IMPACT OF PREPARATION DEPTH AND LENGTH ON FRACTURE RESISTANCE OF ANTERIOR TEETH RESTORED BY ENDOCROWNS AND POST RETAINED CROWNS

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ABSTRACT

Objectives: To evaluate the effect of preparation depth (3mm deep endocrown, 6 mm deep endocrown and post retained crown) and different remaining coronal length (1mm & 2mm) of CAD/CAM fabricated restorations (zirconia reinforced lithium silicate) on fracture resistance of endodontically treated anterior teeth.

Materials & Methods: Twenty zirconia reinforced lithium silicate restorations, VITA Suprinity ceramic (VITA Zahnfabrik, Germany) were fabricated through CAD-CAM on a central incisor root. The specimens were randomly divided to divided into four Groups (n = 5 in each) Group I: CAD/CAM zirconia reinforced lithium silicate short endocrown (3mm depth) with 1mm remaining coronal length, Group II: CAD/CAM zirconia reinforced lithium silicate short endocrown (3mm depth) with 2mm remaining coronal length, Group III: CAD/CAM zirconia reinforced lithium silicate long endocrown (6mm depth) with 1mm remaining coronal length and Group IV: zirconia reinforced lithium silicate crown retained by glass fiber post (Glassix radiopaque, H Nordin, Chailly/Montyreux, Switzerland) and composite core (nano hybrid universal A3 shade Z250XT (3M ESOE Z250XT, Seefeld,Germany)with 1mm dentin collar (conventional treatment). Then, all the specimens subjected to thermocycling (Robota BILGE,Turkey) and fracture resistance test was performed by using a universal testing machine (Lloyd LRX, Lloyd Instruments, Fareham Hants, UK) at 45º angle to the long axis of the teeth. The data was statistically explored using one-way ANOVA and post-hoc Tukey tests *(P value < 0.05)*

Results: The highest mean fracture resistance value was obtained on group II (835.3±7.9 N). While, the lowest mean value of fracture resistance was obtained in group IV (286.8-295.4N). Furthermore, the fracture resistance mean value hadn't statistically significant different between all tested groups.

Conclusions: Anterior endocrown monoblock restorations with short depth (3mm) and 1mm ferrule height can be used as an unusual to post retained crown restorations.

KEYWORDS: Anterior Endocrown, Preparation Depth, CAD/CAM, Fracture Resistance.

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INTRODUCTION

Restoring endodontically treated teeth that are badly destructed has been a challenge for many clinicians over the years. The main problem in wide root canals is the need to reinforce the thin remaining dentin thickness and minimize root fracture in wide canals.

For decades, the fabrication of full coverage crowns, with or without post is the gold standard for endodontically treated teeth restoration.[1] The conservative approach plus the evolution of ceramic materials has introduced valid concepts in the restoring such teeth leaving traditional methods aside [2]

The most common traditional approach for endodontically treated teeth was restored with prefabricated or custom posts retained crown. [3,4]

With the arrival of CAD/CAM technology, endocrowns are considered treatment alternatives. [5]

The first star spark of endocrown was the placement of amalgam into the pulp chamber, which will enter 2-4 mm inside the canal as amalgam tags. The pulp chamber must have enough width and depth to donate the retention. . [6]

Following by the innovation of adhesives and the development of ceramic materials and novel technology was a changing point in the restoration of endodontically treated teeth. [7]

The innovation of Computer Aided Design/ Computer Assisted Manufacturing (CAD/CAM) and the adhesive technology allow the clinicians to restore the endodontically treated teeth with extra management options such as endocrown restoration. [8,9]

Endocrowns were described as monolithic ceramic overlays that restore the coronal part of non-vital tooth characterized by a supra-cervical butt joint, retaining maximum enamel to improve adhesion and extended inside the pulp chamber. Endocrowns were considered as a substitute to traditional endodontically treated teeth restoration. [10]

Posterior endocrowns afford higher fracture resistance [11,12] than restored with post retained crowns.[13] Ceramic endocrowns also recommended for anterior teeth. Unfortunately, the biomechanical behavior of anterior varies from posterior teeth. Anterior' endocrowns have higher length (10 mm) and lower width (7 mm) than posterior endocrown (7.5 mm length, 10 mm width at the cervix). The challenges occur in anterior endocrowns due to the bending moments on the anterior are greater than those acting on posterior. Besides, the anterior endocrowns bonding surface is twice lesser than in posterior (60 mm^2), which decline the endocrown´s retention [14]

Different designs in preparation of endocrown were occur which incorporated with ferrule or circumferential butt joint design. ***Einhorn et al.*** [15] concluded that ferrule design increased the dentin surface available for bonding.

On the other hand, butt joint design was better than ferrule design endocrowns on the force distribution and brought the ceramic in compressive state which prevent the ceramic fracture. [16]

Whereas, to adjust the biomechanical performance of the post retained crown, maintaining cervical tissue to create a ferrule effect.[17,18]

A 1 mm circumferential coronal collar height is described as a durable and high fracture resistance . [19-21] The post insertion in the root canal is less vital than collar to avoid fracture..[22-25]

Many researches drew the attention about the effect of different ceramic materials on the fracture resistance of endocrown restorations. Nevertheless, the influence of preparation depth on fracture resistance for anterior endocrown restoration is not exact clear.

The postulated hypotheses of this study was that the depth of the anterior endocrown preparation has impact on the fracture resistance and restoring of anterior endodontically treated tooth with post retained crown with ferrule would be the highest fracture resistance

MATERIALS AND METHODS

Twenty recently extracted, sound, intact human maxillary central incisors were collected were collected from oral and maxillofacial surgery clinics. These teeth were removed as per routine clinical indications.

Maxillary central incisors of about identical size (6 ± 0.2 mm diameters in the cervical area,10 ± 0.5 mm coronal lengths and 13 ± 0.3 mm root lengths) were selected, inspected to be crack free, ultrasonically cleaned and then stored in distilled water. Teeth were decoronated with a super coarse diamond disc (Diatech, Coltene, Switzerland) under copious water. Fifteen incisor teeth of them were decoronated leaving 1 mm above the cement-enamel junction CEJ and following its contour. While the other five central incisors were decoronated 2 mm above the CEJ. Remaining coronal length was measured from the CEJ using periodontal prob

Endodontic Treatment

All endodontic treatments were carried out by the same operator using the same procedure and instruments for standardization purposes. Teeth were endodontically treated using Protaper system to size F5 (Dentsply, Maillefer: Ballaigues, Switzerland) in between instruments 5.25% NaOCl (Egyptian company for household bleach-Egypt) was used as irrigation, for final irrigation 3ml of 17 % EDTA (smearclear,sybronEndo, USA) for 3 min was used followed by3ml of 5% NaOCl for 3 min and final flush with 5 ml of distilled water . Root canals were dried with paper points size F5 (Dentsply, Maillefer, Switzerland) .[26]

Bioceramic based sealer (Total fil, brasseler, USA) with a single cone technique by the equivalent size gutta percha point (Dentsply, Maillefer: Ballaigues, Switzerland) were used for obturation. Excess gutta percha removed 1 mm below the CEJ with red hot plugger (Hu-Friedy products, USA). Temporary filling restoration (Cavit, 3M ESPE, Seefeld, Germany) was used to seal the openings of canal. The specimens were stored at 37 °C in distilled water for 24 hours to ensure complete setting of obturation material.

After completion of endodontic treatment, the samples were removed from storage. The specimens were randomly divided to restore with VITA Suprinity ceramic (VITA Zahnfabrik, Germany) zirconia reinforced lithium silicate CAD/CAM ceramic; and divided into four Groups (n = 5 in each) as shown

Group I: CAD/CAM zirconia reinforced lithium silicate short endocrown (3mm depth) with 1mm remaining coronal length (butt joint design),

Group II: CAD/CAM zirconia reinforced lithium silicate short endocrown (3mm depth) with 2mm remaining coronal length(butt joint design),

Group III: CAD/CAM zirconia reinforced lithium silicate long endocrown (6mm depth) with 1mm remaining coronal length(butt joint design),

Group IV: zirconia reinforced lithium silicate crown retained by glass fiber post (Glassix radiopaque, H Nordin, Chailly/Montyreux, Switzerland) and composite core (nano hybrid universal A3 shade Z250XT (3M ESOE Z250XT, Seefeld, Germany) with 1mm dentin collar (ferrule design -conventional treatment)as shown in fig (1)

A silicone stopper (EEO supplier, Thomas Scientific, Chicago, USA) was attached to the universal gates glidden (3M ESPE, Seefeld, Germany) to adjust the required depth. Gutta percha was removed from root canal by universal gates glidden. Then, a universal drill (3M ESPE,
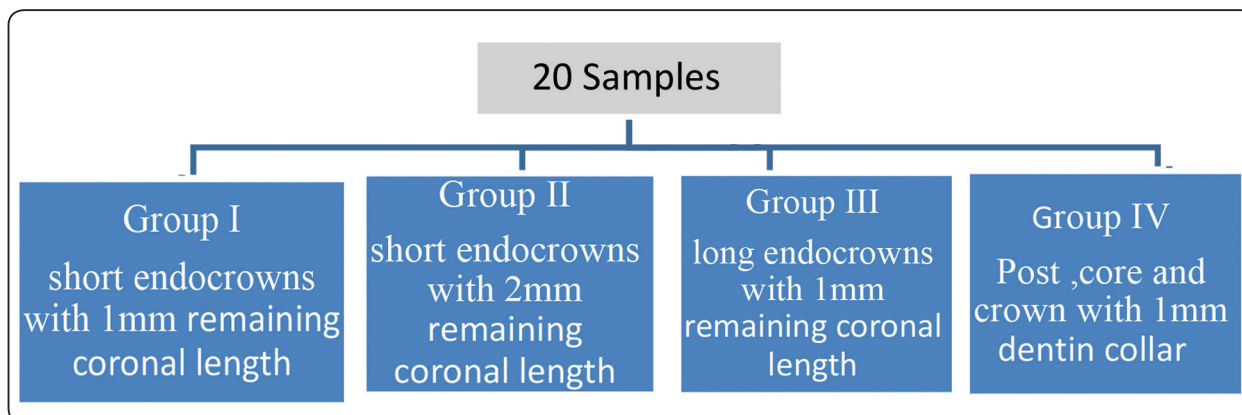
Fig. (1) Experimental groups according to restoration design

Seefeld, Germany)was used to gain 3 and 6mm from the canal base for short & long endocrown specimens respectively and to a depth 8mm for post space. A periodontal probe was used to check the preparation depth. In order to standardization the root preparation, all of them were carried out by the same operator. Then, the canal was irrigated with saline to remove debris. Group IV specimens (n=5) were subjected to receive glass fiber post (Glassix radiopaque, H Nordin, Chailly/Monteux, Switzerland) .The post diameter was corresponding to the final flaring drill used. Then, the post was seated in the canal and then x- rays were taken to check the adaptation in length & diameter before cementation. The extruded part was removed after cementation and leaving 3mm of post extruded to allow retain and buildup of composite core (nano hybrid universal A3 shade Z250XT (3M ESOE Z250XT, Seefeld, Germany)

Before taken an optical impression, each specimen was placed on simulated jaw model (Kavo Dental, Biberach, Germany) to make sure the same level of the margin of the preparation.[27]

An optical impression was used to fabricate the endocrowns and post retained crowns via the Cerec Omnicam Scanner (CEREC; Dentsply Sirona Dental System, USA) and Cerec Premium4.4.4 software. All scanned specimens were subjected to mill using a zirconia reinforced lithium silicate VITA Suprinity ceramic (VITA Zahnfabrik,

Germany) . First design modes and restoration type was selected. Determination the teeth on the visual cast, unnecessary parts of the model was removed by selecting model tools then cut and discard parts. The preparation margins as well as the incisal limits were identified, contoured and marked with the software, and insertion axis was detected. [16,28] To provide the thickness of the cement, the internal gap was set to $30\mu m$ between the prepared specimens and the internal surface of the endocrown and post retained crown, While the marginal gap was adjusted to $0 \mu m$. [29-30]

Once the design of each crown was completed, block size was selected. Placement the ceramic block was placed in position in milling unit (Milling machine MCXL , Dentsply Sirona Dental System, USA). The information was sent to the milling unit through a wireless connection to start milling. **As shown in fig (2)** All specimens were crystalized at 850˚C in a ceramic oven (Programat P310, Ivoclar , Vivadent)the completed crowns will be tried on the respective prepared specimens.[16&28]

Cementation Procedure

Before cementation, surface treatment of all endocrowns and post retained crowns was performed according to manufacturers' instructions. Etching was performed by hydrofluoric acid gel 9.5% (BISCO-Schaumburg, USA) for 60 sec. [38& 39] After etching, the restorations were washed with
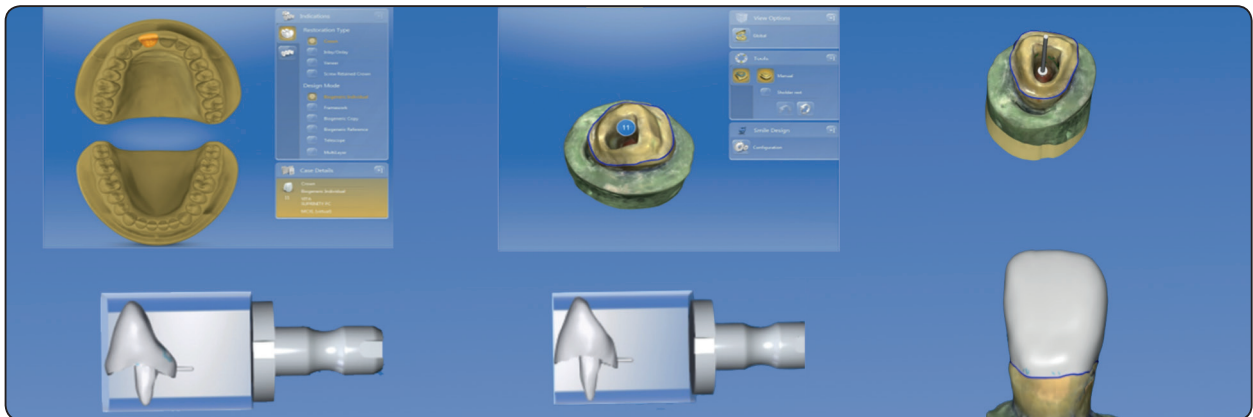
Fig. (2) Design of endocrowns (short & long depth) & post retained crown on CAD/CAM software.

water and dried using air spray(Dental chair Roson, China). Then, the etched restorations were brushed with silane coupling agent (Monobond Plus, Ivoclar Vivadent) using a microbrush and lift for dry for 10 sec.

A Rely X Ultimate adhesive dual cured clicker (3 M Espe,seefeld,Germany)was used for all specimens cementation according to manufacturer's instructions . endocrowns and post retained crown were cemented to their corresponding central incisors under a constant load of 5 kg, using the loading device (Model 3345, Industrial products, MA, USA). which was maintained for 10 minutes.[31]

Thermocycling Loading:

All specimens were kept in 37° C distilled water for 2 days then subjected to thermo cycling between 5°C and 55°C water temperatures with a dwell time of 20 seconds for 5000 cycles, via Robota, automated thermal cycling machine. (Robota BILGE,Turkey) The number of cycles used in this study is equivalent to 2 years clinical service according to (International Organization for Standardization- ISO/TS 11405). [32-35]

Load to Fracture:

Before subjected to the fracture resistance test, all specimens roots were shielded by a 0.2 mm layer of light rubber base impression (Speedix, Ivoclar, Vivadent, Germany) for periodontal ligament

simulation .Then inserted into an auto polymerizing acrylic resin (cold cure acrylic resin Acrostone, Egypt) up to2-mm below the CEJ. [36]

Specimens were tightened in a metal holder and gripped firmly in the lower fixed compartment of the a universal testing machine (Lloyd LRX, Lloyd Instruments, Fareham Hants, UK). Load was applied on for each tooth individually under crosshead speed of 0.5 mm/min to the palatal surface at 45°to the long axis till a fracture happened **as shown in Fig(3).** Fracture loads were recorded using corresponding software
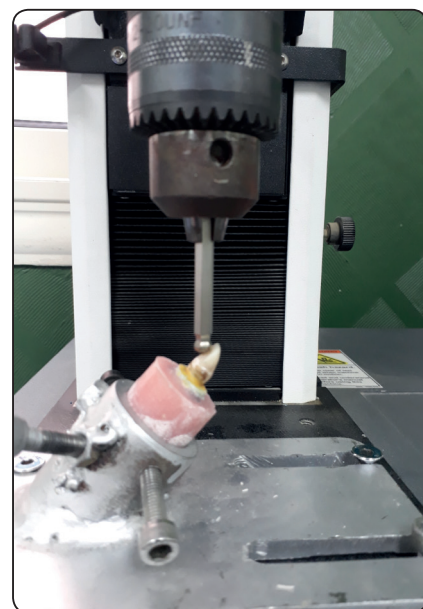

Fig. (3) Application of fracture resistance test.

Then, All Descriptive data were collected, tabulated, and the data distribution normality was tested. Then, all data were evaluated using one-way ANOVA then followed by Tukey post-hoc tests ($p < 0.05$) (SPSS 15.0, SPSS Inc., Chicago, IL, USA).

RESULTS

Mean values, standard deviations, and differences of fracture load OF all of the groups are presented in **Fig.(4)**. One-way ANOVA revealed significant differences in the fracture load values between post retained crown and endocrowns ($p < 0.05$).

The mean fracture load values were ranked as follows: group II (835.3±7.9 N) > group III (765.4±8N) ≥ group I (700.4±7.9N) > group 1V (290.3±4N). The highest and lowest fracture load values were obtained in group II (823.4-842.8N) and group IV (286.8-295.4N), respectively. Moreover, the mean fracture resistance was not significantly different between groups. As shown in table (1)

TABLE (1)   Fracture resistance mean values (N) of CAD/CAM endocrowns prepared with different preparation depths & post core

	Group I	Group II	Group III	Group IV	P value
	N=5	N=5	N=5	N=5	
Fracture resistant *Range* *Mean ± SD*	(688.5-707.7) [c] 700.4±7.9	(823.4-842.8) [a] 835.3±7.9	(753.4-773.5) [b] 765.4±8	(286.8-295.4) [d] 290.3±4	*<0.001**

One-way ANOVA test for parametric quantitative data between the four groups followed by post Hoc Tukey's analysis between each two groups

Superscripts with same small letter indicate significant difference between each two groups.

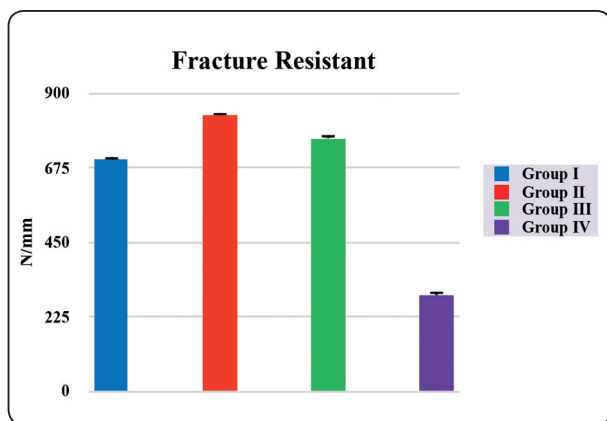**: Significant level at P value < 0.05*

Fig. (4) Fracture resistance mean values& standard deviation of the different tested groups

DISCUSSION

In regards to the current study, the effects of various preparation depths were investigated for the fracture resistance of CAD/CAM endocrown restorations on central incisors compared with conventional treatment approach restoring with post retained crown with ferrule. The postulated hypothesis was totally rejected, because the highest fracture resistance values were obtained in short endocrown preparation depth and no significant difference occur. In addition, the lowest fracture resistance values were obtained with traditional method restoring with post retained crown with ferrule

The improvement of glass ceramic material by enhanced with zirconia (about 10 % by weight) which called a zirconia reinforced lithium silicate ceramic (as VITA suprinity ceramic). [37]

There were controversies about surface treatment time of VITA suprinity ceramic *Zogheib et al,* [38] concluded that VITA suprinity ceramic require more than 60 sec of hydrofluoric acid etching for the an effective bonding. While *Menees et al,* [39] found that surface treatment with hydrofluoric acid etching in concentrations from 5% and 9.5%for 20 seconds is enough to remove the glass matrix. Also *TP Sato et al,* [40] concluded that the bonding of zirconia reinforced lithium silicate ceramic had not effective with the silica coating, and hydrofluoric acid etching for 20 or 40 seconds was similarly in effect of creating stable bonding.

Endocrown preparation which had a butt joint with a band of peripheral enamel had a wide, even, stable surface that resist the stresses and optimized bonding, unlike chamfer or shoulder preparation techniques (ferrule design). [41]

While *Marchionatti et al.* [42] concluded that there were no statistically significant differences between the specimens with periodontal ligament simulation versus without on the fracture resistance of post retained crown. In this study, the simulation periodontal ligament was performed all specimens (endocrowns& post retained crowns) before subjected to the test of the fracture resistance in order to simulate the real clinical condition.

Soares et al. [43] found that the simulation periodontal ligament is considered a stress absorber regarding to the fracture resistance and types of fracture.

On the other hand, various investigations which described that periodontal ligament simulation is interesting in standardization and stability[44-46] *Ramírez-Sebastià et al (2014)* [47] found that post lengths had no effect on the fracture resistance due to no statistically significant differences were obtained among long and short glass fiber post. Also, they concluded that no statistically significant differences on fracture resistances between the endocrowns and the post retained crown.

Because the stresses concentered at the cervical area of the tooth, the force was applied at 45 ° to the long axis of the tooth[48]

Chang *et al*. (2009) [49] investigated the fracture resistance and modes of failure of endocrowns versus traditional designed supported with glass FRC posts and composite cores retained crown .they found that concluded that ceramic endocrown groups had a higher significantly fracture resistance than classic post retained crown groups. In accordance with the current study, all endocrown groups (I, II and III) represented higher fracture resistance mean values than post retained crown (group IV).

There was debates about the preparation depth of endocrown *Kanat-Ertürk B et al* [27] concluded that the depth of endocrown preparation show a major influence on the fracture resistance of endocrowns. The previous study conclusion was disagreement with the conclusion of the current study may be due to the different in ceramic materials used and their properties.

This *in vitro* study has several limitations for simulating real tooth behavior against masticatory forces so recommended for further in vivo studies to clarify the depth effects and ferrule height on endocrown.

CONCLUSION

Within the limitations of the present study, the following conclusions could be careworn:

1- CAD/CAM endocrowns revealed higher fracture resistance mean values than post retained crown

2- The endocrowns might be an unconventional to post retained crowns.

3- The depth of the endocrown preparation has no significant consequence on the fracture resistance of ceramic endocrowns

4- Short depth of endocrowns (3mm) is recommended for restoring anterior endodontically treated tooth with 2 mm ferrule height.

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