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Failure Load of Maxillary Central Incisor Restored with CAD/CAM Endocrown Using Different Designs

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Abstract **Statement of problem**: Restoration of a severely destructed non-vital tooth is usually challenging, especially, in case of incomplete circumferential tooth structures. **Materials and methods:** Sixty intact maxillary central incisors were collected. All teeth were decoronated leaving 2 mm above the CEJ then were divided into two divisions (30 specimens for each) according to the radicular depth (2 mm &4 mm). Each division was divided into three groups (10 specimens for each) according to residual coronal tooth structures (circumferential, only labial and only palatal) to obtain six groups of testing. Then milling was done for (IPS e.max CAD) followed by final cementation. Fracture resistance was tested using a universal testing machine. **Results:** Specimens restored with endocrowns having 2 mm radicular length, exhibited fracture resistance better than that with 4 mm radicular length, without statistical significant difference. Endocrowns with 2 mm circumferential residual coronal tooth structures in both radicular lengths exhibited fracture resistance better than that having either labial or palatal residual coronal tooth structures with a statistically significant difference. The specimens having 2 mm labial residual coronal tooth structures in each radicular length exhibited fracture resistance better than that with 2 mm palatal residual coronal tooth structures in each radicular length with a statistically significant difference. **Conclusion:** For restored endodontically treated maxillary central incisor by endocrown: residual 2 mm circumferential wall presented better fracture resistance than that with only residual labial or palatal wall and residual labial wall presented better fracture resistance than the palatal wall.

Keywords: *CAD CAM, emax cad, endocrown, failure load*

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1. Introduction

Usually endodontically treated teeth have insufficient residual sound tooth structure as a result of caries, cavity preparation or trauma with high probability for biomechanical failure when compared to vital teeth [1]. Selection of restorative materials used and suitable restoration type that preserves the residual tooth structure plays an important role for a longevity of tooth treatment [2]. Post and core was the traditional treatment modality to restore such cases [3]. However, installing a post include some risks as root perforation and removal of radicular dentin to facilitate the space for the post, thus weakening the tooth-root complex [4].

Recently, endocrown restoration has been introduced as a mono - block for both core and crown with butt margin and a radicular extension which is indicated in case severely destructed crowns [5], and characterised by its low cost, easy to construct and reduced chair time [6]. In addition, endocrowns are also an alternative restoration in case of teeth with short clinical crowns, curved or short root canals that make post construction challenging [7,8]. In this situation, monolithic CAD-CAM endocrown, could represent an alternative treatment modality to restore severely destructed endodontically treated teeth [9].

Adhesive methods and ceramic materials recent improvements arouse clear advantage to adhesive restorations since macro-retentive designs are no longer a pre-requisite for the choice of the restoration if the preparation leaves sufficient tooth structure/ surfaces for bonding [10]. In addition to a pleasing appearance, these materials are biocompatible, and the coefficient of thermal expansion is similar to enamel [11]. The present study aim is to assess the failure load of maxillary central incisor restored with CAD/CAM endocrown with different amount and place of residual coronal tooth structures, which differs from the studies that have been carried out before on the same context, which were conducted on posterior teeth.

2. Materials and Methods

Sixty intact, recently extracted, caries-free maxillary central incisors were collected with 10 ± 0.5 mm coronal heights, 13 ± 0.3 mm root lengths and (6 ± 0.2 mm) diameters in the cervical region. All the teeth were decoronated using straight diamond burs under water, leaving 2 mm [12] above the CEJ and following its contour. The specimens were divided randomly into two divisions (30 specimens for each) according to the radicular depth (2 mm &4 mm) [13], then each division was divided into three groups (10 specimens for each) according to their residual coronal tooth structures (circumferential, only labial and only palatal) to obtain six groups of testing (Table 1).

Table 1. Six tested groups with their dimensions.

Length	Groups	Residual coronal structure
Long (4 mm)	(1)	2 mm circumferential
	(2)	2 mm labial with 0.5 mm palatal
	(3)	2 mm palatal with 0.5 mm labial
Short (2 mm)	(4)	2 mm circumferential
	(5)	2 mm labial with 0.5 mm palatal
	(6)	2 mm palatal with 0.5 mm labial

All residual coronal tooth structures were at 2 mm in height from the cemento – enamel junction and 1 mm width using digital caliper. Half of the coronal wall was eliminated (palatal halves in case of groups 2 & 5 and labial halves in case of groups 3 & 6) starting from the line bisecting mesial wall extending to the line bisecting distal wall [14] until 0.5 mm from cemento – enamel junction as shown in Figure 1. Working root length was determined by a size No. 10 K file (0.5-mm away from the apical foramen). The root canals were prepared up to No. 40 K file using manual instrumentation [15].

Each canal was then irrigated using normal saline and obturated using cold lateral condensation of the gutta-percha. The canal orifice was sealed with temporary filling. The teeth were stored in incubator at 37°C with 100% humidity for one week to ensure complete setting of sealer. The radicular depth was standardized using a rubber stopper positioned on the drill (1.5-mm-diameter) to obtain 4mm (for groups 1, 2 and 3) and 2 mm (for groups 4, 5 and 6) from the level of cemento – enamel junction.

Each tooth was fitted to an artificial model in the position of maxillary right central incisor with standardization of cemento – enamel junction level using putty index. Using CAD/CAM software, crown restoration for maxillary right central incisor was selected followed by an impression registration using a scanner (in Eos Blue scanner).

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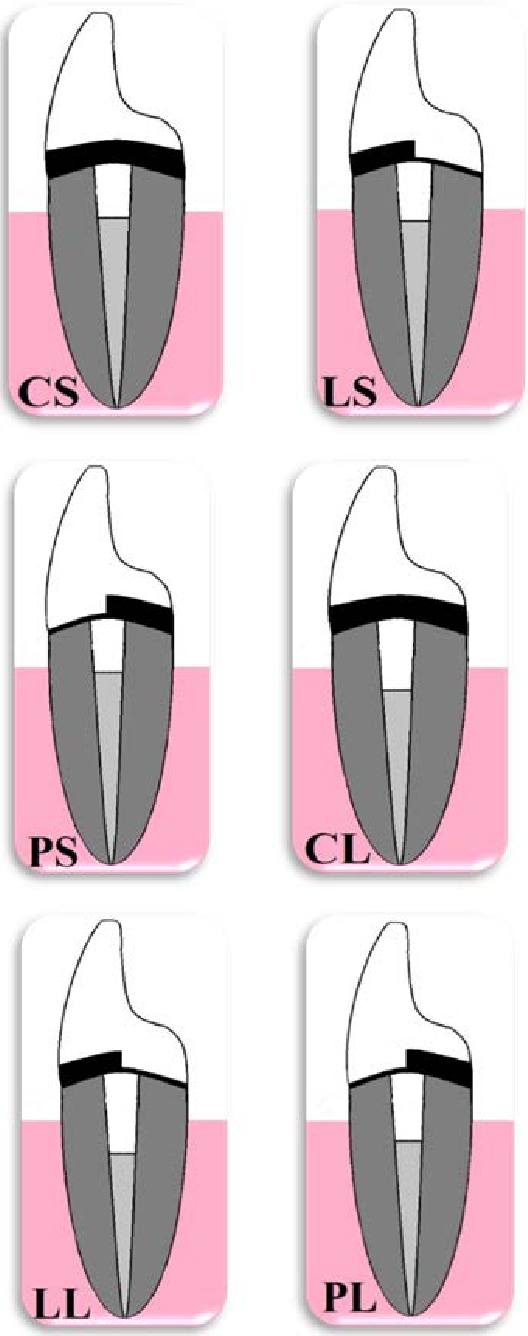

Figure 1. Different endocrown designs with different residual coronal tooth structures. CS, 2mm circumferential with 2 mm radicular depth, LS, residual labial wall with 2 mm radicular depth, PS, residual palatal wall with 2 mm radicular depth, CL, 2mm circumferential with 4 mm radicular depth, LL, residual labial wall with 4 mm radicular depth, and PL, residual palatal wall with 4 mm radicular depth

External root margin, and path of insertion were determined according to the external dimensions of radicular extension of endocrown restoration. Milling was done for the CAD/CAM blocks (IPS e.max CAD) using (Cerec in Lab 3D software version 4.2).

All restorations were crystalized Using programat furnace (P510, Ivoclar, Vivadent), the accuracy of milled restoration was checked. The prepared enamel and dentin surfaces were etched for 15 seconds using phosphoric acid 37.5% (Ultradent, USA), rinsed and blot-dried. The dual-cured bonding agent (Clearfil TRI-S Bond Plus, Kuraray) was applied to the posts and root canals using micro brushes for 10 s. The bonding agent was dried for 5 s and then light cured for 10 s. A dual cure resin cement (Variolink N; Ivoclar Vivadent) was applied, then, using a specially designed device, a constant vertical pressure by 4 Kg on the endocrown [17]. When the restoration was properly seated, the material was allowed to self-cure for 90 sec_s to reach the gel state. Then according to the manufacturer instructions, each surface was allowed to tack curing for 2 sec_s.

Following the removal of excess cements, the luting material was finally cured using a light-curing unit (700 Mw/Cm2. Elipar 2500), then, the specimens with their restorations were stored in distilled water at room temperature for 24 days before testing. The specimens were subjected to thermos-cycling at 5 - 55°C for 5,000 cycles at dwell time temperature for 30 seconds. After thermocycling, fracture resistance was tested using universal testing machine (Instron 4411, Instron, High Wycombe, UK) at a 45 degrees angle and crosshead speed of 0.5 mm/min until fractures occurred.

3. Results

Descriptive statistics, including the maximum, minimum, mean, median values and standard deviation were calculated for each tested group (Table 2). A one -way analysis of variance (ANOVA) was used to analyze the data for significant differences at P< 0.05. All calculations and statistical analysis were performed using SPSS version 21 (SPSS Inc., Chicago, IL, USA).

Regarding radicular length of endocrown restoration, the analysis of variance showed that, the specimens restored by endocrowns with short radicular length (2 mm as in groups 4, 5 and 6 [*515.80 N ±10.58, 445.30 N ± 10.30 and 401.81 N ± 12.15*] respectively) exhibited fracture resistance better than that with long radicular length (4 mm as in groups 1, 2 and 3 [*513.96 N ± 11.01, 442.00 N ± 11.98 and 399.34 N ± 12.76*] respectively) without statistical significant difference among the tested groups ($P > 0.05$) (Table 2) and (Figure 2).

Regarding residual coronal tooth structures, the analysis of variance showed that, the specimens restored by endocrowns with 2 mm circumferential residual coronal tooth structures in both radicular lengths (groups 1 and 4 [*513.96 N ± 11.01 and 515.80 N ±10.58*] respectively) exhibited fracture resistance better than that have either labial or palatal residual coronal tooth structures (Groups 2, 3, 5 and 6 [*442.00 N ± 11.98, 399.34 N ± 12.76, 445.30 N ± 10.30 and 401.81 N ± 12.15*] respectively) with statistical significant difference among the tested groups ($P < 0.05$) (Table 2) and (Figure 2).

Furthermore, the specimens restored by endocrowns with 2 mm labial residual coronal tooth structures in each radicular length (Groups 2 and 5 [*442.00 N ± 11.98 and 445.30 N ± 10.30*] respectively) exhibited fracture resistance better than that with 2 mm palatal residual coronal tooth structures in each radicular length (Groups 3 and 6 [*399.34 N ± 12.76 and 401.81 N ± 12.15*] respectively) with statistical significant difference among the tested groups ($P < 0.05$) (Table 2) and (Figure 2).

Table 2. Descriptive statistics, including the maximum, minimum, mean, median values of load failure with standard deviation for each tested group (Newton)

G	N	Max.	Min.	Mean	S.D
(1)	10	530.10	502.10	513.96	11.01
(2)	10	459.60	430.30	442.00	11.98
(3)	10	417.40	384.90	399.34	12.76
(4)	10	532.60	502.20	515.80	10.58
(5)	10	459.20	432.90	445.30	10.30
(6)	10	419.80	387.60	401.81	12.15

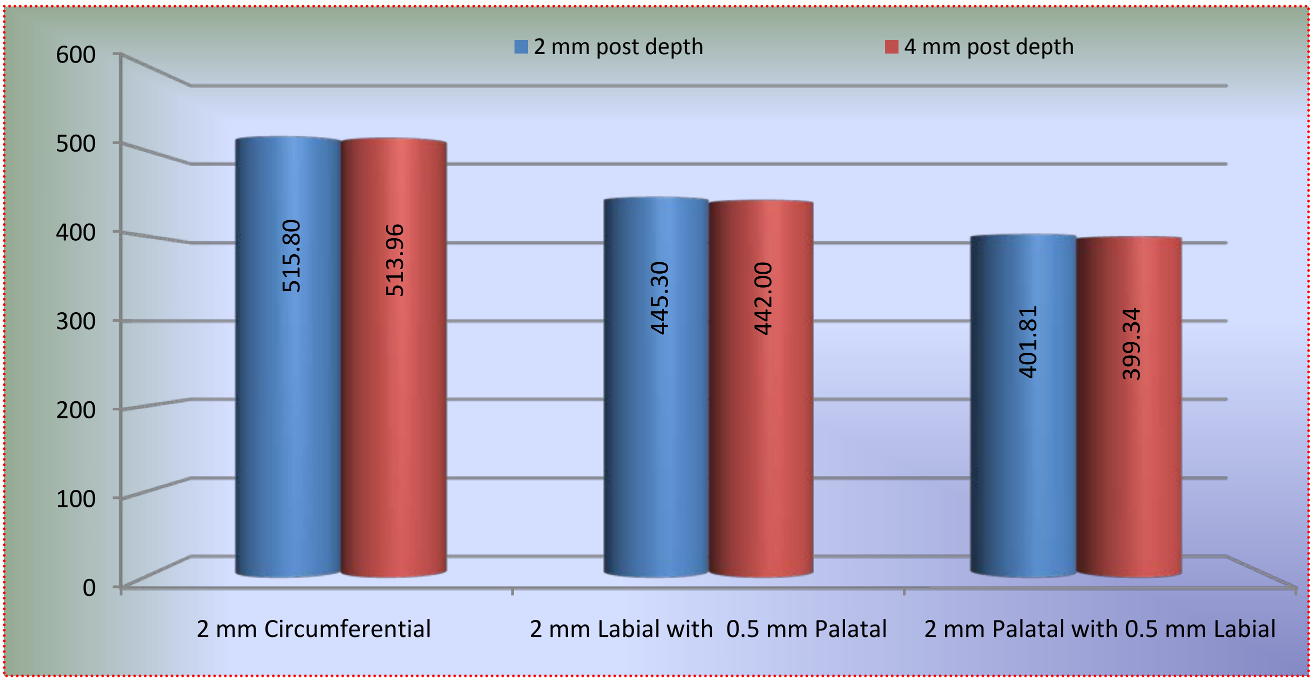

Figure 2. Bar charts for mean values of fracture resistance for tested groups(Newton)

4. Discussion

Pissis [18], developed the *Endocrown* technique, describing it as the 'mono-block porcelain technique'. The term *Endocrown* was firstly described in 1999 by Bindl and Mormann [19] as adhesive endodontic crowns characterized as total porcelain crowns fixed to endodontically treated posterior teeth. These crowns would be anchored to the internal portion of the pulp chamber and on cavity margins, thus obtaining macro-mechanical retention provided by the pulp walls, and micro-retention would be obtained with the use of adhesive cementation. This type of restoration is indicated when there is excessive loss of coronal structure or limited interproximal space [20], and it is technically easy to do, a cost-effective procedure that requires less chairside time, acceptable by the patient. In addition, the supragingival margins facilitate the oral hygiene procedures and clinical inspection [4].

Maxillary central incisor was selected in the study to benefit from the symmetric central tooth image by using the biogeneric reference option in CAD/CAM, to standardize the form of all endocrowns [12]. In this study, standard deviations were large, this may be attributed to that, despite a standard protocol was followed during all the steps of the study, it is impossible to achieve an exact uniformity among the experimental teeth and although teeth may be selected of equal dimensions, there are multiple factors such as variation in moisture content and number of dentinal tubules. This is in accordance with Heydecke et al [21], who has reported that, the main disadvantage of natural teeth is the relatively large variation in size and mechanical parameters, often resulting in large standard deviations.

Despite these drawbacks, the utilization of human teeth is the only and the most reliable methodology in fracture testing and has also been adopted by many authors who performed studies of a similar nature [22,23,24,25]. In cases of groups 2, 3, 5 and 6, half of the coronal wall was eliminated (palatal or labial halves leaving 0.5 mm from the level of cemento-enamel junction in order to benefit from the presence of enamel layer to increase bonding efficacy.

In this study, the direction of applied testing load was at 45 degrees which represent loading features exerted on the maxillary incisors in class I occlusion [26,27,28]. Comparing the values of fracture resistance gained in our study, with the normal biting force which ranged from 150 to 200 N [21], it can be observed that lithium disilicate ceramic could be used reliably [29,30,31] in clinical applications of endocrown restorations with long and short radicular depths.

From the results of this study, the fracture resistance values in all tested groups were lower than that, in other study. This may be attributed to the difference in tested tooth (incisors instead of molars) and also, to the difference in applied occlusal load (45 degrees instead of 90 degrees).

Among teeth with different radicular depths examined in the present study, the highest fracture resistance was determined in the groups having a 2 mm radicular depth rather than that in the groups having 4 mm radicular depth but, without statistical significant differences. This increase in mean fracture resistance may be due to that, increasing radicular depth requires increasing in root canal preparation and subsequently more weakness of endodontically treated teeth [32].

Among teeth with different examined groups in the present study, the highest fracture resistance was determined in the groups having a 2 mm circumferential residual coronal tooth structures followed by groups having 2 mm in the labial region rather than that in the groups having 2 mm in the region palatal which exhibited low values of fracture resistance. The force was applied from the palatal direction (inward – outward direction), for this reason, the residual tooth structures at the palatal region does not receive the applied force directly, but in case of residual tooth structures at the labial region possibly reinforced the endocrown by receiving the applied palatal load which necessitated greater forces for fracture. This is not in accordance with other study [26], which evaluated the effect of the same residual tooth structures on the fracture strength of teeth restored with post and core which proved that, residual tooth structures on palatal region exhibited fracture strength better than that with residual tooth structures on labial region. This is because, butt joint that has been used in our study transmit the applied load into labial tooth structure rather than other study that used ferrule design with cervical finish line which transmit the applied load into palatal tooth structure more than labial tooth structures

5. Conclusion

For restored endodontically treated maxillary central incisor by endocrown the following conclusions were drawn:

1. Residual 2 mm circumferential wall presented better fracture resistance than only residual labial or palatal wall.
2. Residual labial wall presented better fracture resistance than residual palatal wall with no statistical differences.
3. 2 mm radicular depth presented better fracture resistance than 4 mm radicular depth with no statistical differences.
4. CAD/CAM endocrown is a conservative treatment option that could be used to restore endodontically treated teeth with extensive coronal tissue loss

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