Influence of Three Different Restorative Materials on the Fracture Resistance of Endodontically Treated Tooth

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ABSTRACT

BACKGROUND

We wanted to investigate in vitro the fracture resistance (FR) of endodontically treated teeth (ETT) with a conservative access cavity restored using three different restorative materials.

METHODS

Forty freshly extracted human mandibular molars were collected. All teeth were cleaned of tissue fragments and visible debris by ultrasonic scaler and were stored in saline. The collected teeth were divided into four groups of 10 specimens each. Teeth were randomly allocated into the four groups 'Group 1', 'Group 2', 'Group 3', 'Group 4','. Group 1: control group, sound teeth without any preparation or restoration; Group 2: conservative endodontic access cavity (CEAC), RCT, and amalgam restoration; Group 3: CEAC, RCT and restored with direct composite restoration; Group 4: CEAC, RCT and restored with Cention N. The fracture load was determined in newton (N), and the mode of fracture was recorded and classified by using a stereomicroscope.

RESULTS

Among the four groups, Group 1 (control group) had the highest fracture resistance (2.390 KN). This difference was significant with $p<0.05$. There was a significant difference between the control group and ETT groups. Within the Endodontically treated groups, group 3 (composite, 1.300 KN) had the highest fracture resistance followed by group 4 (1.24 KN) and group 2 (amalgam 1.192 KN). With regard to the type of fracture, the composite group had 100% unfavourable fractures, whereas the Cention N group showed more favourable fractures when compared to other groups.

CONCLUSIONS

All restorative techniques tested led to a significant reduction in fracture resistance of endodontically treated mandibular molars. Cention N had more favourable fractures than composite and amalgam even though composite had the highest fracture resistance.

KEYWORDS

Fracture resistance, Cention N, Composite, CEAC

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BACKGROUND

Endodontic treatment is generally associated with reductions in the resilience and fracture resistance of the treated teeth.[1] The primary factors for loss of tooth structure include dental caries, cavity preparation, endodontic access, and root canal preparation.[2] Loss of dentine, including anatomic structures such as cusps, ridges, and arched roofs of the pulp chamber, may result in tooth tissue fracture after the final restoration.[3] The position of the tooth in the dental arch, tooth anatomy, and changes in mechanical and physical properties of dentin can also influence the fracture resistance (FR) of teeth.[4,5] Therefore, intracoronal strengthening of teeth to protect them against fracture is essential, particularly in posterior teeth where stresses generated by forces of occlusion can lead to fracture of unprotected cusps.[3] Restoration of endodontically treated tooth is designed to protect the remaining tooth structure, prevent reinfection of the root canal system, and replace the missing tooth structure.[6]

Although long-term functional survival rates can be high for initial endodontically treated permanent teeth, they are generally more susceptible to fracture than teeth with vital pulps.[7] Thus, root canal treatment should not be considered complete until the final coronal restoration has been placed. An optimal final restoration for a root-filled tooth maintains aesthetics and function, preserves remaining tooth structure, and prevents microleakage. The quality of the coronal reconstruction directly affects the success and the longevity of endodontic treatment.[8]

Thus the aim of the study was to investigate the influence of various restorative materials on the fracture resistance of endodontically treated teeth.

METHODS

Forty freshly extracted human mandibular molars were collected. All teeth were cleaned of tissue fragments and visible debris by ultrasonic scaler and were stored in saline. The specimens were stored in saline at room temperature to prevent dehydration.

Samples and Grouping

The sample teeth were divided into four groups of 10 specimens each. Teeth were randomly allocated into the four groups by picking a paper from a brown bag marked either 'Group 1', 'Group 2', 'Group 3', 'Group 4', 'Group 5', or 'Group 6'. Group 1: control group, sound teeth without any preparation or restoration; Group 2: conservative endodontic access cavity (CEAC), RCT, and amalgam restoration; Group 3: CEAC, RCT and restored with direct composite restoration; Group 4: CEAC, RCT and restored with Cention N.

Endodontic Protocol

A standard straight-line conservative access cavity outline was drawn on the occlusal surface of the tooth and prepared to maintain the mesial and distal marginal ridges (Figure 1). Surgical carbide round burs (Dentsply Tulsa Dental Specialties, Tulsa, Oklahoma, USA) were used starting with size 4 mm in diameter and 25 mm shank length, followed by size 1.4 mm (diameter) and 25 mm (shank length). The buccal and lingual cusps were maintained (Figure 1). The pulp tissues were removed with barbed broaches. The working length was determined by inserting a #10 size K-file (Dentsply Tulsa Dental Specialties) into the canal and determining the point at which the file exited the apical foramen of the root. The file length was then reduced by 0.5 mm, and the glide path was established. The root canal preparation (cleaning and shaping) was performed with machine-driven rotary files ProTaper following the sequence S1, S2, F1, F2, F3 (Dentsply Maillefer, Ballaigues, Switzerland) using ethylenediaminetetraacetic acid solution (EDTA) for 30 s to remove the smear layer. After each episode of canal instrumentation, the root canals were irrigated with at least 15 ccs of 2.26% sodium hypochlorite (NaOCl) solution using a 27-gauge endodontic needle. The canals were dried with paper points and obturated with matching Gutta-Percha points using cold lateral condensation technique and AH 26 sealer.

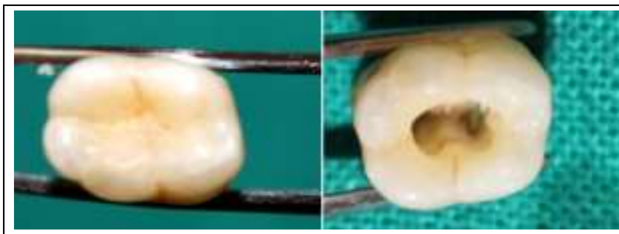

Figure 1. Sound Unprepared Tooth (left). After Access Cavity Preparation Maintaining Mesial and Distal Marginal Ridges (Right)

Amalgam Restoration (Group 2)

The teeth selected for this group received a slight modification of the endodontic access cavity to follow the principles of cavity preparation for a class I amalgam restoration (25). The dimensions of the mesial and distal marginal ridges (not less than 1.5 mm) were maintained. The cavity was cleaned and a high-copper amalgam restoration (Cavex Avalloy-II spills, Cavex Holland BV, Harleem, The Netherland), was applied and condensed in increments until filled the cavity and carved to the proper occlusal anatomy following the standard technique (25). Amalgam restorations were finished and polished using the standard technique after 24h (25). For standardization, all procedures were performed by only one operator (S.M.).

Composite Restoration (Group 3)

Ten teeth were assigned to this group and received composite restorations without modification in the original access cavity preparation. The cavity was cleaned, etched (Ultraetch, Ultradent, South Jordan, Utah, USA), and a bonding agent using a fifth-generation 40% filled ethanol-based adhesive system (Ivoclar Vivadent) was applied, gently air thinned and light-cured for 20 s according to the manufacturer's recommendations. The composite restoration (TE Econom Plus, Ivoclar Vivadent) was applied in increments and light-cured (Bluephase; Ivoclar Vivadent). Occlusal anatomy was made according to the standard occlusal anatomy of the mandibular first molar. For standardization, all procedures were performed by only one operator (M.S.).

Cention N (Group 4)

Ten teeth were assigned to this group and received Cention N (Ivoclar Vivadent) restorations without modification in the original access cavity preparation. As it is a dual-cure filling material, it starts to slowly self-cure as soon as powder and liquid are mixed. Cention N is a full volume replacement material, designed to be applied quickly and conveniently in bulk. In this context, it is important that the material exhibit low polymerization shrinkage and low shrinkage force.

Fracture Resistance Test

Teeth in Groups 2, 3, and 4 were stored for 24 h after finishing the restorations before exposing them to the fracture resistance test. The universal testing machine (Instron 8500 Plus; Instron, Canton, Massachusetts, USA) was used to deliver a compressive load to the central fossa at a crosshead speed of 1 mm/ min until failure (Figure 2).
The fracture load was determined in newton (N), and the mode of fracture was recorded and classified by two independent observers using a stereomicroscope (Stereoscopic zoom microscope; Nilpa 10 x). The favourable fracture was defined as are a pairable failure, including adhesive failure that is above the level of bone stimulation, while unfavourable failure was defined as a non-repairable or vertical root fracture (Figure 3).

Figure 2.* *Specimen under Universal Testing Machine

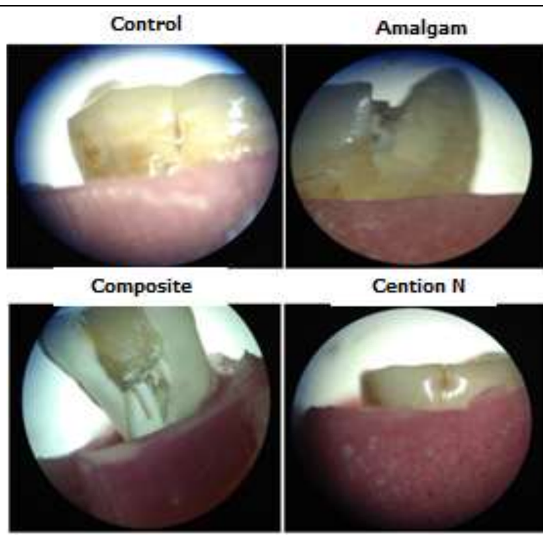

Figure 3. Specimens under Stereomicroscope after Fracture Resistance Test Showing the Type of Fracture

Statistical Analysis

The data were analysed using Statistical Software (SPSS 21.0; SPSS Inc, Chicago, Illinois, USA). Data were assessed using the Kruskal-Wallis test to determine significant differences in failure loads among groups. When the Kruskal-Wallis test indicated a significant difference, multiple comparisons were performed using the Mann-Whitney test to determine which group differed from the others. Percentages were determined for the mode of failure, and statistical evaluation was completed using a chi-square test to determine significant differences in the mode of failure among groups. A pre-set alpha level of 0.05 was used for all statistical analyses.

RESULTS

Among the four groups, Group 1 (control group) had the highest fracture resistance (2.390 KN). This difference was significant with $p < 0.05$. There was a significant difference between the control group and ETT groups. Within the Endodontically treated groups, group 3 (composite, 1.300 KN) had the highest fracture resistance followed by group 4 (1.24 KN) and group 2 (amalgam 1.192 KN) (Table 1). With regard to the type of fracture, the composite group had 100% unfavourable fractures, whereas the Cention N group showed more favourable fractures when compared to other groups. Graph 1 shows the distribution of favourable and unfavourable fractures among the six groups.

Groups	Frequency	Minimum	Maximum	Mean	Std. Deviation
Group 1	10	2.12	2.67	2.39	0.19
Group 2	10	0.90	1.45	1.19	0.15
Group 3	10	1.15	1.65	1.30	0.15
Group 4	10	1.11	1.44	1.24	0.11

Table 1. Mean and Standard Deviation of Fracture Resistance (KN) for All The Groups

Graph 1. Mode of Fracture against the Type of Restoration

DISCUSSION

A sufficient post-endodontic restoration influenced the long-term result significantly more positively than a sufficient root canal filling. Furthermore, it was reported that the success rates of sufficient root canal treatments dropped from 81%

to 71% if the coronal restoration was insufficient. This indicates that for the healing of an apical lesion, a high-quality root canal filling and a bacteria-tight post-endodontic restoration are of importance.[9,10]

The prognosis of an ETT is directly related to the amount of remaining sound tooth structure and the strength of the final coronal restoration. Therefore, the root canal treatment should not be considered complete until an appropriate permanent coronal restoration has been placed.[11] Mandibular molars were used in this study because they reportedly comprise the most common extracted tooth profile within endodontically treated posterior teeth. In this study, different post-endodontic restorations are used to assess the fracture resistance of these mandibular molar teeth. Although the marginal ridges were left intact in the present investigation, the strength of the restored teeth was significantly reduced when compared to unrestored sound teeth regardless of the restoration type used.[12] The loss of one marginal ridge resulted in a 46% loss in tooth rigidity, and a MOD preparation resulted in an average loss of 63% in relative cuspal rigidity.[1]

Amalgam has traditionally been used as the best build-up material. As amalgam is strong in the bulk section, it can be used in various restorative needs, but its slow setting process, mercury content, and unpleasant colour were some of the reasons why alternative restorative materials were developed. The major disadvantage of amalgam, however, is its inability to bond to dental hard tissues, which necessitate the use of macro mechanical retentive features, which cause further weakening of the remaining tooth structure.[13]

In the present study, the amalgam group displayed the poorest results because these materials were not able to stabilize the tooth and did not prevent it from any fracture. Furthermore, cavities to be restored with amalgam require undercuts, which may additionally weaken the tooth structure. Some studies[9, 14] have reported that high fracture resistance was noticed in ETT restored with amalgam, but other studies showed that bonded composite restorations are more suitable in strengthening an ETT than amalgam[15, 16] Amalgam restorations may fail as a result of continued flexure of tooth structure caused by a lack of bonding to the tooth structure. This type of failure would result in eventual fatigue of the tooth structure, with lower loads required to fracture the tooth structure. The use of dentin bonding agents splints the cusps together, decreasing cusp flexure and, therefore, the fatigue within the tooth structure. This procedure relies on maintenance of the bond to the tooth structure, a factor that would need to be examined by the addition of load cycling to the procedure.[1]

Composite resin restorations are widely used in dentistry today. However, one of the most challenging problems related to these materials is volumetric shrinkage during polymerization, resulting in contraction stress, which may be the most critical factor in adhesion failure, as well as the creation of marginal gaps, and secondary caries. In the present study, the mean fracture resistance of teeth restored with composite fillings was 1.3 ± 0.022 KN. Because composite fillings require an adhesive technique, teeth are better protected from fractures when compared with the non-adhesive technique.[17]

Cention N is an innovative filling material for the complete and permanent replacement of tooth structure in posterior teeth. Due to the sole use of cross-linking methacrylate monomers in combination with a stable, efficient self-cure initiator, Cention N exhibits a high polymer network density and degree of polymerization over the complete depth of the restoration. Moreover, the release of large numbers of fluoride and calcium ions forms a sound basis for the remineralization of dental enamel. The highly cross-linked polymer structure is responsible for the high flexural strength. The initiator system enables good chemical self-curing. It also includes special patented filler (Isofiller), which acts as a shrinkage stress reliever minimizing the shrinkage force.[18] According to paromita et al., Cention N showed the highest hardness values among all the other materials like amalgam, GIC, composite resins. Probably their increased microhardness is related to the nanoparticle size of the inorganic filling. Fillers are responsible for imparting restorative materials with the desired handling characteristics and adequate strength to withstand the stresses and strains of the oral cavity and to achieve acceptable clinical longevity.[19] The filler composition of Cention N is found in the Cention N Powder.

The failure modes were classified as favourable and unfavourable according to the position of fracture line in relation to the cementoenamel junction, which is useful in predicting the prognosis of a restored tooth in case of failure. According to the results, a favourable fracture pattern was observed when Cention N was used as a post endodontic restoration followed by amalgam. Composite showed 100% unfavourable fractures. The selection of the proper post endodontic restorative materials should not be entirely depended upon the fracture resistance of the teeth due to the fact that composite had higher fracture resistance, but it had 100% unfavourable fractures that are irreparable. The method of loading might be controversial because the compressive static loading used in this in vitro study is different from the dynamic loading in the mouth.[20]

CONCLUSIONS

All restorative techniques tested led to a significant reduction in fracture resistance of endodontically treated mandibular molars. Sound unrestored teeth present significantly higher fracture resistance compared with endodontically treated teeth restored with various restorative materials used in this study. Conventional amalgam core showed the least fracture resistance, whereas; composite resin and Cention N showed higher fracture resistance. Cention N had more favourable fractures than composite and amalgam even though composite had the highest fracture resistance.

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