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FRACTURE RESISTANCE OF CAD CAM ENDOCROWNS BONDED TO TEETH WITH DIFFERENT NUMBER OF REMAINING WALLS : AN IN-VITRO STUDY

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ABSTRACT

Objective: Currently, there is no recommendation for the minimum number of remaining walls for Zirconia endocrown. **Materials and methods:** Fifty resin specimens were divided into 5 main groups according to the remaining wall number; group W0 no remaining walls, group W1 1 remaining wall, group W2 2 remaining walls, group W3 3 remaining walls, group W4 no missing walls. Ten resin dies for each group were fabricated using epoxy resin and assigned to each group. Resin dies from all groups were individually scanned using an extraoral scanner. Second generation zirconia monolithic (three mol% yttria-stabilized tetragonal zirconia polycrystal (3Y-TZP) endocrowns were milled. All endocrowns were sintered according to the manufacturer's recommendations. After trial fitting, all endocrowns were cemented to their corresponding resin dies using resin cement. After 1000 thermal cycles alternating between hot and cold baths with 20-second immersions at 55±1° C and 5±1ºC, respectively, and a 10-second delay between each immersion, each specimen was fixed to the lower fixed part of a universal testing machine with a load cell of 5 kN at a crosshead speed of 0.5 mm/min. All specimens were loaded to failure, and recorded in Newton using computer software. Data were collected, tabulated and statistically analyzed. **Results:** Group W1 showed higher mean values (2933±733.61) followed by W0 group (2453.5±492.48), then W4 group (2187±576) and group W2 (2108.17±451.28) and finally W3 group (1992±205.63). At a 95% of confidence level, One-Way ANOVA revealed significant differences between tested groups (P= 0.033). **Conclusions:** There was a significant difference in fracture resistance between groups with different numbers of remaining walls. The mean fracture resistance values were not consistent with the number of remaining walls. The number of remaining walls is not directly proportional to the fracture resistance values.

KEYWORDS: Fracture resistance, CAD CAM, endocrowns, and remaining walls.

INTRODUCTION

The primary obstacle to restore endodontically treated teeth, as opposed to vital ones, lies in their distinct biological and mechanical dissimilarities. These variations manifest in the tissue composition, as well as the gross and micro-structure of dentin, resulting in a substantial loss of tooth structure that complicates the restoration process [(1)]. Numerous restoration protocols have been proposed for endodontically treated teeth, which encompass

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a range of techniques such as intra-radicular post systems, extra- and intra-coronal complex restorations that can be constructed either indirectly or directly, as well as adhesive systems and adhesive cementation protocols [1–3]. Out of all the available restorative options, extra-coronal crown restorations that provide full coverage are the most popular among clinicians and have been shown to have a higher survival rate compared to direct intra-coronal restorations [4]. Traditionally, amalgam and resin composite materials have been used as core materials for restoration, with composite resin exhibiting comparable[5] or superior longevity compared to old cast metallic cores [6]. In terms of reducing fracture rates in endodontically treated teeth that are restored with direct intra-coronal resin composite restorations, it has been discovered that the presence of an optimal amount of sound enamel supported by dentin is crucial to the survival of these teeth. Conversely, intra-radicular posts have been found to significantly reduce the tooth's fracture resistance due to the removal of root dentin [4].

Computer-aided designing and manufacturing (CAD/CAM) has become increasingly popular for producing full-coverage ceramic restorations that exhibit reliable esthetic and marginal accuracy results and are easy to fabricate. However, it is worth noting that the retention of endocrowns restorations relies on adhesive cementation to a greater extent[7-16]. In response to the growing trend among clinicians toward tooth preservation, CAD/CAM-produced endocrown restorations have been developed[7]. An endocrown is an intra-coronal restoration that consists of integrated core and crown components, which can be indirectly constructed using CAD/CAM technology and then adhesively cemented into the pulp chamber and remaining tooth structure of an endodontically treated tooth. In addition to being more conservative, endocrown restorations have been shown to provide fracture resistance results comparable to post and core systems[7-16]. Furthermore, some proponents of CAD/CAM suggest that the bond between a ceramic endocrown and dentin walls is stronger than that between a ceramic crown and the underlying amalgam or composite core and that the need for additional retentive preparation features can be eliminated through the adhesive cementation technique used for endocrowns [12].

Endocrown tooth preparation generally involves reducing the cusp height by 2-3 mm, creating a 90° butt joint margin, diverging the inner walls of the pulp chamber coronally by 6°, creating smooth internal line angles, ensuring a relatively flat pulp floor with sealed canal orifices, and placing the margins supragingivally wherever possible [9-11), (15]. Although a flat pulp chamber is not a mechanical requirement, many authors view it as a critical guideline for achieving a symmetrical and even taper of the internal pulp chamber walls.

There is much controversy and a lack of actual clinical evidence regarding the relation of remaining walls to the longevity of endocrown. However, despite revisions to the literature, there is still a lack of consistent guidelines regarding the minimum remaining walls required to achieve optimal retention for endocrowns. Therefore, this study aimed to assess the effect of different numbers of remaining walls on the fracture resistance of CAD/CAM endocrown restorations in molar teeth.

The null hypothesis for this study was that there would be no difference in fracture resistance between endodontically treated teeth with different number of remaining walls.

MATERIALS AND METHODS

Sample grouping:

Fifty resin specimens were divided into 5 main groups according to the number of remaining walls into n=10; group W0 where there are no remaining walls, group W1 (Figure 1), where there is 1 remaining wall, group W2, where there are 2 remaining walls, group W3, where there are 3 remaining walls, group W4 where there are no missing walls.

Tooth preparation:

The ethical approval number was registed as 2022/0069 Misr University for Science and Technology/Institutional Review Board, as a natural tooth were used.

The tooth was scanned using an extra Oral scanner (S107, Wieland Dental + Technik GmbH & Co. KG Lindenstraße 2, Germany). The tooth was endodontically treated using the step-back technique and obturated using lateral- condensation (META BIOMED Co, Ltd., Chungbuk, Korea). The molar was then placed vertically in a 15X15X25 mm resin block (Vertex Orthoplast, 3D systems, Soesterberg, Netherlands) using a parallelometer (af350, Amann Girrbach AG, Koblach, Austria).

Endocrown pulp chamber (access cavity) preparation following these guidelines (criteria): 6° diverging coronally inner walls, 90° butt joint margin, smooth internal line angles, flat pulp floor with sealed canal orifices, and all walls of the tooth were shortened to 4 mm height from the cementoenamel junction [17].

Stone dies construction:

A silicon impression was taken using Vinyl polysiloxane impression material (Suflex Heavy and light, Kompodent, KOUVOLA, Finland). One wall was then removed one mm above the cemento-enamel junction, and a second silicon impression was taken. A second wall was further removed, and a third silicon impression was taken. Then a third wall was removed, and a fourth silicon impression was taken. Finally, the last remaining wall was then removed, and a fifth silicon impression was taken. Each impression was poured 5 times using type IV dental stone (Elite Master, Zermack S.P.A, Badia Polesine (RO), Italy).

Resin dies construction:

Silicon mold was fabricated for fast and accurate construction of specimens. Ten resin dies for each group were poured from the final silicon mold using resin (Vertex Orthoplast, 3D systems, Soesterberg, Netherlands) and assigned to each group.

Zirconia endocrown Fabrication:

Resin dies from all groups were individually scanned using an extra oral scanner (S107, Wieland Dental + Technik GmbH & Co. KG Lindenstraße 2, Germany). The STL file that was taken of the tooth before endodontic treatment was recovered and used to design a full monolith zirconia endocrown for all groups. (Fig. 1) Monolith generation 2 zirconia (ST, Shenzhen Upcera Dental Technology CO., Ltd.) endocrowns were milled accordingly using a milling machine (Zenotec select, Wieland Dental + Technik GmbH & Co. KG Lindenstraße 2, Germany). All endocrowns were collected, inspected under magnification, cleaned by steam jet and sintered according to the manufacturer recommendation's (TABEO-1/M/ZIRKON-100 (MIHMVOGT GmbH & Co. KG, Germany)). Endocrowns were finished and polished mechanically using dedicated rubber discs (ZiLMaster Finishing & Polishing Kit HP, Shofu, Kyoto, Japan).

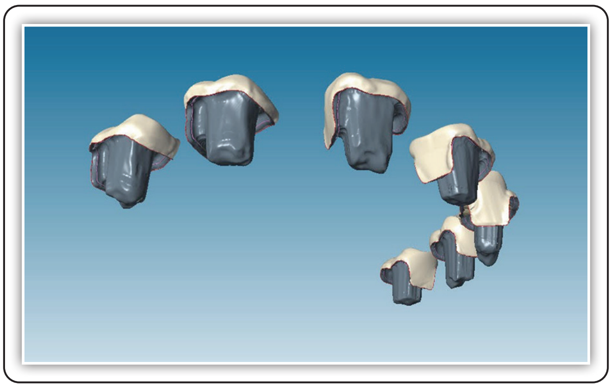

FIG (1) Monolithic endocrowns design for 1 missing wall.

Zirconia endocrown cementation:

The endocrowns were fitted on their corresponding resin dies and cemented using a dual cure resin cement (Allcem, FGM, Joinville, SC Brazil).

After a 3 sec tack curing, any extra cement was removed using a surgical blade size 12. To allow the final setting, the endocrowns were left under a 5 kg load. The specimens were immersed in distilled water for a period of 48 hours before testing.

Thermal cycling of specimens:

The samples were thermo-cycled for 1000 cycles which represents one year in service(18), using (THE-1200, SD MECHATRONIK GMBH, Feldkirchen-Westerham, GERMANY) each cycle includes immersion for 20 seconds into the hot bath at 55±1ºC followed by immersion for same time into the cold path at 5±1ºC with 10 seconds delay between the hot and cold (18).

Fracture Resistance Testing:

Each specimen was securely attached to the lower part of a universal testing machine using a load of 5 kN. To prevent stress concentration, a 1 mm thick tin foil was placed between the occlusal surface and the metallic indenter used to apply the load. The load was applied uniaxially to the inclined cuspal planes of the endocrown at a crosshead speed of 0.5 mm/min. The specimens were loaded until failure, which was determined by an audible crack sound or a sudden drop in the load/deflection curve. The failure load, measured in Newtons, was recorded using computer software (Nexygen-MT-4.6 from Lloyd Instruments, Largo, FL) (19).

Statistical analysis:

The fracture resistance values were calculated in Newton. Descriptive statistics, including mean, standard deviation, minimum and maximum values, were calculated. The Shapiro-Wilk test was used to check for the normality of the data distributions. The statistical analysis was performed using SPSS v.17, and charts were created using Microsoft Excel 2016. Statistical significance was determined using a significance level of 0.05

RESULTS

1. Shapiro-Wilk normality tests

Shapiro-Wilk test was conducted to test the normality of the data distributions. The results of the tests were not statistically significant with $p > 0.05$, indicating a normal distribution of the data and, thus, allowing the use of parametric statistical tests (Fig 2).

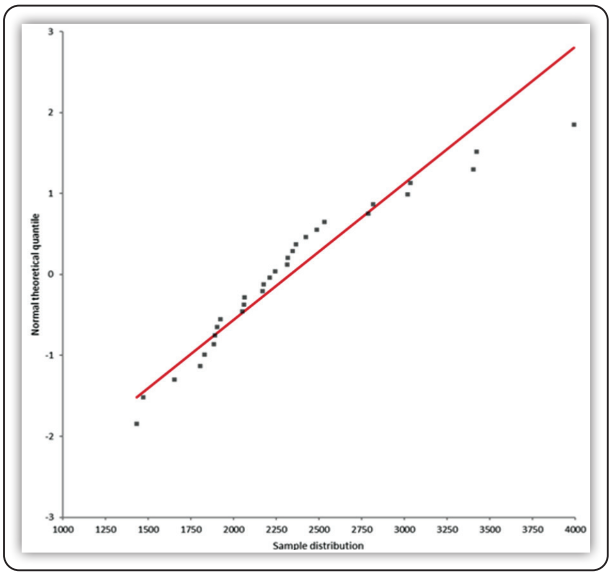

FIG (2) Monolithic endocrowns design for 1 missing wall.

Descriptive analysis

Group W1 scored mean of (2933±733.61) followed by group W0(2453.5±492.48), then group W4 (2184±576), then W2(2108.17±451.28), the least group was W3 (1992±205.63) (Table 1) (Figure 3).

TABLE (1) Fracture Resistance values (in newton) according to the remaining wall variable.

Remaining Wall Number	Mean	Std. Dev.	Min.	Max.
W0	2453.50	492.48	2051	3404
W1	2933.00	733.61	1886	3994
W2	2108.17	451.28	1471	2818
W3	1992.00	205.63	1804	2318
W4	2187.00	576.00	1434	3035

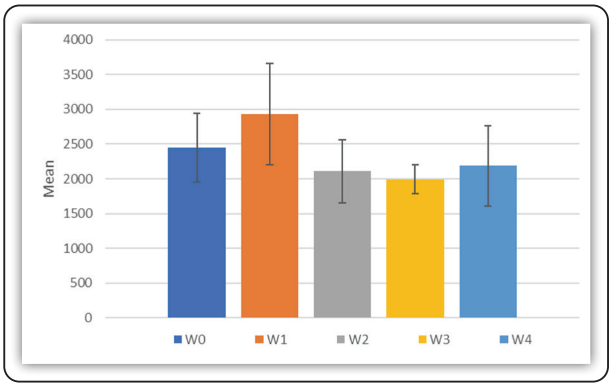

FIG (3) Monolithic endocrowns design for 1 missing wall.

2. Analysis of Variance (ANOVA) One-way ANOVA result

One-Way ANOVA test revealed significance difference between the tested groups (P=0.033).

DISCUSSION

The endocrown restoration was introduced by Pissis in 1995 [11], and in subsequent studies, Bindl and Mormann [7] reported a high clinical survival rate of 95% for endocrowns after an average follow-up period of 26.6 months. Lander and Dietschi [12] also reported that endocrowns were a suitable solution for restoring teeth with short clinical height and missing walls. The endocrown is a useful clinical approach for restoring endodontically treated teeth as it can seal the access cavity and restore the lost part of the tooth at the same time. It can also be a suitable solution for teeth with complicated canals that are difficult to treat with conventional methods, such as calcified, short, or dilacerated canals [9]. Dejak and Młotkowski [14] conducted an in vitro finite element analysis model and found that endocrowns transmitted fewer functional stresses to the dentin of molar teeth than post and core systems. Another study by Sahafi et al. [20] found that endocrown restorations had higher fracture resistance than conventional post and core restorations, further highlighting the benefits of this treatment option.

The present study investigated the effect of the remaining wall number on the fracture resistance of CAD/CAM endocrown restorations in molar teeth. Our results suggest that there is a significant difference in fracture resistance between the groups, as indicated by the statistically significant p-value.

The null hypothesis was rejected, this suggests that having no remaining walls significantly reduces the fracture resistance of endocrown restorations.

The findings of the current study are consistent with previous studies investigating the impact of different parameters on the fracture resistance of endocrowns. According to the findings of Zhu et al.'s study [21], the fracture resistance of endocrowns was found to be higher in cases where there was a larger amount of remaining tooth structure. This could be due to the fact that the conservative preparation of teeth for endocrowns can help protect the remaining tooth structure. However, the current results also suggest that this approach may increase the risk of cohesive bonding failure in the future.

Although prior studies have indicated that the quantity of remaining tooth structure plays a crucial role in determining the fracture resistance of endocrown restorations, our results did not provide evidence to support this claim. Whereas our study found a significant difference in fracture resistance between groups with different numbers of remaining walls, the mean fracture resistance values were inconsistent with the number of remaining walls, suggesting that other factors may play a more critical role in endocrown restoration durability. Despite that, the average fracture loads observed in the test groups greatly exceeded the maximum mastication force exerted in the molar region[22].

However, it is important to note that preserving as much of the residual tooth structure as possible is still a crucial factor in the success of restorative treatment. Studies such as those by Tribst et al. [23], Arunpraditkul et al. [24], and Koosha et al. [25] have emphasized the importance of preserving remaining dental tissue for better biomechanical properties and fracture resistance. Furthermore, retaining the coronal structure can create a larger surface area for adhesive bonding and enhance stress distribution in the region where the tooth and restoration come into contact. This can improve the retention of the restoration and increase its resistance to rotation. Therefore, while the amount of remaining tooth structure alone may not be the sole determinant of endocrown restoration durability, preserving as much of the coronal structure as possible remains an essential consideration for successful restorative treatment.

It is important to note that the current study had some limitations. One of these limitations is that we only investigated the effect of the remaining wall number on fracture resistance, while other factors, such as the type of material used, the preparation technique, and the adhesive system employed, may also impact restoration durability. Additionally, the study used a laboratory testing model, not a natural tooth. Our justification is that, natural teeth are difficult to standardize as each tooth has a different histological and compositional structure due to developmental or aging differences, so further clinical studies are needed to confirm our findings in a real-world setting.

Current results suggest that the number of walls is not directly proportional to maintaining adequate fracture resistance in CAD/CAM endocrown restorations. However, it is worth noting that the minimum amount of remaining tooth structure required for optimal fracture resistance remains unclear, and may depend on various factors, such as the type of material used and the extent of tooth structure loss.

CONCLUSIONS

Based on the limitations of this in-vitro study, it can be concluded that:

1. There was a notable significant difference in fracture resistance between the groups that were tested.
2. The number of remaining walls is not directly proportional to the fracture resistance values.

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