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Original Article

Dentistry Section

Comparison of Fracture Resistance of Endodontically Treated Human Mandibular Molars Restored with Paracore Dual-cure Composite and EverX Posterior Composite: An In-vitro Study

RUPANKAR DEY[1], RAGHUNATH SIL[2], PRITI DESAI[3], LABONI GHORAI[4]

ABSTRACT

Introduction: Endodontic treatment is an elective dental procedure that is performed when the dental pulp becomes irreversibly damaged or necrotic due to dental caries or trauma. Considerable loss of coronal tooth structure together with large cavity designs and access cavities compromise the mechanical behaviour of endodontically treated teeth, making them more susceptible to catastrophic fracture. Hence, following endodontic treatment, it is imperative to provide a suitable restorative material to avoid subsequent tooth fracture following occlusal loading.

Aim: To assess and compare the fracture resistance of endodontically treated human mandibular first molars restored with dual-cure composite (Paracore) and newer short fibre-reinforced composite (EverX Posterior) in occlusal (Class-I) cavities.

Materials and Methods: The in-vitro study was performed in January 2023 to February 2023 using 30 freshly extracted sound adult human mandibular first molars (divided in three groups) at Guru Nanak Institute of Dental Sciences and Research, Kolkata, West Bengal, India. A total of 10 intact teeth served as positive controls (Group-1). Class-I access cavity preparation followed by endodontic therapy was performed on the remaining 20 teeth, which were randomly divided into two groups (Group-2 and 3), which were coronally restored with Paracore dual-cure composite and EverX posterior composite, respectively. Teeth were mounted in acrylic resin, and subsequently, measurements of fracture strength were performed using a universal testing machine. Data were analysed statistically using One-way Analysis of Variance (ANOVA), Post-Hoc Tukey, and Chi-square tests, with a p-value of ≤0.05 considered as the level of significance.

Results: The mean fracture resistance values (in kilonewtons) were as follows: Group-1 (1.5750 kN) > Group-3 (1.0450 kN) > Group-2 (0.6350 kN). Group-3 showed a significantly higher mean fracture resistance value (p=0.035) than the other experimental group. The levels of fractures were also evaluated, and a significant difference between the groups was noted (p=0.001), concluding that the frequencies of unfavourable fractures were significantly higher in Group-2 than in the other groups.

Conclusion: Short fibre-reinforced composite (EverX) showed fracture resistance similar to that of a natural tooth and hence can be used as a direct core build-up material to reinforce the remaining tooth structure in endodontically treated teeth.

Keywords: Core build-up material, Endodontic therapy, Fibre-reinforced composite, Occlusal cavities

INTRODUCTION

Over the past decades, endodontic treatment has been the mainstay for salvaging a pulpally exposed tooth. However, the treatment is considered incomplete until an appropriate post-endodontic coronal restoration is done, as these endodontically treated teeth are generally weaker than sound teeth and are more vulnerable to fracture [1]. Trope M et al., believed that endodontically treated teeth are weakened by the loss of tooth structure from caries, preparation of access cavity, and instrumentation of the root canal [2]. In addition, the loss of moisture in dentin, age-induced dentinal changes, decreased proprioceptive function, conditioning of radicular dentin with endodontic irrigant and medicament, and the effect of bacterial colonisation on the dentin substrate have been considered the major factors for the loss of resiliency and fracture resistance of endodontically treated teeth [3]. Therefore, intracoronal strengthening of these teeth is important, particularly in posterior teeth where the fracture of undermined tooth structure is common with the stress generated by normal masticatory forces. An ideal post-endodontic restoration has the advantages of the preservation of the remaining tooth structure, maintenance of aesthetics and function, and prevention of microleakage [4].

Studies have suggested various types of post-endodontic restorations, which include amalgam restorations, composite materials, cast restorations, and full-coverage crowns. However, amalgam restorations lack adhesion to the tooth structure and promote microcrack propagation under fatigue loading, while full-coverage crowns and cast restorations involve multiple visits and increased cost [5-7]. Hence, composite resin is often preferred by clinicians due to its excellent aesthetic and mechanical properties with the ease of handling [8]. However, conventional composites have the inherent drawbacks of polymerisation shrinkage and insufficient fracture resistance [9]. These limitations have encouraged researchers to innovate a new generation of composites. ParaCore, a dual-cure composite that has been developed as a core build-up material, has promised to have better fracture resistance compared to conventional composites. Composites reinforced with fibres such as EverX Posterior improve marginal integrity and are reported to have better fracture resistance properties [10,11].

Since the literature lacks sufficient data regarding the strength and success of these newer composite materials, this in-vitro study was proposed to assess and compare the fracture resistance of endodontically treated human mandibular first

molars restored with dual-cure composite (Paracore) and newer short fibre-reinforced composite (EverX Posterior) in occlusal (Class-I) access cavities.

MATERIALS AND METHODS

The in-vitro study was performed in January 2023 to February 2023 using 30 freshly extracted sound adult human mandibular first molars. Patients visiting the OPD of Guru Nanak Institute of Dental Sciences and Research, Kolkata, West Bengal, India were examined, and mandibular first molars with sound tooth structure but required extraction due to weak periodontal status, orthodontic, or prosthetic reasons were selected for the study. Since the study was carried out in-vitro, ethical clearance was deemed unnecessary by the ethical committee. The study was conducted in accordance with the principles of the Helsinki Declaration of 1975, as revised in 2000.

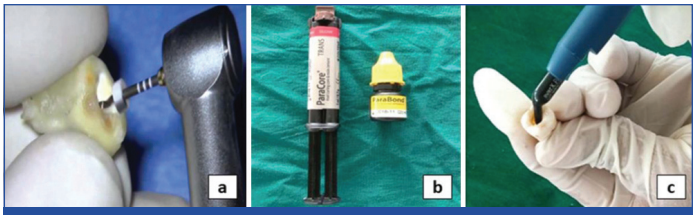
Inclusion and Exclusion criteria: Fully erupted teeth with mature apices and sound tooth structure were included in the study. Teeth with open apices, resorption, developmental anomalies, carious lesions, crown or root fractures, severe attrition or abrasion, and previous restorations were excluded from the study.

Study Procedure

Sample size: A total of 30 samples were included, with 10 in each group.

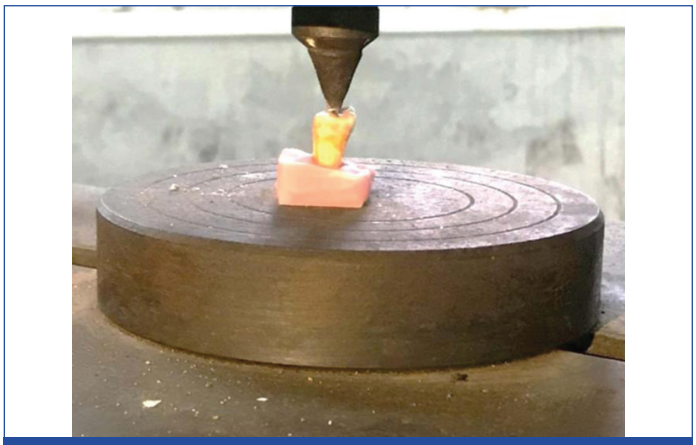
Sample preparation: Following gross debridement of all tooth specimens under running tap water, cleaning of calculus deposits and any attached periodontal tissue was performed using an ultrasonic scaler unit (Biosonic, Coltene Whaledent, Switzerland) and then stored in distilled water at 4°C until further processing. A total of 10 intact teeth were randomly selected and used as positive controls (Group-1). An endodontic access cavity of 3×3 mm dimensions was prepared in each of the remaining 20 teeth using 2.3 mm round and 1.4 mm straight fissure diamond points (SS White, USA) with a water-cooled high-speed air-rotor handpiece (NSK, Japan), and the remnants of pulpal tissue were extirpated using a barbed broach (Dentsply Maillefer, Switzerland). The working length was assessed by subtracting 1 mm from the length obtained by inserting a size 10 K file (Mani Prime Dental Pvt., Ltd.) into each canal until it could be seen at the apical foramen. Root canal instrumentation [Table/Fig-1a] was carried out with sequential ProTaper Gold Nickel Titanium (NiTi) rotary files (Sx, S1, S2, F1) {Dentsply Maillefer, Ballaigues, Switzerland} in a crown-down technique using Glyde {10% carbamide peroxide and 15% Ethylenediaminetetraacetic acid (EDTA), Dentsply Maillefer} as the lubricant. Following each instrumentation, the root canals were recapitulated and adequately irrigated with a 2.5% sodium hypochlorite solution. Subsequently, the canals were dried with absorbent paper points (Dentsply Maillefer, Ballaigues, Switzerland) and obturated with F1 ProTaper Gold gutta-percha points and AH Plus root canal sealer (Dentsply Maillefer, Ballaigues, Switzerland). The gutta-percha was then cleaned up to the level of the canal orifice.

Subsequently, the endodontically treated teeth were randomly divided into two groups: Group-2 and Group-3, with 10 teeth in each group. The teeth were then air-dried, and the bonding agent G-Bond (GC, Japan) was applied in Group-2, while ParaBond (Coltene Whaldent, Switzerland) was applied in Group-3, following the manufacturer's instructions. They were then light-cured for 20 seconds using an LED light curing equipment (Coltolux LED, Coltene Whaldent, Switzerland) with an intensity of 1400 mW/cm^2. All the teeth samples in Group-2 were restored with Paracore dual-cure composite [Table/Fig-1b], and those in Group-3 were restored with EverX Posterior [Table/Fig-1c]. All the restorations were light-cured for 40 seconds. The final finishing and polishing of the restorations were done with fine-grained composite finishing and polishing discs (Soflex, 3M, Japan).



[Table/Fig-1]: a) Root canal instrumentation with sequential ProTaper Gold NiTi rotary files; b) Paracore dual cure composite; c) Teeth being restored with EverX posterior composite.

Fracture testing: For fracture testing, each tooth specimen was vertically mounted 2 mm below the Cementoenamel (CEJ) junction in an auto-polymerised acrylic resin block measuring 25×25×20 mm. Before mounting, a layer of light body elastomeric impression material simulating the periodontal ligament was placed around the root surfaces. Each mounted tooth was then subjected to static loading using a Universal Testing Machine [Table/Fig-2] with a cross-head speed of 0.5 mm/minute, onto the central pit vertically down the long axis of the tooth until tooth fracture occurred. The force required to fracture each tooth was recorded in Kilo-Newton (KN). In addition to the fracture resistance values, the levels of fractures were also evaluated. Fractures limited to the enamel levels can be considered favourable as they can be easily repaired without additional reinforcement. However, when the fracture line extends up to the level of dentine or below the CEJ, it is considered it is considered unfavourable, as more complex restorative procedures may be required or may even result in tooth loss [12].



[Table/Fig-2]: Mounted tooth subjected to static loading using a Universal Testing Machine.

STATISTICAL ANALYSIS

The data thus obtained were tabulated, and statistical analysis was performed using Statistical Package for the Social Sciences (SPSS) version 16.0. The data were evaluated statistically using One-way ANOVA, Post-Hoc Tukey, and Chi-square tests. The level of significance was fixed at p=0.05, and any value ≤0.05 was considered to be statistically significant.

RESULTS

It was observed that the mean fracture resistance values (in kN) were as follows: Group-1 (1.5750 kN) > Group-3 (1.0450 kN) > Group-2 (0.6350 kN). Group-3 (teeth restored with EverX Posterior) showed a significantly higher mean fracture resistance value than the other experimental group (Group-2: teeth restored with Paracore dual-cure composite) (p=0.035) and a lower mean fracture resistance value than the control group, but the data were not statistically significant (p=0.134) [Table/Fig-3,4].

The present study further evaluated the levels of fractures. In both Group-1 and Group-3, the fracture modes were mostly at the level of enamel (favourable), whereas all the fractures in Group-2 were at or below the level of CEJ (unfavourable). Hence, the frequencies of unfavourable fracture patterns varied among different groups, with

Groups	n	Mean	Std. deviation	Std. error	p-value
Control group (Group-1)	10	1.5750	0.10607	0.07500	0.003*
Teeth restored with Paracore (Group-2)	10	0.6350	0.35750	0.11305	
Teeth restored with EverX (Group-3)	10	1.0450	0.33537	0.10605	
Total	30	0.9068	0.43624	0.09301	

[Table/Fig-3]: Mean value of fracture resistance in all the three groups.
*Significant p≤ 0.05

(I) Group	(J) Group	Mean difference (I-J)	Std. Error	p-value
Teeth restored with Paracore (Group-2)	Teeth restored with EverX (Group-3)	-0.41000*	0.15127	0.035*
	Control Group (Group-1)	-0.94000*	0.26200	0.005*
Teeth restored with EverX (Group-3)	Teeth restored with Paracore (Group-2)	0.41000*	0.15127	0.035*
	Control group (Group-1)	-0.53000	0.26200	0.134
Control Group (Group-1)	Teeth restored with Paracore (Group-2)	0.94000*	0.26200	0.005*
	Teeth restored with EverX (Group-3)	0.53000	0.26200	0.134

[Table/Fig-4]: Pair-wise comparison of fracture resistance between the groups.
*The mean difference is significant at the 0.05 level

the highest rate reported in Group-2 (100%), followed by Group-3 (30%), and the lowest in Group-1 (10%). A significant difference in fracture patterns between the groups was noted according to Chi-square analysis (p=0.001), implying that the frequencies of unfavourable fractures were significantly higher in Group-2 compared to other groups [Table/Fig-5].

Type of fractures/ groups	Control group (Group-1) (n=10)	Paracore (Group-2) (n=10)	EverX (Group-3) (n=10)	Total (N=30)	p-value
Favourable	9 (90%)	0 (0%)	7 (70%)	16 (53.3%)	0.001*
Unfavourable	1 (10%)	10 (100%)	3 (30%)	14 (46.66%)	

[Table/Fig-5]: Comparison of type of fractures between the groups.
*p≤0.05 considered statistically significant

DISCUSSION

Clinical experience and research reveal that the tooth becomes weakened due to the reduction of tooth structure during an endodontic procedure, with the access opening only contributing to a reduction of the relative rigidity of the tooth by 5% [13]. Hence, an endodontically treated tooth possesses a higher risk of fracture, which has been conclusively stated by several studies [14-16]. Determining the amount of remaining tooth structure for optimum strength against fracture and selecting the type of restorative material are thus the key factors for a successful treatment outcome. Keeping this in mind, the present in-vitro study was designed for the assessment of differences in fracture resistance and comparison of fracture patterns between intact teeth and teeth that underwent restoration with two different coronal restorative materials following endodontic therapy. In the present study, mandibular first molars were selected as they are the most commonly extracted teeth among the endodontically treated posterior teeth [17].

The importance of conservative cavity preparation in minimising the reduction in the strength of the remaining tooth structure is well documented. In comparison to an endodontically treated tooth, an intact tooth is much more resistant to fracture due to the presence of tooth-reinforcing structures such as the roof of the pulp chamber and the marginal ridges [18]. In the present study, occlusal Class-I access cavities were prepared because of the importance of conservative access preparations to preserve the original strength of the tooth and to lay emphasis on the evaluation of the efficiency of the newer restorative systems currently available.

The choice of an ideal restorative material that can compensate for the lost coronal tooth structure is considered crucial for the success of post-endodontic restorations [12]. Several studies have proven that composite restorative material reinforces the remaining tooth structure [19,20]. This adhesive resin develops both micromechanical retention with the tooth structure and chemical bonds via phosphate esters, which interact with calcium ions present in the tooth. However, reinforcement of the weakened tooth structure is facilitated by the low elastic modulus of composite resin, which enables the transmission of the energy produced by the compressive forces to the adjacent dental structure [21]. Although conventional composites have certain drawbacks as a core build-up material, today various newer generation composites have emerged that claim to overcome these limitations of their predecessors and possess superior fracture resistance, eliminating the need for more extensive tooth preparation for the placement of laboratory-aided full-coverage prosthesis, thereby providing potential economic benefits to patients [12].

In the present in-vitro study, the fracture strength of a dual-cure composite (Paracore) and a newer short fibre-reinforced composite (EverX Posterior) were compared. The present study demonstrated that the intact teeth in Group-1 had the highest mean fracture resistance because there was no loss of tooth structure. Among the experimental groups, Group-3 (teeth restored with EverX posterior composite) showed a significantly higher mean fracture resistance value than Group-2 (teeth restored with Paracore dual-cure composite). This can be attributed to the large filler particle size of 0.5-1.6 mm present in EverX Posterior compared to the average filler particle size of 2 µm in Paracore [22,23]. Furthermore, the filler content of Paracore being less than that of EverX Posterior, early crack propagation and decreased fracture resistance are reported to be its major limitations [24]. The new fibre-reinforced composite EverX Posterior is a nanohybrid composite impregnated with E-glass fibres, which are known to be resistant to tension and impede crack propagation in the composite mass. The high tensile strength, density, and percentage of elongation of this new-generation composite help to withstand high stresses without fracturing [11].

Similar results were obtained in the study conducted by Kamath AK et al., where the fracture toughness of EverX posterior was comparable to that of a healthy intact tooth, and EverX posterior proved superior to Smart Dentin Replacement (SDR) and 3M Filtek bulk-fill [25]. Shah KK et al., in their study on endodontically treated mandibular premolars, showed that Fibre-reinforced composite (EverX Posterior) had the highest resistance to fracture compared with nanohybrid composite (Filtek Z350), which was comparable to that of intact teeth [26].

Several studies have shown that when force is applied along the long axis of the tooth, the force is transmitted fairly uniformly, determining the maximum loads that lead to fracture [27,28]. In the present study, force was also applied vertically at a constant speed using a universal testing machine to evaluate the capacity of the restorative materials used to support vertical tension in areas of high masticatory load.

In addition to the fracture resistance values, the fracture patterns were also evaluated in the present study. In both Group-1 and Group-3, the fracture modes were mostly favourable, suggesting adequate reinforcement in endodontically treated teeth. On the contrary, all the fractures in Group-2 were at or below the level of CEJ, indicating its less reinforcing effect. A significant difference in fracture patterns between the groups was noted (p=0.001), with the frequencies of unfavourable fractures being significantly higher in Group-2 than in the other groups. This result is as per the study conducted by Mudunuri S et al., where the highest proportion of favourable fractures was observed with fibre-reinforced composites compared with the no-fibre group, although the data was not statistically significant [29].

Limitation(s)

One important limitation of the present study is that it was carried out under in-vitro conditions. The in-vitro results cannot be directly extrapolated to a clinical setting such as the oral cavity. Clinically, teeth are exposed to various types of forces, unlike the method of applying a continually increasing load to teeth, as performed in the present study. Hence, more relevant in-vitro test methods should be innovated to simulate the failure mechanisms of restored teeth that are observed clinically. Furthermore, it is necessary to assess and compare fracture resistance and fracture patterns according to the types of restorations performed.

CONCLUSION(S)

Within the limitations of the present in-vitro study, the highest fracture resistance is exhibited by the short fibre-reinforced composite over the other composite filling materials. Hence, it can be concluded that EverX Posterior, which displayed the maximum reinforcement of the remaining tooth structure, can be used as a direct core build-up material in endodontically treated teeth.

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PARTICULARS OF CONTRIBUTORS:
1. Medical Officer, Department of Dentistry, Katwa Subdivision Hospital, Purba Burdwan, Katwa, West Bengal, India.
2. Associate Professor, Department of Conservative Dentistry and Endodontics, Guru Nanak Institute of Dental Sciences and Research, Kolkata, West Bengal, India.
3. Professor, Department of Conservative Dentistry and Endodontics, Guru Nanak Institute of Dental Sciences and Research, Kolkata, West Bengal, India.
4. Associate Professor, Department of Oral Medicine and Radiology, Kusum Devi Sunderlal Dugar Jain Dental College and Hospital, Kolkata, West Bengal, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:
Laboni Ghorai,
6, Ram Gopal Ghosh Road, Cossipore, Kolkata-700002, West Bengal, India.
E-mail: dr.labonidey@gmail.com

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