ORIGINAL ARTICLE

Turk Endod J 2022;7(1):13–20
doi: 10.14744/TEJ.2021.74046

The effect of different endodontic access cavity designs on the amount of apically extruded debris

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Purpose: The present study aimed to examine the effect of different endodontic access cavity designs on the amount of apically extruded debris.

Methods: Sixty caries-free mandibular first molars were used. Before starting the access cavity preparations, all teeth were scanned on a cone beam computed tomography to outline the pulp chamber of the teeth. Four groups were planned according to the prepared cavity design as follows (n = 15 each): the traditional endodontic cavity (TEC), the conservative endodontic cavity (CEC), the truss endodontic cavity (TREC), and the ninja endodontic cavity (NEC) groups. The weight of extruded debris was determined by subtracting the initial weights of the tubes from the final weights of the tubes containing the debris.

Results: Significantly less apical debris extrusion was observed in the NEC group compared with the CEC and TEC groups. There was no significant difference in the amount of apically extruded debris between the TREC group and the CEC and TEC groups.

Conclusion: NEC and TREC design was associated with less debris extrusion than the TEC and CEC designs.

Keywords: Access cavity, debris extrusion, endodontics.

Introduction

Cleaning and shaping of root canals using files and irrigation solutions is essential for the success of endodontic treatment. During root canal preparation, dentin debris, pulp tissue, microorganisms, and/or irrigating solutions may be inadvertently extruded into periradicular tissues. Cleaning and shaping the root canal system at the working length can reduce this risk, but any debris may still cause postoperative complications, such as flare-ups (1,2).

A properly prepared endodontic access cavity offers many advantages, such as optimum shaping and adequate irrigation of the root canal system, both of which can have positive effects on the success of root canal treatment (3). Modification of the endodontic access cavity design may also affect the amount of apically extruded debris, as it will affect shaping procedures and irrigation efficiency. Therefore, reducing the size of the coronal cavity or increasing it to create a straight access tract may alter the amount of apically extruded debris.

In the traditional endodontic cavity (TEC), the roof of the pulp chamber is completely removed by removing the cervical dentin prominences and widening the canal orifice to localize all root canal orifices and provide direct access to the apical foramen or the initial curvature of the canal (4). Recently, conservative endodontic cavity (CEC) prep-

Cite this article as: Memiş M, Karataş E. The effect of different endodontic access cavity designs on the amount of apically extruded debris. Turk Endod J 2022;7:13-20.

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Submitted: September 03, 2021 Accepted: November 16, 2021

aration has been reported to minimize the loss of intact tooth structure and preserve some of the chamber roof and pericervical dentin (5,6). In addition, conservative/contracted endodontic cavity design is an essential parameter for restorative stability and long-term tooth survival (5,6). Some endodontists have also emphasized the use of ultra-conservative designs such as truss endodontic cavity (TREC) and ninja endodontic cavity (NEC) by developing the CEC principle (7).

Minimizing the amount of apically extruded debris during shaping procedures is essential to prevent flare-ups and postoperative pain (8). However, it is unknown if different cavity designs affect the amount of apically extruded debris during root canal preparation. This study aims to examine the effect of different endodontic access cavity designs on the amount of apically extruded debris. The null hypothesis "there was no difference between the TEC, CEC, TREC, and NEC groups with different endodontic access cavities in terms of the amount of apically extruded debris" was tested.

Materials and Methods

Ethics committee approval of this in vitro study was received by the Ethics Committee of the Faculty of Dentistry of the University (July, 2020). Power analysis was performed to determine the adequate sample's number. Based on the study by Karataş et al. (9), 28 samples were found to be sufficient for the four groups at a significance level of 0.05 on a 95% power scale. However, in order to increase the power of the study, a total of 60 samples were included in the study.

Selection of Teeth

From the collected teeth for the study, 60 caries-free mandibular first molars were used. The pulp chambers and root canal anatomy were evaluated with periapical films taken from the mesiodistal and buccolingual angles. Teeth that did not meet the inclusion criteria were excluded from the study. In order to minimize the effect of size and shape differences, care was taken to ensure that the tooth sizes were approximately similar. For this purpose, anatomical crown height (from the occlusal surface of the teeth to the cemento-enamel junction) and buccolingual and mesiodistal dimensions (from the occlusal surface) were measured using a digital caliper (Digimatic 500; Mitutoyo, Kanagawa, Japan), and approximately similar teeth were included. Teeth with a deviation of up to 10% from the average size were accepted. Teeth were examined under a stereomicroscope at ×20 magnification for cracks or fractures. In order to determine the pulp chamber outline of the teeth and the position of the pulp horns, all teeth were examined using a cone beam computed tomography (CBCT; NewTom FP, Quantitative Radiology, Verona, Italy) device. A film holder was used to take standard periapical radiographs.

Inclusion Criteria

1. Caries-free, intact mandibular first molars
2. According to Vertucci's classification (10), mesial root with type IV configuration and distal root with type I configuration teeth with similar crown heights and widths
3. Teeth with a root curvature angle between 10° and 20° according to the Schneider method (11).

Exclusion Criteria

1. Endodontically treated teeth
2. Teeth with internal and external resorption
3. Teeth with pulpal calcification
4. Teeth with crown destruction
5. Presence of cracks or fractures
6. Teeth with excessively curved roots and large apical diameters.

Soft and hard tissue residues on the teeth were removed using a scaler. The teeth were kept in distilled water at room conditions until used for the study.

Access Cavity Preparation

Sixty teeth meeting the inclusion criteria were divided into four groups using the randomization program (www.randomizer.org). The number of teeth and groups were recorded. Four groups were planned according to the prepared cavity design as follows:

Traditional Endodontic Cavity (TEC): The access cavity was started using a diamond round bur under high-speed water cooling. The bur was positioned at the level of the central groove, parallel to the long axis of the tooth. The bur was applied in the mesiodistal and buccolingual directions to remove enamel and dentin to give the general contours of the cavity until it reached the pulp chamber roof. First, the largest canal, the distal canal, was localized, then the bur was guided mesially and buccolingually to find the mesial canals. The outline of the cavity was determined as a line connecting the mesial cusp crests mesially and a triangle with rounded edges located a little more distal to the central fossa distally. Then, the entire pulp chamber roof and pulp horns were removed using a safe flame-tipped diamond bur. Straight access was provided from the pulp chamber floor to the occlusal surface so that all root canal orifices could be seen from the same visual angle (Fig. 1 A1, A2).

Conservative Endodontic Cavity (CEC): The access cavity was started using a diamond round bur under high-speed water cooling. The teeth were accessed from the mesial quarter of the central groove and the cavity was expanded distally and apically. Since there are no definite rules for CEC, initial preparations were carried out as in TEC. However, based on previous studies, removal of the mesiodistal, buccolingual, and circumferential pericervical dentin was kept minimal to preserve part of the chamber roof, in accordance with the visual angulation of the canals (Fig. 1 B1, B2) (5–7,12,13).

Truss Endodontic Cavity (TREC): The borders of the pulp chamber, mesial, and distal pulp horns of the teeth were determined by CBCT imaging before preparation. With the help of these images, the coronal entry was first initiated using a round-tipped diamond bur over the mesial pulp horn to open the mesial cavity. The bur was oriented buccolingually on the line connecting the mesial tubercle crests and provided a straight entrance from the occlusal surface to the pulp chamber roof. The pulp roof between the mesial canals was removed using a safe flame-tipped diamond bur. Then, to localize the distal canal, a second access cavity was prepared by directing the bur toward the distal pulp horn over the enamel on the distal pulp horn. Again, the roof of the chamber above the canal orifice was removed using a safe flame-tipped diamond bur. In this way, two different access cavities providing direct access to the canal openings were created and the dentin structure between the two cavities was preserved (Fig. 1 C1, C2).

Ninja Endodontic Cavity (NEC): The access cavity was started from the central groove of the tooth using a diamond round bur under high-speed water cooling. The teeth were accessed as described in the CEC group, but the pulp chamber roof was preserved as much as possible. The outline of the ninja access was determined using an oblique projection toward the central fossa of the root canal orifices in the occlusal plane (7). In this way, the localization of the root canal openings could only be observed from different viewing angles. Expansion was balanced equally between the mesial and distal canal openings (Fig. 1 D1, D2).

Shaping of the Root Canals

After the access cavity was opened, 10-K-type hand files (Mani INC.; Utsunomiya, Tochigi, Japan) were advanced through the canals until they were visible from the root tip. Endodontic working lengths were determined by subtracting 1 mm from these lengths. The size of the minor foramen was checked by inserting 15-K-type hand files (Mani INC.) into the canals. If the 15-K file went beyond the minor foramen, the teeth were excluded. The tooth was excluded if the 20-K-type hand file (Mani INC.) in the distal canals went beyond the foramen.

Preparation of Experimental Setups

An experimental system on apical extrusion of debris de-

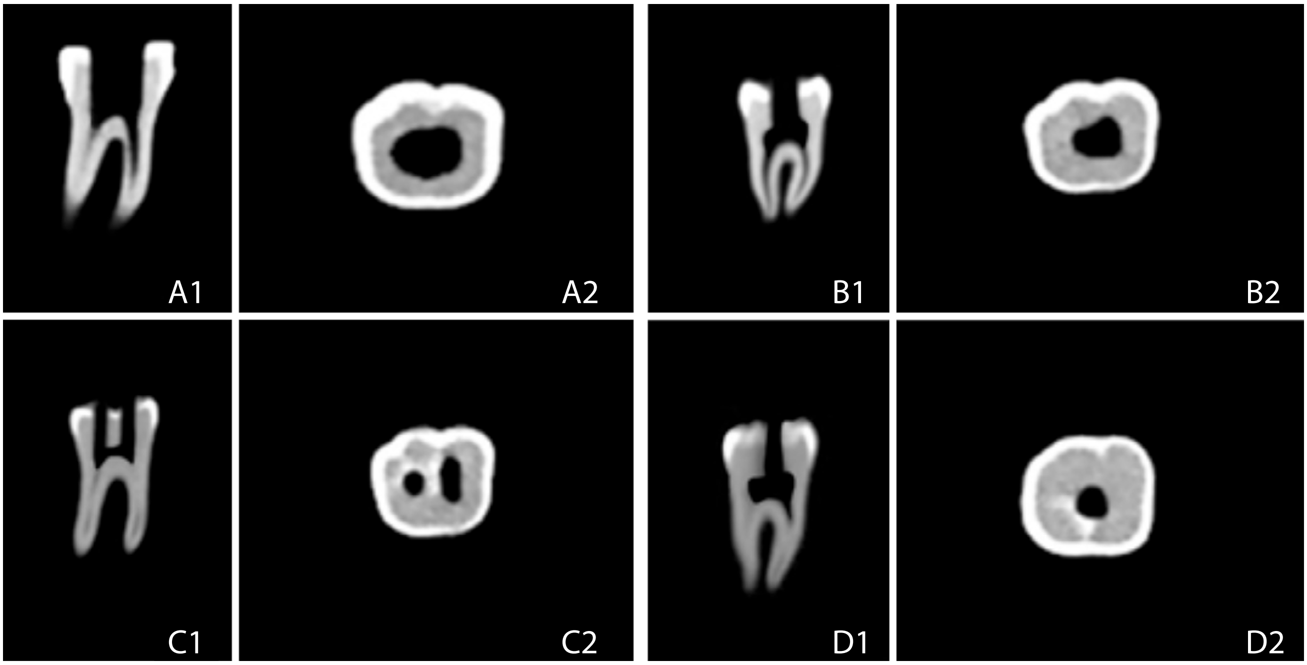

Fig. 1. Cavity designs according to the groups. A: Traditional endodontic cavity. B: Conservative endodontic cavity. C: Truss endodontic cavity. D: Ninja endodontic cavity.

fined by Myers and Montgomery has been adopted in most studies (14) and was used in this study. Tubes to be used in the study were weighed using a precision balance (Ohaus PA224C; Parsippany, USA) (Fig. 2) with a precision of 10^{-4} g in order to record their empty weights before use. The measurement process was repeated three times for each tube and these measurements were averaged for more precise results.

Before the experimental setups were prepared, a hole was drilled in the cap of the tube to be placed in the setup and the teeth were fixed in this hole under pressure up to the cemento-enamel junction. The tooth and cap interface was fixed with cyanoacrylate adhesive to prevent leakage of distilled water. A 27-gauge needle was placed between the cap and the tooth to equalize the internal and external pressure. The cap containing the tooth and needle was placed on the pre-weighed tubes and the tubes were placed in glass bottles so not to be touched during preparation and for standardization. The glass bottles were covered with aluminum foil to prevent the operator from seeing the extruded debris during preparation. This procedure was repeated for all samples.

Root Canal Preparation

WaveOne Gold (Dentsply Sirona, Ballaigues, Switzerland) files were used in reciprocating motion with the VDW Silver Reciproc (VDW GmbH, Munich, Germany) torque-controlled endodontic motor in the "WaveOne ALL" mode as per the manufacturer's recommendation. First, the mesial canals were shaped at the working length with the WaveOne Gold Primary (25/.07) file. The distal canal was then reshaped with the WaveOne Gold Medium (35/.06) file. After every three pecking movements, the root canals were irrigated with 1 mL of distilled water by using close-ended and side-vented irrigation needles. A total of 20 mL of distilled water was used for each tooth during the preparation process. In order to collect the remnants of debris adhering to the root surfaces of the teeth after preparation, the apical parts were washed with 1 mL of distilled water in the tube just before leaving the assembly. Each instrument was used for shaping only one tooth. All endodontic procedures at all stages were performed by a single operator to avoid differences related to the practitioner.

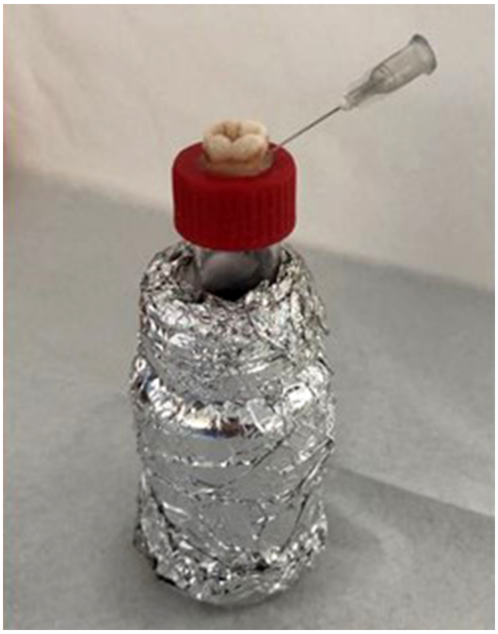

Fig. 2. The experimental setup.

Evaluation of Extruded Debris Amount

After the root canal preparations were completed, the tubes were placed in an oven (BINDER GmbH, Tuttlingen, Germany) for 21 days at 37 °C to evaporate the distilled water before weighing out the dry debris residue (14). After 21 day, the distilled water in all the tubes had evaporated. Subsequently, the tubes were reweighed under the same stable conditions, using the same precision balance to obtain the final weights of the tubes containing the debris. The measurements obtained after three consecutive weightings were recorded and averaged. The weight of apically exuded debris was determined by subtracting the initial weights (specific gravity of the tubes) from the final weights of the tubes containing the debris.

Statistical Analysis

IBM SPSS Statistics Software version 20.0 (USA) was used to analyze the data. Data were tested for normal distribution using Kolmogorov–Smirnov analysis. As the data were not normally distributed, the Kruskal–Wallis-H test and posthoc test was used to compare the amount of apically extruded debris between groups. The results were evaluated at the 95% confidence interval.

Results

One tooth in each TEC and NEC groups was excluded from the study because it did not meet the apical diameter criteria. Instead, new teeth meeting all criteria were included. No instrument fracture occurred during canal preparation. There was no sample loss at this stage.

Excess of debris was detected in all groups. The mean values of apically extruded debris according to the groups are shown in Table 1 and Figure 3. Significantly less apical debris was observed in the NEC group compared with the CEC and TEC groups ($p< 0.05$). There was no signifi-

Table 1. Mean, median, standard deviation, minimum and maximum values of the amount of apically extruded debris according to the groups (gr)

Group	Mean	Median	Standard deviation	Minimum	Maximum
Traditional endodontic cavity	0.002120	0.001800^{A}	0.0012907	0.0006	0.0056
Conservative endodontic cavity	0.001580	0.001500^{A}	0.0004799	0.0009	0.0029
Truss endodontic cavity	0.001193	0.001200^{AB}	0.0003900	0.0005	0.0019
Ninja endodontic cavity	0.000780	0.000700^{B}	0.0003468	0.0003	0.0016

Different superscript letters within the same column represent statistically significant difference.

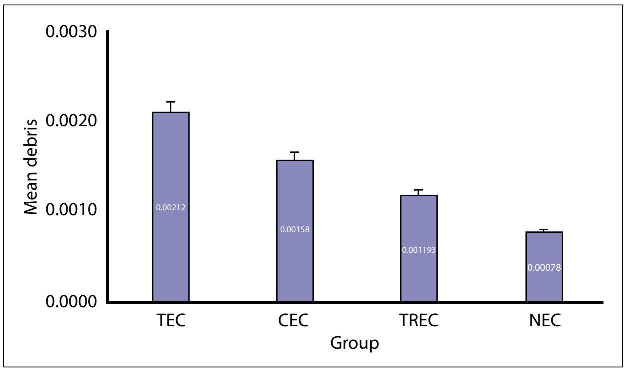

Fig. 3. Mean of apically extruded debris according to the groups.

cant difference between the TREC group and the CEC and TEC groups in terms of amount of apically extruded debris ($p > 0.05$).

Discussion

One of the factors that can affect debris extrusion is the design of the file, which includes features such as cross-section, pitch and helical angles, spacing between flutes, taper, tip design, flexibility, alloy, and number of files (16). The cross-section of WOG files is a parallelogram and has only one cutting edge in contact with the canal wall. There is a constant helical angle of 24° along the active part of the file. Additional space around the instrument also provides space for debris removal (17). The additional space around the WOG instrument, which can provide space for debris collection and coronal removal of debris, and the constant helix angle may result in less debris extrusion apically (18). Based on these advantages and in order to ensure standardization in all groups, we performed the preparation procedures using WOG files as only file type.

In this study, distilled water was preferred to sodium hypochlorite as the irrigation solution because sodium crystals cannot be separated from the accumulated debris after evaporation, which may adversely affect the measurements (8). Fairbourn et al. (19) reported that the weight of apically extruded debris may increase due to humidity in the air. Therefore, all samples were weighed three times with a precision balance under stable conditions and their average values were recorded for a more accurate measurement.

In our study, recently extracted human mandibular first molars were used. Mandibular molars are the teeth that require the most endodontic treatment (20) and, according to the results of a study, the incidence of pain after endodontic treatment was significantly higher when the treated tooth was a molar (21). For these reasons, we preferred to use mandibular molars in our study. For examining the effects of preparation methods on the amount of apically extruded debris, the use of extracted human teeth were generally preferred than acrylic teeth.

Silva et al. (22) used lower incisors, Özsu et al. (23) used mandibular premolars, and Koçak et al. (24) used curved mesial roots of mandibular molars. In studies where mandibular molars were used, the mesial roots of these teeth were generally preferred (25–27). In this study, where we examined the effect of the endodontic cavity on apical debris protrusion, we included both roots of the teeth since our aim was to examine the effect of cavity design that can affect the extrusion in all canals. In order to avoid differences in the endodontic procedures related to the practitioner, all stages of the study were carried out by a single operator.

Post-operative complications following root canal treatment such as inflammation, postoperative pain, and delayed periapical healing are associated with apically extruded debris. In addition, apically extruded debris might enhance the persistent inflammation of the periapical tissues (1). It has been reported that there is a relationship between the amount of apically extruded debris and the severity of inflammatory reactions that more severe reactions occur in the presence of a larger amount of debris extrusion (18). Therefore, it is desirable to reduce the amount of extruded debris to reduce postoperative complications. There are many factors that affect the amount of apically extruded debris (18). These include changes in the working length (12,28,29), the diameter of the apical opening (30,31), screw pitch design of the instrument (32), instrumentation technique (33), and endodontic cavity design. A properly designed endodontic access cavity offers many advantages, such as optimal shaping and effective irrigation of the root canal system, both of which can have positive effects on the success of root canal treatment (3). Accordingly, changing the design of the endodontic access cavity may also affect the amount of apically extruded debris, as it will affect the shaping procedures and the effectiveness of irrigation. Therefore, it has been postulated that reducing the coronal space for debris or increasing it to create a straight entryway may alter the amount of apically extruded debris. According to the results of our study, it was determined that changing the endodontic cavity design affects the amount of apically extruded debris.

The concept of minimally invasive dentistry is based on the assumption that tooth tissue should be minimally removed and that preservation of these tissues will preserve the fracture resistance of the teeth after root canal treatment (5). However, only a few studies (7,11) have reported positive results regarding increased fracture resistance when minimally invasive cavities are made.

Various studies have been conducted to examine the effects of endodontic access cavity designs on the fracture resistance of teeth and the shaping capacity of files. However, none of the previous studies used a combination of TEC, CEC, TREC, and NEC designs to examine their effects on the amount of apically extruded debris. Our study allowed the comparison of these four different endodontic access cavity designs in terms of amount of apically extruded debris. According to the results of our study, apical exudation of debris occurred in all TEC, CEC, TREC, and NEC groups. There was no statistically significant difference between the TEC, CEC, and TREC groups in terms of amount of apically extruded debris; however, a statistically significant difference was found between the NEC group and the TEC and CEC groups ($p< 0.05$). Thus, the null hypothesis "there is no difference in the amount of apically extruded debris between the different endodontic access cavity designs" was rejected.

In the study of Tüfenkçi et al. (34), the effect of contracted endodontic access cavity and conventional endodontic access cavity preparation on the amount of apically extruded debris was investigated, and no statistically significant difference between these two different endodontic access cavity designs in terms of amount of apically extruded debris was reported. In our study, we found that there was no statistically significant difference between the TEC and CEC groups. Unlike the study by Tüfenkçi et al., in our study, we examined the effects of the TREC and NEC designs on the amount of apically extruded debris in addition to the TEC and CEC designs, and found statistically significantly less debris extrusion in the NEC group compared with the TEC and CEC groups.

Krishan et al. (11) reported a greater percentage of intact walls after shaping the distal canals of mandibular first molars with CEC compared with TEC. Since the distal canals of mandibular molars are typically oval-shaped with prominent buccolingual tapers and a wide apical diameter range (35), instrumentation efficiency is often compromised, particularly in the apical third, resulting in more than 60% of the untouched dentinal walls (36). Untouched areas may decrease the debris accumulation in the root canal system that also reduced the amount of apically extruded debris. This may also explain lower debris extrusion in the NEC group.

Barbosa et al. (37) prepared TEC, CEC, and TREC designs in mandibular molars and evaluated the effects of these designs on the percentage of intact area in the root canals and in the amount of dentin removed after shaping procedures. The authors reported a significant difference between the CEC and TEC groups in terms of percentage of untouched area in the root canals, which was significantly higher in the CEC group. The CEC preparation (5,6) is aimed to minimize the removal of tooth structure and to protect some chamber roof and pericervical dentin. However, there are no definite rules for preparing CEC; the aim is to preserve the tooth structure as much as possible and to locate the canal orifices. For this reason, CEC preparations may show differences in studies. Although not a general rule, in studies comparing TEC and CEC designs, CEC preparation seems to be more conservative (11,37), but when ultra-conservative cavity designs (such as NEC) are included in these comparisons, CEC preparation seems to be wider (7). The CEC preparation in the aforementioned study may have been performed with a more conservative approach compared with that in our study. Therefore, the percentages of untouched areas during instrumentation may differ from our study. This can affect the amount of extruded debris. This factor may explain the significant difference we obtained in our study in the NEC group compared with the TEC and CEC groups, while there is no significant difference between the CEC and TEC groups. In the TREC group, however, they did not find a significant difference in terms of percentage of untouched area compared with the other groups. In our study, no statistically significant difference was observed in the TREC group in terms of amount of apically extruded debris compared with the other groups. This may be because in the TREC design the instruments are more in contact with the canal walls as more direct access is provided to the mesial and distal canals via the two separate cavities prepared during instrumentation. This may have caused more debris in the root canal system and more apically extruded debris in the TREC group compared with the NEC group. However, this difference was not significant in our study.

Rover et al. (38) prepared TEC or contracted endodontic cavities in maxillary molars and compared the effects of these designs on instrumentation efficiency. They did not observe any difference between the groups in terms of percentage of hard tissue debris accumulated after preparation. In our study, no significant difference was found between the TEC and CEC groups in terms of amount of apically extruded debris. Silva et al. (22) reported that canal shaping of maxillary premolars prepared with ultra-conservative endodontic cavity design resulted in a higher percentage of hard tissue debris deposition compared with TEC. This finding seems to contradict the results of our study. However, as we mentioned before, the reason for this difference may be be explained by the use of different tooth groups and by differences in shaping and irrigation protocols. NEC preparation was reported to decrease the instrumentation efficiency in the distal canals of the mandibular molars, and increase the percentage of untouched area, and therefore the amount of debris formed in the canal system was lower. This may explain less apically extruded debris in the NEC group in the current study.

According to a previous study, the larger pulp chamber roof area associated with small access cavities may affect the efficiency of irrigation (39), resulting in more dentin debris accumulation within the root canal system. According to the study, the remaining pulp chamber roof interferes with the mechanical movement of the instruments and compromises irrigant flow (40). Accordingly, the remaining pulp chamber roof area in the NEC design used in this study, may have affected the irrigation efficiency and the mechanical movement of the instruments preventing debris accumulation in the root canals and may have resulted in less apical extrution of debris.

In this study, we used the experimental model of Myers and Montgomery (13). Apical extrusion was not limited as there was no physical back pressure provided by the periapical tissues; therefore, the force of gravity may have carried the irrigant solution out of the canal (41). Caution is needed when translating the current results to the clinic. However, studies evaluating apical extrusion of debris have generally used the technique described by Myers and Montgomery (13).

Conclusion

Within the limitations of our study, it was observed that there was significantly less debris extrusion in the NEC group compared with the TEC and CEC groups. According to the results of our study, it can be concluded that reducing the size of the access cavity reduces the amount of apically extruded debris. More studies on ultra-conservative cavity designs are needed to justify its importance during endodontic treatment procedures.

Authorship Contributions: Concept: M.M., E.K.; Design: E.K.; Supervision: E.K.; Materials: E.K.; Data: M.M.; Analysis: E.K.; Literature search: M.M.; Writing: M.M.; Critical revision: E.K.

Acknowledgements: The study was funded by the Scientific research unit of Atatürk University (TDH-2020-8681). Conflict of Interest: There is no conflict of interest.

Source of Funding: None declared.

Conflict of Interest: None declared.

Ethical Approval: The study protocol was approved by the Atatürk University Faculty of Medicine Clinical Research Ethics Commitee (date: 07.07.2020, protocol no: 22).

Informed consent: Written informed consent was obtained from patients who participated in this study.

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