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EVALUATION OF REMAINING DENTIN THICKNESS IN MANDIBULAR MOLARS' MESIAL ROOTS AFTER REMOVAL OF SEPARATED INSTRUMENTS USING TRADITIONAL AND CONSERVATIVE TECHNIQUES: IN-VITRO STUDY

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ABSTRACT

The aim of this study was to assess whether fractured files retrieval using Terauchi file retrieval technique (TFRT) provided a more conservating method than using the technique described by Ruddle. Extracted human mandibular molars were randomly allocated and divided into three groups (n=10): Ruddle's technique with an E25, E40 US tips and TFRT, then the teeth were decoronated. Preoperative CBCT imaging was done, Hyflex EDM files were intentionally fractured in the middle third and retrieved using the allocated technique. The mesial roots were cleaned, shaped and obturated and postoperative CBCT imaging was done. Remaining dentin thickness (measured in mm) was calculated by measuring the difference in dentin thickness from the wall of the canal to the root's outer surface in four directions (buccal, lingual, mesial and distal) pre and post file retrieval. Results showed a statistically significant difference between the three studied techniques at 3 mm root level. Based on our study results, fractured file retrieval using TFRT provides a more conservative approach to retrieving fractured files.

KEY WORDS: CBCT, Fractured File Removal, Microscopy, Molar, ultrasonic

INTRODUCTION

Fracturing endodontic instruments can occur without any prior warning signs for the operator[1]. If it was not done adequately before the incident, the operator may be unable to fully clean and shape the canal[2,3].

Although fracture of the instruments inside the root canal has a relatively lower prevalence than many other complications[4,5], it has proven to be one of the most troublesome to address[6,7].

When an endodontic file fractures, many factors must be considered to properly formulate a treatment

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plan to either try and bypass/retrieve the fragment or leave it as a part of the obturation.

These factors include the preoperative pulp status, which can be healthy, inflamed, necrotic, or with the presence of an infection, the canal's classification, the position of the fractured instruments, and evaluating whether trying to bypass or retrieve the broken file will result in excessive dentin removal; thus, balancing the chances of success with the possibility of complications is necessary[1–3].

Treatment options include bypassing, removal (non-surgical or surgical) and obturation to the level of the fractured instruments. Researchers have suggested many techniques for removing files from the root canal, including ultrasonics, various trephine burs kits, laser welding, and intracanal corrosion of fractured instruments[8].

Among the different techniques, the use of both US tips and a DOM is usually the first line of treatment[9] after being proven to be successful, safe and efficient[10], which can be attributed mainly to the increased magnification of DOM along with the enhanced illumination[3,11].

Throughout the research, the TFRT, a relatively new invention, was the focal point of study in multiple papers. Pruthi et al.[12] compared the TFRK (Terauchi File Retrieval Kit) against ProUltra US tips regarding overall success at removing fractured instruments and the mean time for removing such instruments, concluding that both are clinically acceptable tools for fractured file retrieval. Kumar et al.[13] evaluated the difference in time taken to retrieve fractured instruments using the TFRK when compared with the Satelec E25 tip and the change in root canal volume using Cone-beam CT. The author concluded that using both techniques, all the fractured instruments were successfully retrieved and that the TFRK had a non-significant lower mean time for instrument retrieval and a significantly lower increase in canal volume. Abdeen et al.[14] evaluated the success rate, the time needed for retrieving fractured instruments, and the change in root canal volume when using Ruddle's technique, TFRK and Endo Rescue Kit. The author found that between Ruddle's technique and TFRK, there was no statistically significant difference in success rate or retrieval time. The TFRK showed the lowest increase in canal volume.

To the author's best knowledge, no published study has compared Ruddle's Technique and the TFRT in terms of remaining dentin thickness.

This study aimed to utilize two file retrieval techniques using three different designs and sizes of US tips to determine which technique is more conservative regarding remaining dentin thickness.

The null hypothesis is that there is no statistically significant difference in remaining dentin thickness after fractured file retrieval by the two instrument removal techniques.

MATERIALS AND METHODS

The sample size calculation was calculated and This power analysis used fracture resistance as the primary outcome. Based upon the results of Fu M et al (2019)[10]; the mean values for fracture resistance were 391.2 and 495.8 Newtons, respectively. The mean of the third group was assumed to be 420 Newtons based upon expert opinion and the standard deviation within group was assumed to be 70 Newtons. The effect size (f) was 0.63. Using alpha (α) level of (5%) and Beta (β) level of (20%) i.e., power = 80%; the minimum estimated sample size was 10 specimens per group (Total of 30 teeth). Sample size calculation was performed using G*Power Version 3.1.9.2.

Inclusion criteria included teeth with intact crowns or minimal caries not affecting the mesial side and closed apices. Teeth with severe root curvatures, resorption, perforations and calcifications were excluded. Thirty extracted mandibular first and second molars varying from

18-21 mm in length were collected from the main author's university human teeth bank. The teeth were cleaned of visible blood and debris and stored in thymol solution(to maintain their hydrating state and disinfection) for one week until they were used[1,15]. Caries were removed if present, and the access cavity was opened using a large round bur, tapered with a round end stone and an Endo Z bur. Patency and confirmation of two separate mesial canals (Type IV Vertucci classification)[16] with an angle of curvature less than 30° as described by Schneider[17] were performed using a #10 K file and digital periapical radiography.

The working length was determined by passing a #10 K file to the apical foramen and then retracting it until it was flushed with the apex. The length was recorded, and the final working length was established as 1 mm short of the recorded length[2,18,19]. Canals were then instrumented using Hyflex EDM files using the sequence advocated by the manufacturer (instrumentation with orifice opener #25/.12 (Speed 500 and Torque 2.5 N-cm) until the middle third, followed by instrumentation with manual K-file #10 and glide path file 10/.05 (Speed 300 and Torque 1.8N-cm till full working length). The prepared teeth were then decoronated[20] at the level of the CEJ (cemento-enamel-junction) using a wheel stone mounted on a high-speed handpiece with a water coolant, leaving roots with a standardized length of 16 mm that were later coated in laboratory pink wax and moisturizing jelly (except for the coronal 2 mm of the roots). Each of the Prepared, coated teeth were then placed in acrylic blocks (40 mm X 40 mm X 17mm) made from cold cure clear acrylic resin, which was left for 24 hours to set completely[21].

All blocks were radiographed using CBCT (Vatech Green x, Vatech, Seoul, Korea) (Voxel size 50 micrometer, field of view 4 X 4 cm) CBCT machine* used in this study was characterized by the following: The detector of this machine is composed of CMOS flat panel with isotropic voxel size 50 microns. The X-ray tube used to scan the samples possess a current intensity 16mA, Kilovoltage 85Kvp and a focal spot size 0.5mm with target angle 5 degrees to scan FOV of 4 cm Height x 4cm and Width x 4 cm Depth, FOV adjustment was guided by three laser light beams to centralize the area of interest within the scanning field. The raw DICOM data set obtained from the CBCT scanning were imported to a special third-party software (Ondemand 3D, Seoul, South Korea) for secondary reconstruction.

Hyflex One file (Apical size 25 with a variable taper) was notched 3 mm from the tip of the file using a low-speed diamond disk mounted on a straight handpiece reaching half of the total thickness of the file[22]. Files were mounted on an endodontic motor and inserted passively at the canal 5 mm from the orifice until they were bound to the canal wall. Then, the endodontic motor was turned on (Speed 250 and Torque 3 N-cm), leading to the fracturing of the file in the straight portion of the canal.

The 30 teeth were randomly assigned to one of three experimental groups using the RAND function in a computer program (Microsoft Excel, Microsoft Corporation, WA, USA) to assign a random number to each tooth between 0 and 1 which was then is used to shuffle the teeth randomly using the Sort option form the Data tab. After sorting, the teeth were divided into three groups each containing ten teeth according to the following test techniques: group 1 (n=10): retrieval method according to the technique described by Ruddle using US tips with a tip diameter of 0.25 mm (E25), Group 2 (n=10): retrieval method according to the technique described by Ruddle using US tips with a tip diameter of 0.40 mm (E40), Group 3 (n=10): retrieval method using the TFRT.

For groups 1 and 2, retrieval was performed using the technique previously described by Ruddle. Gates Glidden burs created a uniform tapering funnel to the fractured instrument, deliberately

relocating the coronal one-third of a canal away from the furcation. A staging platform was created using a modified gates glidden bur rotated at a reduced speed and directed apically until it lightly contacts the most coronal aspect of the fractured file. The US instrument tip is placed in intimate contact against the fractured file and activated within the lower power settings in dry conditions to maintain visualization of the fractured file. The selected US instrument is moved lightly in a CCW direction around the fractured file. Trephination and sanding away of the dentin around the broken file and exposing the coronal few millimetres of the obstruction is done. Typically, the fractured file begins to loosen, unwind, and spin during US use. Wedging the energized tip between the tapered file and the canal wall can sometimes cause the broken instrument to jump out of the canal abruptly[23].

The fractured files of group 3 were retrieved by TFRT following the manufacturer's instructions. First, the GG-3M bur was rotated clockwise at 1000rpm at the outer curve of the canal to create a funnel shape. Micro trephine bur was used in CCW motion at 600 rpm to impart an unscrewing effect on the fractured file, which may be spun out of the canal. Following the manufacturer's instructions, the TFRK US tip is now used to complete the root canal preparation. The micro spoon US tip is used around the coronal aspect of the fractured file on the inside of the curvature of the canal to create a semicircular space and to dislodge the file by wedging between the file and the canal's inner wall. If the troughing spoon dislodges the fractured file at this stage, the straight tip is no longer needed. Otherwise, the straight tip is used to extend the space apically and laterally to complete the semicircular space and eventually loosen the fractured file engaged in the canal wall[24].

Aqueous EDTA was used in all groups (when the US tips loosened the file) to take advantage of the cavitation effect created by the US energy (supplied by the straight tip engaging on the inside of the canal curvature only), resulting in the propulsion of the segment out of the canal[21,25]. All file retrieval attempts were given a maximum of 45 minutes (the average duration of a dental visit)[14,15,22]. The tooth was only considered successful if the file was retrieved within this period. In the current study, all fractured instruments in groups 1 and 2 were successfully retrieved, while in group 3, only two samples were unsuccessfully retrieved and were replaced. A successful file retrieval attempt was considered when the entirety of the file was removed and confirmed with periapical radiography[26].

After all files were retrieved, All blocks were radiographed again using CBCT with the same imagine parameters as preoperatively and dentin thickness was evaluated using the fusion technique as follows; After the teeth exposure, the images were acquired in a process called "image acquisition" on a computer connected to the cone beam machine where these images are called "basis images". The basis images were then transferred to the secondary workstation to a special software* Scanora 4.2, Sorredex Finland* through a network where the "Image reconstruction" will be carried out. The image reconstruction was performed using a third-party software *Ondemand 3D ver.1.0.9, Cybermed, Korea*. Both images (Pre file retrieval & Post file retrieval) were superimposed together in three dimensions (Axial, coronal & Sagittal) as follows: One image was set as the primary image & the other image was set as a secondary image. Each image was given a specific color different from the other image to differentiate between the primary & secondary images during the fusion process. One image was set to be more transparent than the other to facilitate the visibility of both images when fused together. Image fusion was performed by first obtaining the same plane in both, primary & secondary images in the axial plane roughly. Using fixed reference points, the images were superimposed in the coronal view & the axial level was then adjusted accurately so that the primary & secondary images are on the same exact axial plane Fine adjustments & rotation in different planes were performed in the coronal &

sagittal planes, when necessary, to ensure accurate image fusion. Both images were checked in the 3D view as a confirmation & finally the primary & secondary images were fused together. An eclipse was drawn at the site of the defect in the coronal view & its size & position was adjusted to the defect. The size & position of the eclipse were then adjusted in axial & sagittal views. The mean values of both the primary & secondary images were obtained at the same site in question. Values of dentin thickness were measured in 4 directions (Buccal, lingual, mesial and distal) from the lumen of the canal to the outer surface of the tooth corresponding to the same direction. The data obtained were recorded in an excel sheet to obtain the difference in measurements & used for statistical analysis.

Statistical Analysis

Numerical data were explored for normality by checking the distribution of data and using tests of normality (Kolmogorov-Smirnov and Shapiro-Wilk tests). Remaining dentin thickness data showed non-normal (non-parametric) distribution. Data were presented as median, range, mean and standard deviation (SD) values. For non-parametric data, Kruskal-Wallis test was used to compare between the three techniques. Wilcoxon Rank test was used to compare between root levels within each group. Wilcoxon Rank test was used for pair-wise comparisons when Kruskal-Wallis is statistically significant. The significance level was set at $P \leq 0.05$. Statistical analysis was performed with IBM SPSS Statistics for Windows, Version 27.0. Armonk, NY: IBM Corp.

RESULTS

At 0 mm root level; there was no statistically significant difference between the three studied techniques regarding amount of change in dentin thickness in buccal, lingual, mesial and distal sides (P= 0.173, 0.207, 0.113 and 0.168; respectively).

At 3 mm root level; there was statistically significant difference found between the three studied techniques regarding amount of change of dentin thickness in buccal, lingual and mesial sides ($P < 0.001$, <0.001 and <0.001; respectively). Pair-wise comparisons between techniques revealed that there was no statistically significant difference between Ruddle 25 and Ruddle 40; both showed statistically significantly lower amount of remaining dentin thickness than Yoshi.

Also, at distal side, there was statistically significant difference between the three studied techniques regarding amount of change of dentin thickness ($P<0.001$). Pair-wise comparisons between techniques revealed that Ruddle E40 have the lowest amount of dentin thickness than Ruddle E25 and the highest remaining amount of dentin thickness was in Yoshi.

DISCUSSION

The management of fractured instruments is a challenging task that affects the long-term prognosis of endodontic therapy. One of the most crucial factors during the decision-making process in managing a fractured instrument is the amount of dentin that will be removed in order to free the fractured instrument, which can sometimes be the definitive factor in shifting the treatment plan to bypassing instead of retrieving, as dentin removal should be kept at a minimum to decrease the likelihood of subsequent root fracture.

The use of a DOM during file retrieval is of the utmost importance to increase the accuracy of the retrieval procedure by avoiding unnecessary dentin removal and further weakening the tooth which can be attributed to the enhanced magnification and visualization of the separated file and the surrounding space, and additional illumination. All the procedures in the current study were conducted under a magnification of X25.

The technique described by Ruddle was selected as it is the most widely used technique for retrieving fractured instruments. It was used with Satelec

ET25 tips with a tip diameter of 0.3mm, as opposed to ProUltra US tips originally used in the original technique.

The TFRT is based on two US instruments: a straight tip (TRFK-S, 0.2 mm diameter and 1% taper) and a spoon tip (TFRK-6, 0.1 mm thickness, 0.3mm width). It also contains a micro-trephine bur, a loop device, and other instruments. In the present study, only the loop device was not used to maintain standardization parameters, as Ruddle's technique does not use loops.

Forty-five minutes was the set time allocated for retrieval attempt in each sample as this was the average time for a dental visit. a set time for retrieval attempts was needed as surpassing this set time can greatly diminish the success rate due to multiple factors such as operator fatigue , excessive removal of dentin that can weaken the tooth structure leading to fracture or perforation.

The present study compared the difference in remaining dentin thickness after fracture file retrieval from the root canal using both techniques which was examined using CBCT.

Regarding remaining dentin thickness, the results showed that at 3 mm root level, the TFRT group had the highest remaining dentin thickness among the three groups. In contrast, Ruddle's technique with the E25 and E40 US tips had the lowest remaining dentin thickness. There was a significant difference between the techniques, which can be attributed to the mode of US activation. In contrast, in Ruddle's technique, the US tip is vibrated circumferentially around the broken file, while in using TFRT, the US tip is vibrated only on a half-circle shape, which allows less dentin removal.

The results published in this study agree with those of Abdeen et al., who compared three techniques for retrieving fractured instruments (Ruddle, TFRK, and endo rescue kit) in terms of dentin preservation by examining root canal volume changes and concluded that TFRK provides a more conservative way to retrieve a fractured instrument from the middle third of a moderately curved canal[14]

The null hypothesis is rejected in the present study, as there was a significant difference among the study groups regarding the remaining dentin thickness.

The results of this study have important clinical implications for the endodontic practice. Both techniques are effective in removing separate instruments, but their effect on the remaining dentin thickness should be considered when planning treatments. Our results suggest that the choice of restorative technique may affect the integrity of the tooth structure, which may affect long-term outcomes.

Clinicians should be aware that excessive dentin removal during retrieval may compromise the dentin structure, leading to an increased risk of vertical root fracture and therefore a shorter lifespan. Although both techniques are applicable, the TFRT, which requires less dentin removal, offers an advantage in maintaining tooth strength.

The possibility and choice of retrieval technique should be carefully evaluated for each case, taking into account the condition of the tooth, the position and depth of the fractured file, and the overall diagnosis of the patient. Conservative removal of dentin and the use of a dental surgical microscope can improve the long-term success of endodontically treated teeth.

CONCLUSION

Based on the results of this study, the remaining dentin thickness was affected by both the technique and the US tip size. It was concluded that fractured file retrieval using TFRT provides a more conservative and, thus, safer way to retrieve fractured files, which can be attributed to the lower need for dentin removal.

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