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FRACTURE RESISTANCE OF ENDODONTICALLY TREATED MANDIBULAR MOLARS RESTORED WITH TWO ENDOCROWN DESIGNS (AN IN-VITRO STUDY)

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ABSTRACT

Aim: To evaluate the effect of two endocrown designs on the fracture resistance of endodontically treated mandibular molars.

Materials and methods: Fourteen mandibular molars were endodontically treated and randomly divided into two groups according to the endocrown design; group (A) Axial extension (n=7) and group (B) Circumferential extension (n=7). Endocrown preparation was done followed by CAD/CAM endocowns design and fabrication using lithium disilicate glass ceramics. Endocrowns were cemented using a standardized protocol. All samples were subjected to fracture resistance test using a universal testing machine and the maximum loaded was recorded. Statistical analysis was performed using One-Way ANOVA and significance level was set at 0.05.

Results: Endodontically treated mandibular molars with axial extension endocrowns showed significantly higher fracture resistance than those with circumferential extension.

Conclusions: Axial extension endocrown design is recommended to restore endodontically treated mandibular molars.

KEYWORDS: Endocrown, Endodontically-treated molars, Fracture resistance, Glass ceramics.

INTRODUCTION

Restoration of endodontically treated mandibular molars is not an easy procedure due to the high risk of biomechanical failure. The main cause for the reduction in mechanical properties of root canal treated teeth is the loss of tooth structure rather than physical changes in dentin [1]. Proper coronal restoration of root canal treated teeth positively affects its survival rate. This implies the use of appropriate restorative materials in the appropriate design [2].

Different treatment options are available for

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restoration of endodontically treated teeth; yet, none is considered to be the best for all situations [3]. Endocrown is one of the conservative options used to restore root canal treated teeth. Endocrowns are shown to provide coronal seal in addition to strengthening of the remaining tooth structure.

The endocrown is described as a monolithic one piece ceramic restoration, which restores a preparation. Classically, endocrowns have a circumferential butt margin and a central retention cavity inside the pulp chamber with specific preparation criteria. This follows the recent minimally invasive restorative approach implying decay oriented preparation [4, 5]. Recently, a modification to the conventional design has been suggested to have greater failure loads than standard endocrown restorations [6]. The incorporation of axial ferrule in preparations has been proved to increase fracture resistance [7]. Teeth restored with all ceramic, full-coverage restorations showed significantly increased fatigue cycles to failure by adding minimal ferrule of 0.5 mm [8].

The ceramic restorative material used for endocrown fabrication greatly affects its performance. A wide variety of ceramic materials have been introduced into the market. Lithium disilicate glass ceramic is one of such materials that can be manufactured using Computer-Aided Design/Computer-Aided Manufacturing (CAD/CAM). It possesses approximately 70% by volume needle-like crystals in a glassy matrix [9]. This unique crystalline structure provides high edge strength, and fracture resistance allowing them to be ideally used for inlays, onlays, and endocrowns.

This study aimed to evaluate the effect of two endocrown deigns on the fracture resistance of endodontically treated mandibular molars. The null hypothesis tested was that the fracture resistance values would not be influenced by the different endocrown preparation designs.

MATERIALS AND METHODS

Sample Selection

Fourteen sound freshly-extracted mandibular molars were selected of approximately similar size, shape, and crown morphology. All molars showed completely formed apices without caries, fractures, or cracks and no signs of internal or external resorption. Teeth were cleaned, debrided using ultrasonic scaler (Satelec, Cedex, France) and examined under dental operating microscope (Zumax, Suzhou New District, China). Teeth were stored in saline solution of 0.9% concentration at room temperature until used for experimentation.

Sample Preparation

Access cavity preparations of all molars were prepared using high-speed diamond round burs and Endo-Z burs (Dentsply Maillefer, Ballaigues, Switzerland). Complete de-roofing of the pulp chamber was confirmed visually and using sharp endodontic explorer.

A size 10 K-file (Mani Inc., Tochigi, Japan) was passively introduced into each root canal until its tip was seen at the apical foramen. The working length was established by subtracting 1 mm from this length.

All root canals were prepared using Hyflex EDM (Coltene/Whaledent, Altstatten, Switzerland) to the full working length following the manufacturer instructions. Irrigation was done with 5 mL of 2.5% sodium hypochlorite and final flush using 5 ml of EDTA 17% using a 27 gauge needle. Root canals were dried using paper points #25. Obturation was done by gutta-percha and AH Plus sealer using cold lateral compaction technique. Radiographs were taken to ensure three-dimensional filling of the root canals. Sealing was done with intermediate restorative material and teeth were stored at 37°C and 100% humidity.

All teeth were embedded in autoplymerizing acrylic resin in readymade tubes with the cementoenamel junction being 1.5 mm above the resin margin. Web-based algorithm (www.random.org) was used to randomly allocate both groups; group (A): Axial extension endocrown design (n=7) and group (B): Circumferential extension endocrown design (n=7). A computer numerical control (CNC) machine was used to undergo preparation with a total intracoronal occlusal divergence of 10 degrees and flat occlusal preparation to achieve pulp chamber of 4 mm depth for all teeth. CNC machine was adjusted to prepare axial walls according each group extension. For group (A): Axial extension, preparation involved only the buccal wall with a chamfer finish line of 1 mm thickness and at a level of 2.5 mm below the prepared occlusal surface. For group (B): Circumferential extension, preparation involved all axial walls circumferentially with a chamfer finish line of 0.5 mm thickness and at a level of 2.5 mm below the prepared occlusal surface. Then all preparations were finished using finishing stones rotating at low speed to remove any sharp angles as shown in figure 1.

All preparations were then scanned with the Omnicam (Sirona, Bensheim, Germany) in several directions to create a 3D virtual model as shown in figure 2. Fourteen endocrowns were designed on the scanned models, using inLab 3D software where all parameters were standardly set including insertion axis, margin placement, occlusal and wall thickness and cement gap. For group (A), endocrown design involved only the buccal wall while for group (B), it involved all axial walls circumferentially. The window displayed the proposed design of the endocrowns over the model and allowed for any required editing by adding, removing and or smoothening of the material as shown in figure 3.

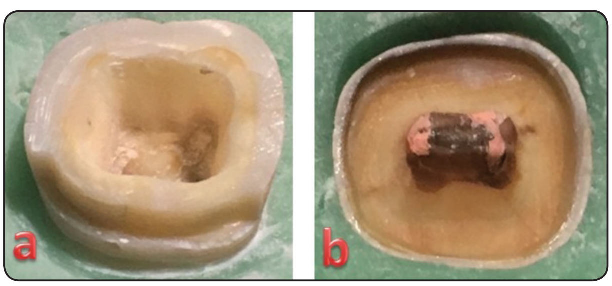

Fig. (1) Photograph of a prepared tooth, a) axial extension preparation involving the buccal wall only; b) circumferential extension preparation involving all of the axial walls.

Lithium disilicate glass ceramic blocks UP CAD (Shenzhen Upcera Dental Technology Co., Ltd., China) with appropriate size were selected for endocrowns fabrication using CAD/CAM CEREC MC XL 4 axis milling machine (Sirona, Bensheim, Germany). Low speed and light pressure were used in finishing and adjusting the lithium disilicate endocrowns (precrystallized/blue), checked on their corresponding models.

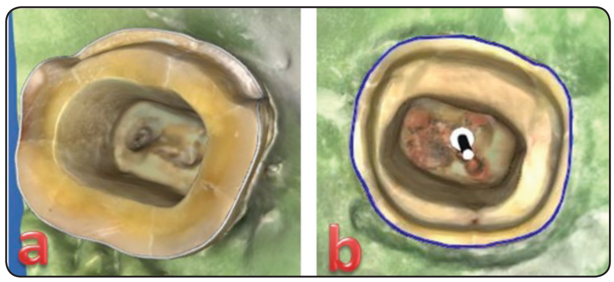

Fig. (2) Screen shot showing the three-dimensional virtual model of the scanned preparation; a) axial extension preparation involving the buccal wall only; b) circumferential extension preparation involving all of the axial walls.

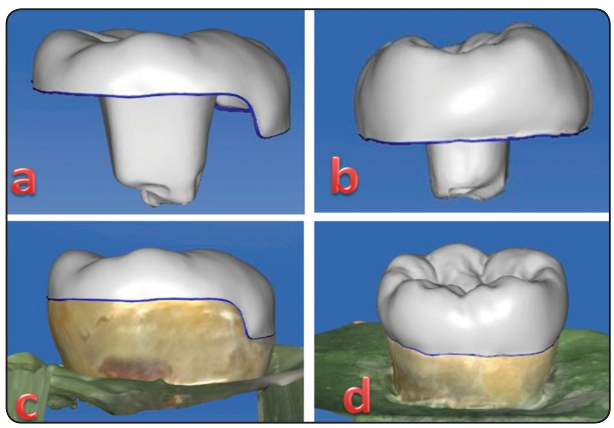

Fig. (3) Endocrown fabrication; screen shot of the designed endocrown a) axial extension preparation involving the buccal wall only; b) circumferential extension preparation involving all of the axial walls; c) screen shot of the designed endocrown with axial extension seated on the virtual model; d) screen shot of the designed endocrown with circumferential extension seated on the virtual model.

The endocrcrowns were then secured on crystallization tray/firing tray with crystallization/ firing pins by object fix material putty. IPS e.max CAD Crystall/Glaze Paste was applied evenly on the outer surfaces and placed into the furnace Programat EP 3010 (Ivoclar vivadent, Liechtenstein) where the program started to run automatically. Endcrowns were removed from the furnace and allowed to cool to room temperature followed by cleaning in ultrasonic water bath to remove any residues and checked again for any minor adjustments.

Endocrowns were etched in the bonding surfaces using 9.5% hydrofluoric acid gel according to the manufacturer instructions for 20 seconds, then rinsed thoroughly for 20 seconds with water and dried with oil free air. The surfaces were then silanized by applying a thin coat of Monobond plus primer a micro-tip then the material was left to react according to the manufacturer instructions for 60 seconds.

All teeth was cleaned using fluoride-free cleaning past and brush then rinsed and dried with water and oil free air. Multilink cement auto mix tips were used to mix and apply the resin cement to the fitting surface, lightly thinned with air. Endocrowns were placed on their relevant models by static finger pressure then axially loaded with a 5 kg static load and left for 10 minutes to ensure cement setting. Excess cement was removed with a scaler, and then light curing was done for 40 seconds for each side.

Fracture Resistance Testing

All samples were loaded in a universal testing machine (Lloyd, Ametek, Kuala Lumpur, Malaysia). Compressive loading of the specimens were then applied vertically at a crosshead speed of 0.5 mm/ min. The breaking load was recorded in Newtons (N).

Statistical Analysis

Statistical analysis was performed using statistical package for social sciences (IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY). Significance was analyzed by one-way ANOVA. Data were expressed by mean and standard deviation and P<0.05 was considered as statistically significant.

RESULTS

Mean and standard deviation values of fracture resistance for both groups are shown in table 1. Group A (Axial extension) showed higher fracture resistance than group B (Circumferential extension) with a highly statistically significant difference (p=0.000219) as shown clearly in table 1.

TABLE (1) Mean and standard deviation values of fracture resistance results of both groups in Newtons.

Group	Mean	Standard Deviation	n
A (Axial extension)	2014.286 [a]	146.385	7
B (Circumferential extension)	1666.4 [b]	98.94224	7

Different letters in the same column indicate statistically significance difference

****; significant (p<0.05), ns; non-significant (p>0.05)***

DISCUSSION

Restoration of endodontically treated teeth remains a controversial issue in restorative dentistry. Different treatment options, designs and materials are available. Endocrowns are considered nowadays a reliable conservative alternative for restoration of endodontically treated molars [10]. Thus, the aim of our study was to evaluate two of such new designs regarding the fracture resistance.

A diversity of strengthened adhesive ceramic materials have been introduced into the market and selected by clinicians for different intracoronal and extracoronal restorations. Lithium disilicate glass ceramic is one material that has been used for long time as clinically successful adhesive restoration based on long term clinical and laboratory studies which support its use as a reliable endocrown restoration in our study [11].

Developing CAD/CAM materials and fabrication methods have been considered among the cutting-edge technologies in restorative dentistry eliminating human error in the manufacturing of prosthetic elements which ensures restoration quality and standardization among samples.

Static loading to fracture can only show the strength of a restoration immediately after bonding. The obtained values of fracture resistance are most likely not indicative of the long term success of the restoration. Nevertheless, it is the most commonly used test to give an indication of a material and a type of restoration suitability as a viable option for clinical situations [3].

The study results showed the failure load values of this study were all way higher than that reported for normal human function; however, axial extension endocrown preparations approached those suggested for accidental biting and/or trauma [12,13,14].

The high results observed in this study are matching with Magne et al [15] who reported endocrown failure loads of 2606 N as well as Gresnight et al [16]. Furthermore, lithium disilicate material demonstrated a mean fracture load of 1368 N in a similar study by El-Damanhoury et al [17].

Endocrowns with axial extension was shown to be statistically significantly more resistant to fracture than endocrowns with circumferential extension. Therefore, the null hypothesis was rejected under. The high mean fracture resistance values of endocrowns with axial extension are going well with Taha et al [3] who proved that adding a short axial wall and shoulder finish line to the preparation design of endodontically treated teeth restored with endocrown can increase the fracture resistance of such teeth. Additionally, the study results are in accordance with Einhorn et al [6] who showed that ferrule-containing endocrown preparations demonstrated significantly greater failure loads than standard endocrown restorations.

One biomechanical explanation is that the intracoronal restoration allows adaptation to strain at the bonded joint. These forces are distributed over the cervical butt joint (compression) or axial walls (shear force). As such, the addition of short axial walls might have resulted in counteracting the shear stresses through the walls and better load distribution thus moderating the load on the pulpal floor [18]. It is also worth mentioning that incorporation of axial ferrule in preparations has been proved to increase fracture resistance [7, 19, 8].

The significantly high failure load values of the axial extension endocrowns compared to the circumferential endocrowns could be also interpreted by scanning and milling limitations in reproducing the intaglio surface of the endocrowns that might affect restoration performance. The more complex the preparation design due to extracoronal extension results in intaglio endocrown surface less adapted to the preparation due to awkward scanning and milling strategies [14, 20].

Addition of extracoronal circumferential extension on all axial walls might result in areas with limited dentin wall thickness between the endocrown cervical part and the extracoronal extension causing over-milling of the intaglio features of that area due to the limitations of the milling bur diameter entailing less adaptation than the axial extension. The poor adaptation results in more stress concentration and less the fracture resistance. Thus, a more conservative pulp chamber access is recommended with extracoronal extensions to allow for increased dentin thickness and less complex design to overcome the scanning and milling limitations.

CONCLUSION

Within limitations of this study, it can be concluded that adding axial extension to the endocrown design for endodontically treated mandibular molars can increase the fracture resistance of these teeth. Notwithstanding, further investigations, especially the fatigue behavior, are needed to ensure the increase of fracture resistance with axial extension together with a more conservative pulp chamber access.

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