EGYPTIAN
DENTAL JOURNAL
www.eda-egypt.org

VOL. 71, 1767:1775, APRIL, 2025

PRINT ISSN 0070-9484 • ONLINE ISSN 2090-2360

CONSERVATIVE DENTISTRY AND ENDODONTICS

Submit Date : 20-01-2025 • Accept Date : 30-03-2025 • Available online: 25-04-02025 • DOI : 10.21608/edj.2025.354351.3350

FRACTURE RESISTANCE OF ENDODONTICALLY TREATED POSTERIOR TEETH RESTORED WITH THREE DIFFERENT CORONAL RESTORATIONS (AN IN-VITRO STUDY)

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ABSTRACT

ABSTRACT: **Aim of the study:** was to evaluate the fracture resistance of endodontically treated posterior teeth restored with three variable coronal restorations.

Methods: Fifty freshly extracted human mandibular molars were randomly allocated into five groups of 10 samples each. Group A served negative control group / n=10; samples were kept untreated .Group B served as positive control group / n=10; samples were endodontically treated and pulp chamber floor was covered with 2mm thick cement layer to represent endodontically treated tooth fracture resistance in absence of coronal restoration. While groups (C, D and E) served as test groups and were restored with Ever X composite direct restoration, IPS e-max endocrown restoration and IPS e- max full coverage restoration respectively. All specimens were tested for fracture resistance, data were tabulated and statistically analyzed.

Results: The comprehensive comparison of FR values among all five groups; the one-way ANOVA test revealed a significant difference in fracture resistance among the five groups at p value <0.001. The post-hoc LSD analysis indicated that Group A had the highest fracture resistance, followed by Group D, Group C, Group E, and Group B, with all pairwise comparisons being statistically significant.

Conclusion: IPS E-max CAD endocrown and short fiber reinforced composite (Ever X) show significantly higher efficacy in restoring endodontically treated molars and provide higher fracture resistance than the IPS E-max CAD full coverage crowns.

KEYWORDS: Endodontically treated teeth – Endocrown- Fracture Resistance-Crown .

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INTRODUCTION

The main goals of endodontic therapy are preventing and/or curing apical periodontitis, preserving the tooth's functionality for as long as feasible, removing bacteria from the root canal system and closing the root canal to stop bacterial infiltration. (1) Successful an endodontic treatment is multifactorial. Many factors; such as the tooth's structural integrity during root canal preparation and the quality of the final restoration; influence the longevity and functionality of a restoration. (2)

Restoring function and aesthetics to severely damaged teeth that have undergone endodontic treatment is possible using a number of restorations available in the dentistry. Full coverage crowns have been employed for many years as a coronal restorative modality for many teeth, particularly the posterior teeth. However, these days, they have been seen as an un-conservative alternative to restore lost tooth structure. (3)

The year 2019 marked the introduction of Ever-X composite restorations; which include both posterior and flow; The composition includes a resin matrix (30 % by weight), randomly oriented glass microfibers (25 % by weight), and inorganic silanated particle filler (45 % by weight). The used glass microfibers have a diameter of 6 μm and a length ranging from 200 to 300 μm. (4,5) Ever-X Flow has very high fracture toughness because it contains short fibers. The utilization of fibers in Ever-X Flow makes it an ideal material for endodontically treated teeth, as it helps to divert fractures and prevent catastrophic failures. (6,7)

Dental professionals have recognized the value of IPS E-max endocrown restorations which are manufactured using computer aided designing and manufacturing technology (CAD/CAM). These unique restorations have improved patient safety, shorter treatment times, provide longer lasting restorations, with more precise digital impressions, fewer mistakes, more design alternatives and higher treatment appreciation all are factors improving success rate of dental treatments. (8)

Full coverage restorations made from CAD/CAM IPS E-max blocks are also gaining popularity as successful restorative alternative; due to their high fracture load values, favorable esthetics, short laboratory steps, excellent bonding characteristics, and lack of veneering porcelain requirements, as well as their long-term clinical acceptability. (9)

AIM OF THE STUDY

Fracture resistance assessment and comparison of three different coronal restorations for endodontically treated posterior mandibular teeth. The null hypothesis was that there would be no difference in the fracture resistance of the three experimental groups.

MATERIALS AND METHODS

Study design:

This study was a comparative/ control in-vitro study.

Sample size calculation:

A power analysis was designed based on the results of a previous study **(10)** to apply a statistical test regarding the null hypothesis that no difference would be found between fracture resistance of the different tested groups. A total of fifty samples was the predicted sample size (n= 10 samples per group). Sample size calculation was performed using statistical analysis software version 4.3.2 for Windows2.

Sample selection and disinfection:

The research ethics committee of Minia University's Faculty of Dentistry granted its approval to the project in 2022 (number 90/643). Fifty extracted, healthy lower first molars were gathered from the Faculty of Dentistry at Minia University's Department of Oral and Maxillofacial

Surgery. All collected teeth had completely formed roots, no restorative defects or fracture lines, and possess two separate canals in the mesial root and a single canal in the distal root. After removing any calculus or soft tissue attachments, the teeth were disinfected by submerging them in a 5% sodium hypochlorite solution for 10 minutes. After washing, they were soaked in a saline solution and kept in thymol. Human extracted teeth mimic; the bonding-ability properties, modulus of elasticity, and thermal conductivity; the clinical situation, due to this, extracted human mandibular molars were utilized instead of replicas made of metal, plastic, or bovine. [11]

Sample grouping

All teeth had similar sizes and configurations. A digital caliper was used to record their buccolingual and mesiodistal dimensions as well as their root length to ensure no statistical variation was present. [12] The samples were equally divided into five groups; Group A acted as a negative control group with 10 untreated samples; these teeth were utilized to determine the fracture resistance values for healthy teeth so that the repaired teeth could be compared to the intact teeth. Endodontic treatment was performed on all samples of the remaining four groups (B, C, D, and E). Group B, a positive control group consisted of 10 samples. These teeth were endodontically treated and had a 2 mm thick cement covering the pulp chamber floor. Ever X composite (BEAUTIFIL FLOW PLUS F00 - SHOFU) restored Group C samples, IPS E-max CAD/ CAM endocrown restoration was employed for Group D finally IPS E-max CAD/CAM (Ceramil, Mind, DENTSPLY, Sirona) full coverage restoration restored samples of Group E. A single operator followed preformed all restoration steps in a standard manner. [13]

In order to simulate the periodontal ligament, the external surface of roots was covered with a 0.2 mm layer of a light rubber base impression (EasyVac Gasket, 3A MEDES). Their subsequent mounting in self-cured acrylic (acrostone dental and medical supplies, Egypt) was done in an upright position within a standard cylindrical ring, utilizing a centralization device, to guarantee that their position was consistent. For specimen attachment in the mold, self-cured epoxy resin was used because its modulus of elasticity is similar to that of human bone, which mimics the teeth's location in the alveolar bone. [14]

Root canal treatment procedures:

(Groups B, C, D, E)

Access cavity preparations were established using a diamond bur #2 mounted in a hand piece (Synea WA-99LT) and an electric motor (EM-E6 TP, W&H) followed by working length determination by inserting a standard type k file #10 (Dentsply/ Switzerland) into the root canals until the tip of the file was visible at the apex and then 1mm was subtracted from the length. Mechanical-preparation was established using Protaper rotary files (Dentsply/ Switzerland) according to the manufacturer's instructions; mesial canals were prepared up to F2 and distal canals up to F4. Sodium hypochlorite 2.5% was used in between files followed by a final 5 milliliters of saline as a flush. The root canals were dried using corresponding sized Protaper paper points (Dentsply/ Switzerland).

All samples were obturated using the appropriate gutta percha point (either F4 or F2) with sealer AD seal (Dentsply/ Maillefer). A hot plugger was used to remove excess gutta percha (Vetro Power; Mumbai, India), and then left to set for seven days at 37 degrees Celsius in 100% humidity.

Restoration procedures: Group (C, D, E):

Regarding Group C:

Thorough irrigation and drying of the access cavities was performed followed by 37% phosphoric acid was applied to both enamel and dentine (30 and

15 seconds) respectively. Then, after 20 seconds of complete water washing, the cavities were gently dried with air for 5 seconds. Futurabond M+ universal dental bond (VOCO Cuxhaven, Germany) was applied for 10 seconds and then air-thinning for 2 seconds and then cured for 10 seconds under 2000 mW/cm2 of light intensity from APOZA (Enterprise Co., Ltd., Taiwan's LED cordless). A 1mm thick layer of Ever X Flow was placed to cover the floor of the access cavity and subsequently Light curing was performed using a 2000 mW/cm2 LED cordless light from APOZA (Enterprise Co., Ltd. of Taiwan). successive 2mm thick layers of Ever X posterior were then applied in to the access cavity and light cured using the same curing parameters; leaving 1mm of the occlusal surface to be restored with Z350XT composite (3M ESPE) to a standard predetermined contour. [5] . The surface of the restorations was finished and polished with SofLex discs (3M ESPE).

Regarding Group D and E (Preparation, Designing & milling of IPS E. max CAD/ CAM restorations):

For the Endocrowns a conventional butt-joint preparation, three millimeters coronal to the CEJ, was established for endocrown restoration. Followed by a digital impression using a scanner (E2 Lab scanner / Denmark) and transported to the STL format then sent to the lab directly

For the Crowns a standard full coverage preparation with deep chamfer margin (1mm) and a 2mm occlusal clearance was established. Followed by a digital impression using digitally scanned using E2 Lab scanner (3 shape, Copenhagen/ Denmark) and transported to the lab.

Designing was conducted using software (Dental system 2016 v 1.6.3/ Denmark), the data was sent to the milling machine (vhf CAM 5S1; vhf camfacture AG, Ammerbuch, Germany) and the restorations were milled, then they were examined for full seating on their respective prepared teeth.

Cementation procedures for endocrown restorations and full coverage crown restorations:

For the ceramic endocrowns and crowns the internal surface were etched, a silane coupling agent was applied and left 60 seconds to dry. Next, the fitting surfaces were coated with self-adhesive dual cure depend x cement. As for the tooth surface acid etching with 35% phosphoric acid for 30 s was performed followed by a 10s rinse then two coats of 3M adhesive bond were applied and air dried for 5 s before being light cured for 10 s. Then, resin cement was utilized to cement the restorations in to place with a dual curing process.

Fracture Resistance assessment:

The specimens were tested for fracture resistance using a computer-controlled material testing machine (Model 3345; Instron Ind Products, Norwood, MA, USA) with a 5 kN load cell. [15]

Statistical analysis:

All data were collected, tabulated and recorded using a special computer software (Instron® Bluehill Lite Software), as it offers valid, reliable and repeatable results. [18] Data distributions normality was evaluated using Shapiro-Wilk test. The results of the test were not statistically significant with $p > 0.05$, indicating a normal distribution of the data and, thus, allowing the use of parametric statistical tests.

RESULTS

The fracture resistance (FR) values were calculated in Newtons. For all samples; means, standard deviations, minimum and maximum values; were established. The statistical analysis was performed using SPSSv.17, and charts were created using Microsoft Excel 2016. Statistical significance was determined using a significance level of 0.05.

Comparison between FR of the study groups A, B, C, D and E: tab (1), fig (1,2).

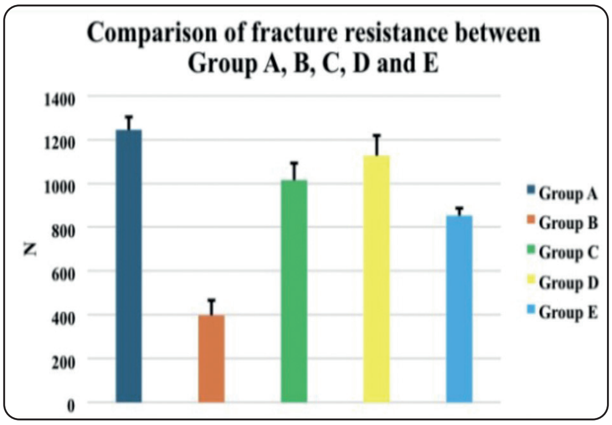

Fig. (1) Bar chart representing mean value of FR for all study group

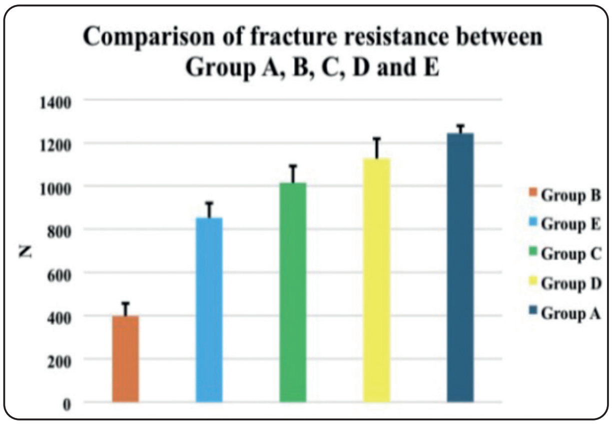

Fig. (2) Bar chart representing mean value of FR in ascending order

Regarding the comprehensive comparison of FR values among all five groups: Groups A, B, C, D, and E; the one-way ANOVA test revealed a significant difference in fracture resistance among the five groups at p value <0.001. Post-hoc LSD analysis indicated that Group A "1244.32±59.46 "had the highest fracture resistance, followed by Group D "1126.27±92.86", Group C "1014.58±78.19", Group E "852.02±34.76", and Group B "397.23±68.85", with all pairwise comparisons being statistically significant.

TABLE (1) Mean and standard deviation (SD) values of FR of all the study groups:

	N	Fracture resistance Range Mean ± SD
Group A	10	(1182.03-1347.1) [a] 1244.32±59.46
Group B	10	(311.7-499.31) [e] 397.23±68.85
Group C	10	(943.91-1193.12) [c] 1014.58±78.19
Group D	10	(1003.69-1300.02) [b] 1126.27±92.86
Group E	10	(811.93-911.33) [d] 852.02±34.76
P value		***<0.001****

-One Way ANOVA test for quantitative data between the five groups followed by post hoc LSD analysis between each two groups.

-Superscripts with different small letters refer to significant differences between the two groups.

****: Significant level at p value < 0.05***

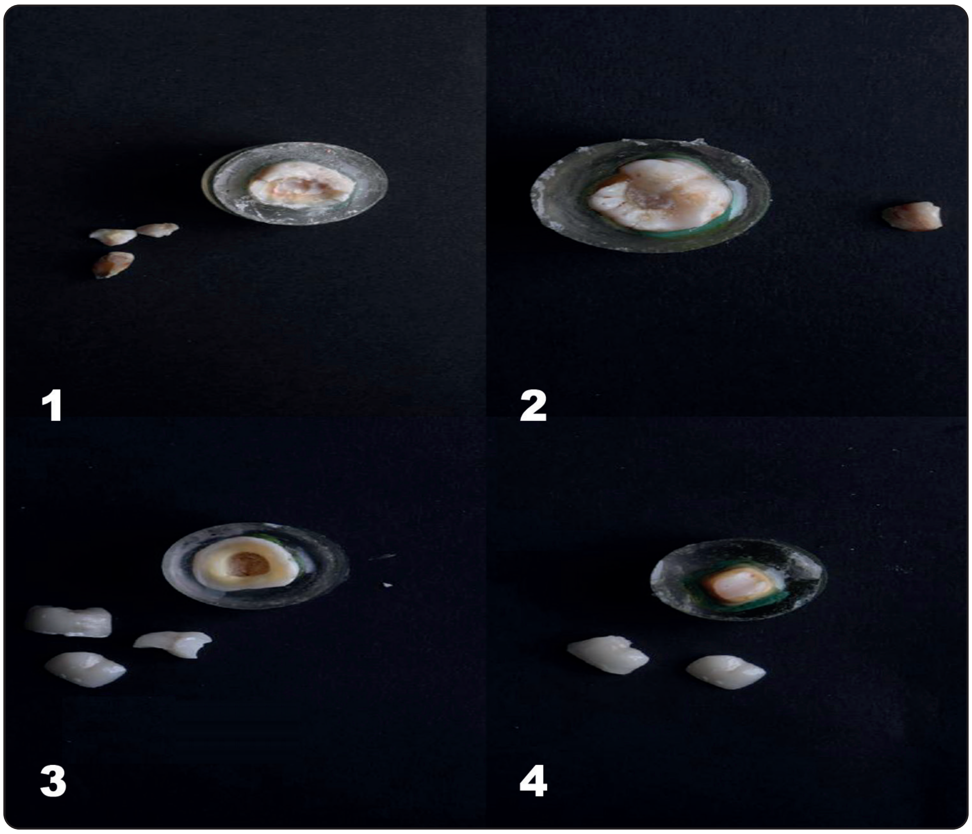

Fig. (3) Showing different group samples following FR test. 1; group B (ETT with 2mm cement covering pulp chamber floor), 2; group C (ETT restored with Ever X composite, 3; group D (ETT restored with IPS E- max endocrown, 4; group E (ETT restored with IPS E -max full coverage crown)

DISCUSSION

Due to the ongoing development, improvement, and implementation of new procedures and technology, endodontics is an ever-evolving subject. Various materials and procedures have been proposed and developed to extend the life of teeth that have had endodontic treatment. These approaches aim to maintain the optimal root strength while also balancing biological, mechanical, functional, and cosmetic requirements. [16]

By comparing fracture resistance across all the study groups, it was found that there was a significant difference in FR with in the three tested coronal restorations groups (C, D, and E). Group D had the highest FR value, followed by group C, and then group E. It is important to note that all the three groups recorded FR values higher than the normal masticatory loading range. [17,18]

The results of this study corroborate previous research showing that lithium disilicate endocrowns exhibit superior fracture resistance under axial and lateral loads (**El Ghoul etal**) [20] and higher load-to-failure after mechanical fatigue **(Tribst etal).** [21] Group C, which was restored with Ever X composite, exhibited lower FR than group D, which was restored with IPS e.max CAD endocrown.

However, there are a number of limitations to using direct resin composites to restore endodontically treated teeth, such as marginal leakage, postoperative sensitivity, and secondary caries. Despite the fact that they are commonly used because of their low cost, good aesthetic qualities, ease of handling and repair, and preservation of tooth tissues through adhesive bonding; the tooth is more likely to have wear, bulk fractures, marginal deficiencies, and secondary caries, especially in the regions that endure the majority of stresses in the posterior area. Group D higher fracture resistance is due to IPS e.max CAD blocks, which are indirectly manufactured and less technique sensitive than the direct technique. This makes them ideal for large posterior restorations, as they do not require multiple layers during application, which can be influenced by factors such as the operator's skill, the forces exerted during composite layer application, the intensity and direction of the light curing, and the distance between layers which are factors influencing direct restorations. (19)

The use of computer-aided design and manufacturing (CAD/CAM) ceramic materials in the fabrication of endocrowns may also have a role in these outcomes, since they allow for the creation of restorations with better anatomical contour, better fracture resistance (FR), and an exact intra-coronal fit. All of them contribute to a more balanced distribution of stress within the tooth structure. Many studies have shown that endocrowns are more successful than other coronal restorations. For example, a 2019 systematic review found that molars restored with endocrowns had excellent survival rates in the short, medium, and long terms. This is probably due to the unique microstructure of the material, which has a high modulus of elasticity and fracture strength similar to that of natural dentition (enamel and dentine). Additionally, the presence of nano zirconia reinforces the glassy matrix of lithium silicate, creating a fine crystalline homogeneous structure with exceptionally high mechanical properties. **(20,21)** Furthermore, compared to crowns (with or without post-retained repair), endocrowns had a lower rate of catastrophic failures (6% of root fractures vs. 29%). (22)

Group E, which received IPS e.max CAD full coverage crowns for restoration, had significantly lower fracture resistance values compared to group C, which received ever X composite. These finding are in line with **Krishan et al. (23)** who stated that the greater the preservation of the tooth structure, particularly the Pericervical dentin, the higher the fracture resistance. This was in accordance with **Manisha et al.** (24) who demonstrated that using adhesion at the orifice level and in the pericervical region actually improves FR of endodontically treated teeth.

In a finite element investigation on mandibular first molars; elevated stress concentration at the orifice level were found; this was attributed to canal enlargement during chemo-mechanical preparation and the necessity for coronal external reduction during full coverage restoration. (25,26) Because of the location and magnitude of these stresses, vertical root fractures can develop in the root's cervical region and then spread apically and/or coronally. **(27)** One possible explanation for this finding is that different restorations require different methods of preparation. Additionally, in the case of endocrown restoration, it is clear that the critical PCD thickness is preserved which explains its higher fracture resistance.

Another possible explanation is that the endocrown high elastic modulus glass ceramic bulk fills the whole pulp chamber and occlusal surface. Consequently, the material absorbs more energy and transfers less to the dental structure, particularly to the PCD around the restoration. This effect, known as stress shielding phenomenon, causes the stress close to these regions to decrease. (28)

The results of this in-vitro investigation disprove the null hypothesis that the three experimental groups would have identical fracture resistance.

CONCLUSION

1. IPS E-max CAD endocrown and short fiber reinforced composite (Ever X composite) show significantly higher efficacy in restoring endodontically treated molars and provide higher fracture resistance than the IPS E-max CAD full coverage crowns.
2. IPS E-max CAD endocrown (Group D) will perform the highest fracture resistance in endodontically treated posterior teeth.

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