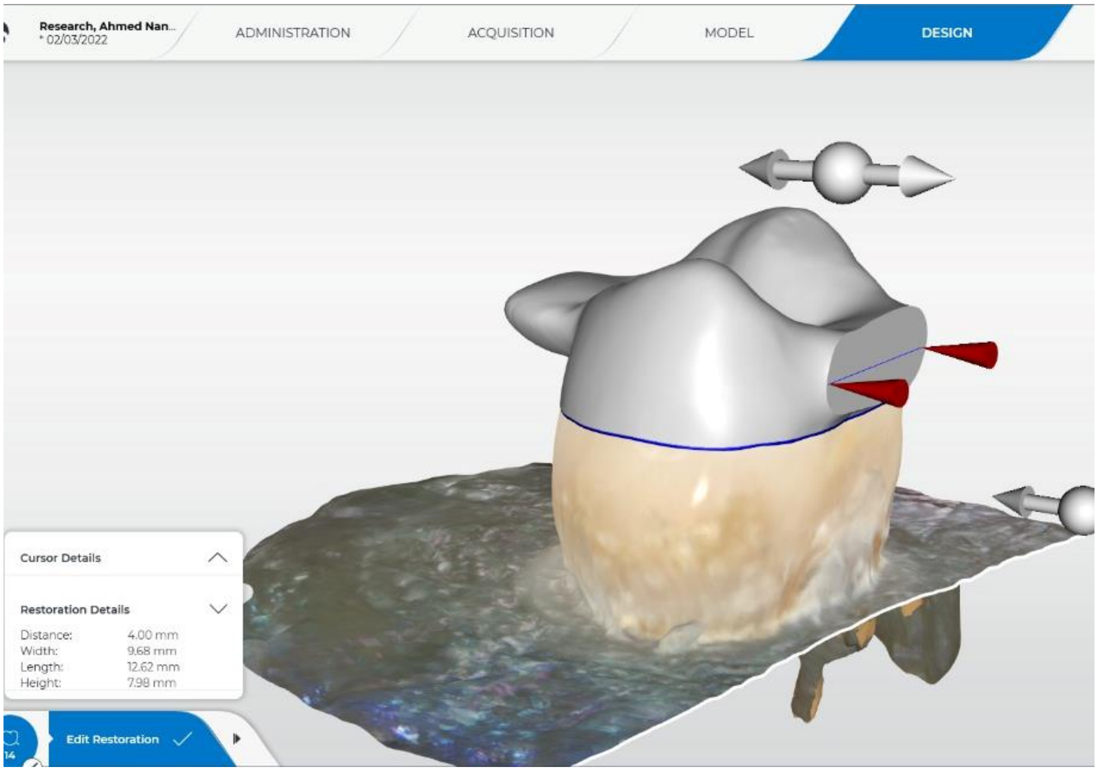
Two lateral projections made within the design to allow even distribution of pulling tensile forces while testing the retention using a universal testing machine. Dimensions of the projection was 2 ± 0.25 mm height and 4 ± 0.25 mm width (Figure 2). The dimensions and form of the first restoration in both designs were saved as a biogeneric copy for further standardization of the following restorations. (6)

A 4-axis milling machine (CEREC MC XL SW 5.0, Sirona Dental System, Germany) was used for the fabrication of all samples in this study. After completion of the milling process, restorations were separated manually with a diamond cutting instrument from the block holder. All endocrowns were placed over their corresponding teeth samples for seating verification (Figure 3).

Finishing was done using ultimate finishing and polishing kit (GC America, Tokyo, Japan) in addition to Diapolisher paste (GC America, Tokyo, Japan), which was done using low speed hand piece. The luster appeared immediately as the restorations were being polished.

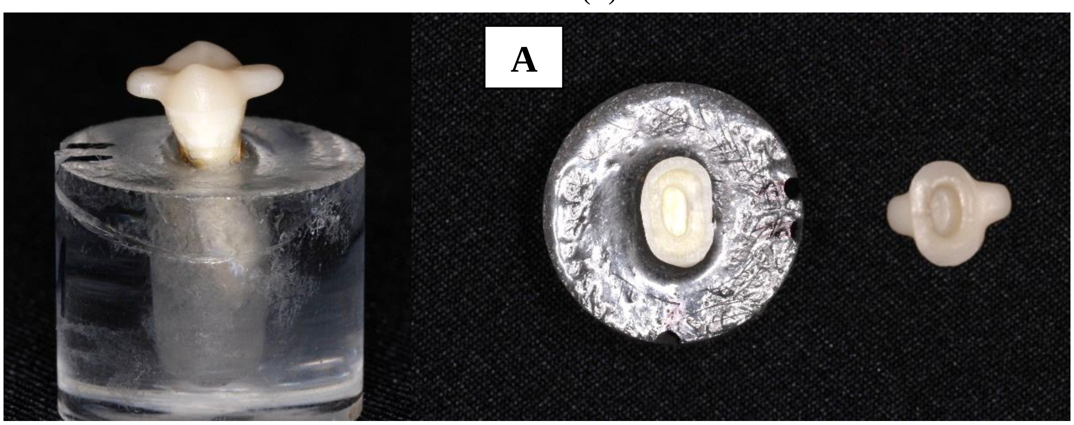


A



B

Figure (2): Virtual model of the two lateral projections included to the endocrown design. Height dimensions (A) width dimensions (B)



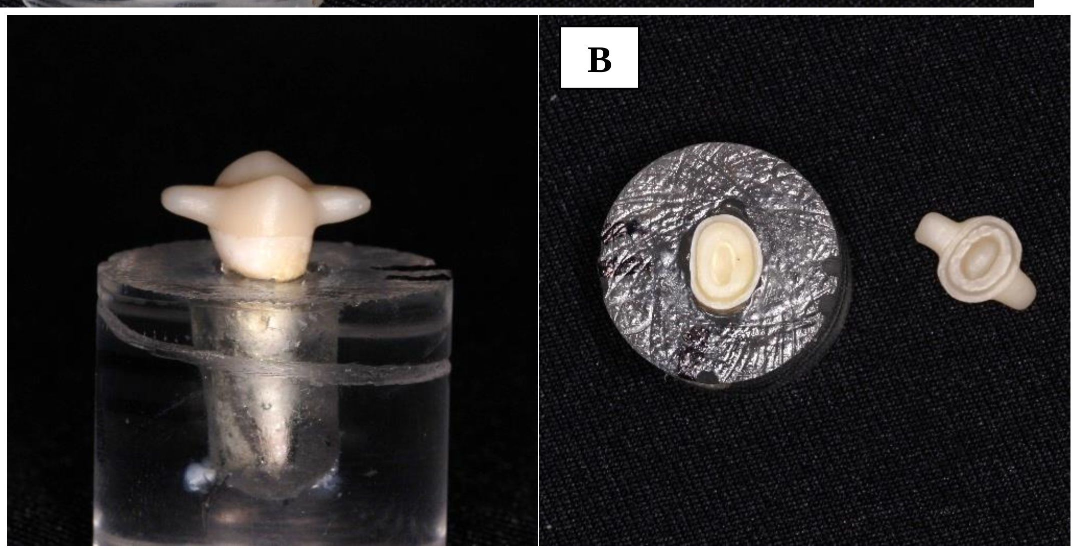


Figure (3): Cerasmart endocrown with butt joint (Group B) (A) Cerasmart endocrown with ferrule finish line (Group F) (B)

Bonding of endocrowns to premolars

Fitting surfaces of each restoration was treated following the manufacturer 's instructions. By application of 5% hydrofluoric acid, Cerasmart was etched for 60 seconds. Restorations were then rinsed for 60 seconds under air/water spray and dried for 30 seconds with moisture and oil free air. A ceramic primer containing silane coupling agent was applied to the fitting surfaces of all restorations and allowed to dry for 60 seconds. (6)

37.5% phosphoric acid etchant was applied on all teeth surfaces for 15 seconds, rinsed for 20 seconds, and dried with oil free air for 5 seconds. Two separate coats of ALL-BOND were applied on the preparations without curing in between coats. Gentle air drying was applied to dry excess solvent for 3 seconds followed by 20 seconds light curing with constant light output and intensity.

DUO-LINK UNIVERSAL dual cure resin cement was applied on the prepared surfaces using an auto mixing tip followed by seating of the endocrowns on their corresponding teeth with finger pressure. The samples were then placed in a specially designed cementation device under constant load of 3 kg to ensure standardization of cementation procedure (Figure 4).

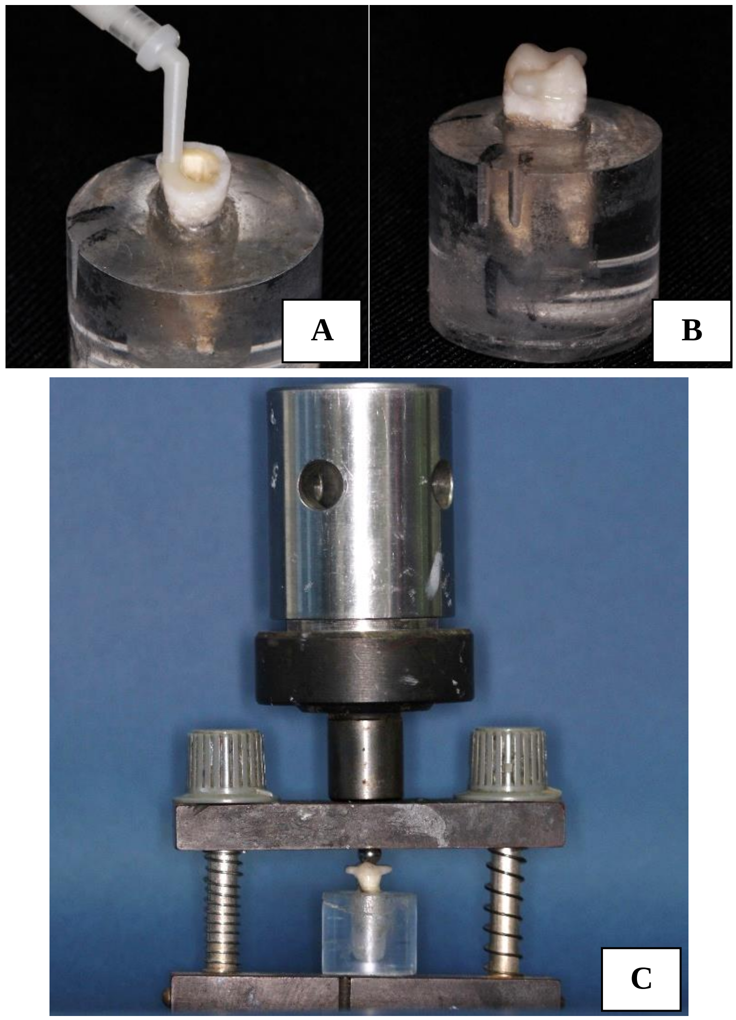


Figure (4): Dual cure resin cement application on the prepared surfaces using an auto mixing tip (A) Endocrown cementation on corresponding sample (B) Sample placement in the cementation device (C)

Thermal cycling

All samples were subjected to 2500 cycles which is nearly equivalent to 3 months clinically. Dwell times were 25 s. in each water bath with a lag time 10 s. The lowest temperature point was 5 0C), the highest temperature point was 55 0C.

Retention test

To test the retention of the specimens, a universal testing machine was used (Model 3345; Instron Industrial Products, Norwood, USA). The samples were fixed to the lower compartment of the testing machine. The crown was suspended through the upper movable compartment of the testing machine by double orthodontic wire loop (0.7 mm) through lateral projections made during milling to ensure even distribution of pulling tensile forces. The cemented crowns were pulled out along the path of insertion subjected to a slowly increasing vertical load (1mm/min) until total dislodgment of the endocrown. The forces required for dislodgment of the endocrowns were recorded in Newton. Data were recorded using computer software (Bluehill

Lite; Instron Instruments) (Figure 5).

Figure (5): Pulling out the crowns using specially designed loop in a universal Testing Machine

3. Results

The collected data were statistically analyzed using SPSS 20®, Graph Pad Prism® and Microsoft Excel 2016. All quantitative data were presented as minimum, maximum, mean and standard deviation (SD) values.

Comparison between group I (Butt) and group II (Ferrule) was performed by using Independent t-test which revealed that group II Ferrule (145.16 ± 39.46N) was significantly higher than group I Butt (99.35 ±17.84N) as $P < 0.05$, with (45.81) difference between them in Table (1) and (Figure 6)

Table (1): Comparison between group I & II regarding retention.

Independent T-test		Group I Butt	Group II Ferrule
M		99.35	145.16
SD		17.84	39.46
MD		45.81	
t		3.66	
df		22	
P value		0.001*	
SED		12.502	
95% CI	Lower	19.88	
	Upper	71.73	

*Significant difference between both groups as $P < 0.05$.

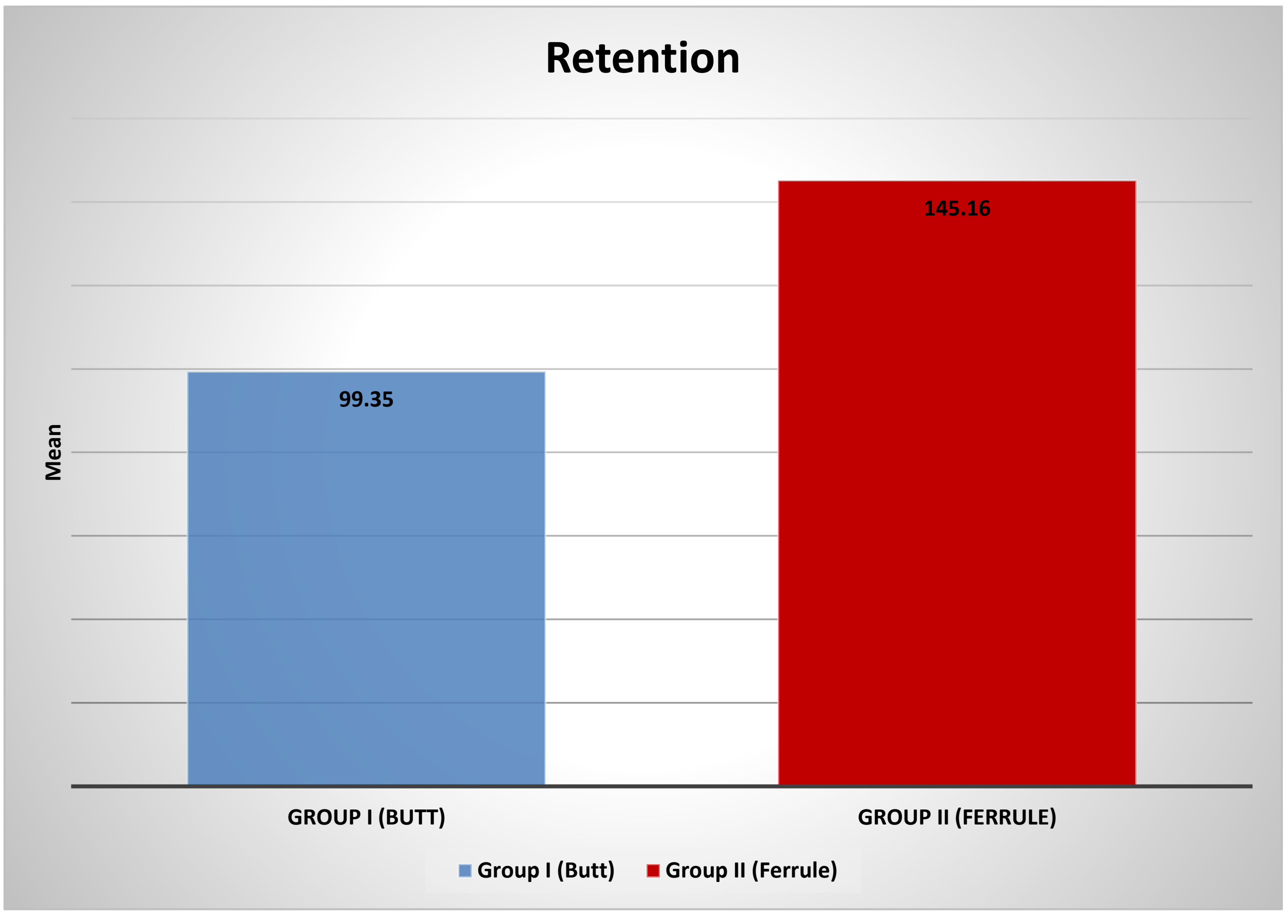


Figure (6): Bar chart showing comparison between Group I (Butt) and Group II (Ferrule) regarding retention

4. Discussion

Endodontically treated teeth with inadequate remaining tooth structure require foundation restoration to increase resistance and retention form for definitive restoration. However, the price of added resistance and retention may lead to an increased risk of damaging tooth structure. (7)

Endocrown restorations have proven to be easier on many aspects. It is simpler and faster than the traditional post, core and crown procedure and has been clinically reported to be a successful restoration. Endocrowns are also superior to conventional crowns by eliminating the need for the ferrule concept which may lead to the loss of sound enamel and dentin necessary for bonding. In addition, endocrowns need minimal tooth reduction leading to strengthening the tooth structure. This conservative treatment has been feasible due to the recent progress in adhesive systems and recent ceramic materials. (8,9)

Multiple hybrid materials have lately been introduced to the market forming a new class of CAD/CAM materials. Cerasmart is a hybrid ceramic material joined the market in 2014, it is a Nano-filled high-density composite resin containing 71% filler particles by weight. Cerasmart was selected in this study since it has particular merits such as being less brittle and more flexible when compared to conventional ceramics. In addition, it has stress absorbing properties, fewer flaws and the ability to be easily repaired and modified. The innovative composition of cerasmart makes the material close to dentin regarding the modulus of elasticity (18 +/- 2) with 220 to 240 MPa flexural strength. The stress absorption ability is owed to their high flexural strength and low modulus of elasticity. (10,11)

Human teeth were used in this study instead of bovine, metal or plastic teeth owing to their bonding characteristics, thermal conductivity, strength and modulus of elasticity that is closer to the clinical conditions. (12)

Performance of endocrowns on premolar teeth in previous studies has shown to have non-satisfactory results in comparison to molars under occlusal forces. This is owed to their smaller bonding surface which is a mandatory factor in the construction of endocrowns. (13)

Teeth were positioned inside epoxy resin blocks. Epoxy was used since its modulus of elasticity 12 GPa which is close to that of the human bone 18 GPa. Position standardization was ensured using a centralizing device which was used to insert the teeth vertically in the center of the epoxy resin block. (14)

The selected premolars were endodontically treated to simulate the clinical conditions with induced stresses. The walls of both preparations were done with 80 divergence angle since it provides better internal fit for the endocrowns. A layer of flowable composite of 1 mm thickness was injected and cured to block all undercuts. Pulp chamber height was 3 mm in depth measured with periodontal probe to improve the accuracy of the optical impression during scanning of the preparation.

For the retention test, the endocrowns were designed with exaggerated two proximal arms or wings to help in engaging the specimens during the pull-out test. (7)

After the restorations were milled, Cerasmart restoration were only finished and polished since they are hybrid composite materials and do not need further firing procedures (crystallization).

For the surface treatment of Cerasmart, hydrofluoric acid etching and silanization was agreed upon in many previous studies to be the pretreatment of choice as recommended by the manufacturer. Hydrofluoric acid etching partially dissolves the glassy phase providing undercuts on the micrometer scale for better micromechanical interlocking with the resin cement. The silica-based ceramic portion of cerasmart hybrid ceramic seems to be the main determinant for the best choice of surface treatments. (19,20)

Restorations were cemented using DUO-LINK UNIVERSAL dual cure self-adhesive resin cement since resin cements ensure micromechanical and chemical adhesion to the tooth structure. It is a dual cure resin cement that ceramic crowns are commonly luted with, as light transmission through indirect restorations is reduced, so that the chemical reaction should guarantee a satisfactory degree of conversion while as mentioned before, self-adhesive type was utilized in the present study since it saves time and decreases number of steps. It also enhances the bonding when accompanied by selective-etching technique to overcome the compromised surface area of bonding in premolars. (21)

Cementing device was used with static load of (3 kg) to ensure proper standardized cementation for all restorations. Thermal cycling was performed for all the specimens to mimic the oral conditions as they were proved to have an effect on retention of dental ceramics. In this study the number of cycles used was 2500 cycles nearly equivalent to 3 months. Dwell times were 25 s. in each water bath with a lag time 10s. The low-temperature point was 50C. The high temperature point was 550C. (4)

The results acquired in this study showed that the endocrowns with ferrule design reported statistically significant higher mean retention values than endocrowns with butt joint design. These results are probably related to the greater surface area for bonding in endocrown with 2 mm ferrule compared to endocrown without ferrule. It has been demonstrated that the increase in the surface area of resin cement coverage positively influence the retention of ceramic restorations. It may be also linked to the unique design of the endocrown with 2mm ferrule, where it utilizes the pulp chamber for macro mechanical retention provided by pulpal walls as well as micro retention attained with the use of adhesive cementation. In addition, it embraces the whole circumference of the tooth extra coronally thus providing both external and internal retention. Furthermore, the ferrule in endocrown preparations promotes the presence of four axial wall instead of none in other designs which positivity influence the retention. (17)

Another explanation may relate to stress distribution. As confirmed by Ausiello P. et al. in 2017 (18) through FEA, Tooth without ferrule showed greater stresses concentration than tooth with a ferrule. With a ferrule, stress was evenly distributed along coronal part and radicular part, without any stress concentration. Authors concluded a beneficial ferrule effect on stress distribution that affect mechanical behavior of the teeth and failure mode of restoration.

The results in this study come in agreement with Elbasty et al., in 2017(7) who conducted a similar study on molars reporting that the mean retention values of endocrowns with 1 mm ferrule was statistically significantly higher than endocrowns without ferrule. This may be explained by the fact that the available surface for adhesive bonding was larger in endocrowns with 1 mm ferrule (94 mm2) compared to endocrowns without ferrule (82 mm2).

Also, the results come in accordance with results of a study by El Ghoul et al., in 2019(16)

who compared the effect of endocrown preparation design on the retention of endodontically treated premolars prepared with or without ferrule. Their results showed that endocrowns with 1mm ferrule reported significantly higher mean retention values than without ferrule.

In addition, the results of this study were supported by Cengiz et al., in 2019(20) who found that Cerasmart has acceptable micro-tensile bond strength due to the filler matrix composition and microhardness which promotes the materials mechanical roughening that aid in the mechanical interlocking with the cement.

The null hypothesis of this study stated that there will be no difference in retention between conventional butt joint and ferrule design endocrown restorations on premolars was rejected as the results showed that there was significant difference between retention values of Group F (Cerasmart endocrowns with Ferrule design finish line) that recorded mean values of (145.16 ± 39.46)N and Group B (Cerasmart endocrowns with Butt joint design finish line) that recorded mean values of (99.35 ± 17.84)N. Therefore, using endocrown restoration with a ferrule preparation design is a promising restoration for endodontically treated maxillary premolars.

5. Limitations

1. The present study is an in-vitro study which doesn't fully simulate the clinical situation of the oral cavity.
2. Thermocycling aging only simulated 3 months in the oral cavity.
3. Other outcomes could have been measured such as marginal gap and fracture resistance.

6. CONCLUSIONS

Within the limitations of this study, these conclusions can be revealed:

1. Retention values of both designs lie within the clinically accepted ranges.
2. Endocrowns with 2 mm ferrule showed superior retention compared to those without ferrule (butt joint) on premolars.

7. RECOMMENDATIONS

- Endodontically treated premolars are better restored with endocrowns with 2 mm ferrule design rather than endocrowns without ferrule to improve their retention.
- Further clinical studies should be carried out to ascertain the results obtained in this study.
- Studies using various cementation protocols and cements with different thermocycling aging periods should be carried out to test the variations in retention.
- Further studies testing other aspects of hybrid ceramic endocrown restorations over premolars as fatigue, fracture resistance and marginal gap should be carried out.

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