Evaluation of Apically Extruded Debris using Two Niti Systems Associated with Two İrrigation Techniques in Primary Teeth

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Purpose: *The aim of this study was to compare the effects of 2 NiTi file systems [Twisted File Adaptive (TFA) and Reciproc (RP)] and 2 irrigation techniques [Conventional needle irrigation (CNI) and Laser activated irrigation (LAI)] on the amount of apically extruded debris in primary maxillary molars.* ***Study design::*** *Sixty extracted primary maxillary molars were randomly divided into 4 groups. The mesio-buccal roots of teeth in 4 groups were instrumented using TFA with LAI, RP with LAI, TFA with CNI and RP with CNI respectively. Debris extruded during instrumentation was collected into Eppendorf tubes and amounts were determined. The data were analyzed using two-way ANOVA test at 0.05 level of significance.* ***Results:*** *The results indicated all instrumentation and irrigation systems caused a measurable apical extrusion of debris. However, no statistically significant difference in debris extrusion was observed between irrigation techniques or instrumentation systems ($P > 0.05$). The total amount of debris extruded apically by LAI was greater than that by CNI.* ***Conclusions:*** *All instrumentation and irrigation techniques caused debris extrusion. However, the optimal laser activation time and power settings should be investigated to ensure minimal extrusion of debris and irrigant due to cavitation and pressure during LAI in root canal treatment.*

Key Words: *Debris extrusion, primary teeth, Twisted File Adaptive, Reciproc, Laser activated irrigation, Er,Cr:YSGG laser.*

INTRODUCTION

Complete preparation of root canal is one of the major step for successful endodontic treatment. During preparation, irrigant and debris such as infected, devitalized, and necrosed pulp and dentin particles may be extruded into the periradicular region, leading to periapical inflammation, postoperative pain and delay of periapical healing [1]. Therefore, the reduction or elimination from apical extrusion of intracanal debris of infected teeth leads to successful treatment. This situation is important for primary as well as permanent teeth. Because of the physiological root resorption, primary teeth have wide apical foramen that allows rapid transportation of intracanal debris, microorganisms and irrigants such as NaOCl to the periapical tissues. Thus, apical extrusion of these materials can damage permanent tooth follicles and periapical tissues [2]. Although all preparation techniques and instruments are associated with extrusion of debris, the amount of debris extrusion may vary with techniques and the design of the file systems [3].

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Despite multiple advantages of rotary NiTi instruments, technological advancements in these instruments have led to new design concepts and easier and faster techniques. Recently, novel NiTi file systems have been developed to reduce the amount of apically extruded debris. One is Reciproc (RP) (VDW, Munich, Germany) system, which has been designed to completely prepare and clean root canals with only one file and reciprocating motion [4]. This motion consists of two special movements counterclockwise (cutting action) and clockwise (release of the file), though in these movements, stress of the file is decreased [5]. Additionally, the files of this system are manufactured with M-Wire technology, improving flexibility and resistance to cyclic fatigue [6].

The Twisted File Adaptive (TFA) (SybronEndo, Orange, CA, USA) system is another novel file that two separate movements' continuous rotation and a reciprocating motion are performed with together. Continuous rotation is performed when the file is exposed to minimal or no applied load and reciprocal motion is performed when it engages dentin and load is applied. This adaptive technology and twisted file design with R-phase treatment increases debris removal and flexibility and reduce the risk intracanal failure, without affecting producer performance [7]. Although shaping of the root canal has been improved with advances in metal technology of instruments, the cleaning of root canal system completely still continue because of the anatomical complexity and irregularity of teeth. Instruments could not reach the whole root canal system alone. Thus, mechanic instrumentation works with irrigation to remove debris [8]. Needle irrigation is the conventional method for irrigation, and the level of needle tip placement in the canal is the most important factor for solution penetration. The penetration of solution in the apical third of the root improves the success of treatment. Therefore, classical irrigation technique with conventional needle irrigation (CNI) is limited to providing this and sonic, ultrasonic, and laser activation are suggested to improve irrigant distribution in the root canal [9].

Laser activated irrigation (LAI) is the activation of irrigant solutions with lasers [8]. The using of pulsed middle infrared lasers erbium: yttrium-aluminum-garnet (Er:YAG) and erbium chromium: yttrium-scandium-gallium-garnet (Er,Cr:YSGG) for irrigation of the root canals has been increased. These pulsed lasers have been reported to create detonating vapor bubbles with secondary cavitation effects, enhancing fluid interchange, high pressure and the removal of debris [10]. It was reported that LAI was more effective than traditional needle irrigation at the removal of debris in permanent teeth [10, 11].

To our knowledge, no studies have assessed apical extrusion of debris in primary dentition and the effect of LAI during the root canal preparation on debris extrusion in both permanent and primary teeth. Therefore, the aim of this study was to compare the effects of 2 NiTi instrumentation systems [(TFA) and (RP)] and 2 irrigation [(CNI) and (LAI)] techniques on the amount of apically extruded debris in primary maxillary second molar teeth.

MATERIALS AND METHOD

This experimental *in vitro* study was conducted on left and right mesiobuccal (MB) canals of 60 extracted primary maxillary second molar teeth. Samples were selected according to the following parameters: minimal apical resorption with presence at least two-third of remaining (MB) root structure, arrangement of working length (WL) at 11 mm, absence of external and/or internal pathological root resorption, perforation in the internal and/or external furcation area, moderate root curvature (angles of curvature ranging between 10° and 20° that was determined according to Schneider's method [12] .

The teeth were decoronated at 12 mm length and access cavities were prepared with a high-speed handpiece (Endo Access Bur, Dentsply Maillefer, Ballaigues, Switzerland). Then the roots were covered with two coats of nail polish and a hole was created in the nail varnish that covered the apical foramen using a size 15 K-file. During this procedure, only 2 mm of instrument was extruded. In this way a standard size of foramen and apical patency was achieved. Also, the working length (WL) of each canal was determined as 1 mm short of the length of a size 10 K-file that was visible at the major diameter of the apical foramen.

Teeth were randomly divided into 4 groups of 15 each according to instrumentation and irrigation techniques.

In this study, to evaluate the apically extruded debris collection, the experimental model described by Myers and Montgomery [13] was used (Figure 1a). A hole was created on each stopper of Eppendorf tube and each tooth was inserted under pressure through the stopper, which was fixed by an adhesive (Pattex Super Glue; Turk Henkel, Istanbul, Turkey). The apical part of the root was suspended within the tube, which acted as a collecting container for apical material evacuated through the foramen of the root. A 27-gauge open-ended needle was inserted into each Eppendorf tube stopper to balance the air pressure between the inside and outside of the tube. Then each stopper, including the tooth and needle, was fitted into the Eppendorf tube and the tubes were fitted into vials.

Empty Eppendorf tubes without stoppers were weighed with an electronic balance (Precisa; Precisa Inst., Dietikon, Switzerland) with an accuracy of 10^{-5} precision.

In each sample, the total activation time was 1 minute and the total volume of 6 mL bi distilled water was used as the irrigation solution after each file or after 3 pecks using the reciprocating files (as recommended by the manufacturers). Two irrigation methods were used:

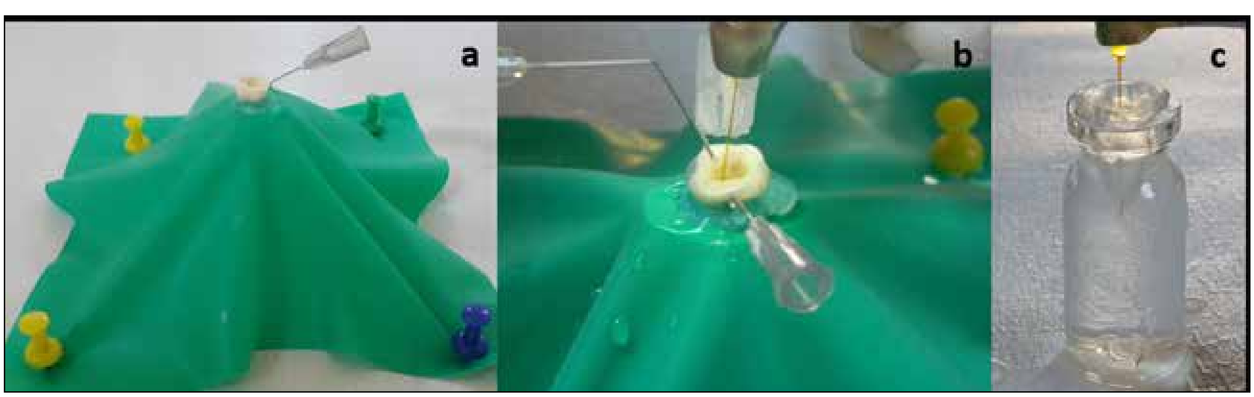
Procedure of LAI

An Er,Cr:YSGG laser system (2780 nm wavelength; Biolase Waterlase MD; Biolase Technology, Irvine, CA, USA) was used at a panel setting of 0.5 W at 20 Hz (25 mJ/pulse) with no air or water. The pulses were focused using a fiber tip (RFT2) with a diameter of 275 µm. First, the root canals were irrigated in a passive manner with 0.2 mL of bidistilled water, and the optical fiber was placed on the entrance of the root canal orifice and activated. During the laser irradiation cycles, root canals were continuously irrigated to maintain hydration and levels using a hand syringe with a 27-gauge open-ended needle positioned above the laser tip in the coronal

The teeth were irrigated with bidistilled water using a 27-gauge open-ended needle. To standardize the irrigation protocol, the needle was inserted into the canal within 2 mm from the WL, without binding, and moved in an up-and-down motion.

The root canal preparation sequences were as follows:

Figure 1: Fig 1a. An experimental system to evaluate debris extrusion; Fig 1b. LAI procedure; Fig 1c. Cavitation effect of LAI.



Group 1 (TFA and LAI): The files were used with the TFA program of TFA Motor (SybronEndo) in the sequence of SM1 (20/.04) and SM2 (25/.06) (full WL). The file was advanced to the canal with a single controlled motion until it engaged dentin. The LAI was applied during each file change, according to the above mentioned LAI protocol.

Group 2 (RP and LAI): A R25 (25/.08) RP file was used with the RP program of Gold Reciproc Motor (VDW) in a reciprocating, slow, in-and-out pecking motion according to the manufacturer's instructions. The flutes of the file were cleaned after 3 in-and-out movements (pecks). The LAI was applied between the pecking sequences, according to the above mentioned LAI protocol.

Group 3 (TFA and CNI): Instrumentation was performed in the same way as for the Group 1. The teeth were irrigated with a 27-gauge open-ended needle during each file change, according to the above mentioned CNI protocol.

Group 4 (RP and CNI): Instrumentation was performed in the same way as for the Group 2. The teeth were irrigated with a 27-gauge open-ended needle between the pecking sequences, according to the above mentioned CNI protocol.

Once the instrument had reached the end of the canal and had rotated freely, it was removed. Each instrument was used only in one canal. During the instrumentation procedure, the teeth were isolated with a rubber dam to prevent debris or irrigation solution extrusion through the hole. An aspirator was used to suck the irrigating solution that overflowed from the tooth crown. To avoid variation and eliminate biases, the cleaning, shaping, and irrigation procedures were carried out by a single operator and evaluation was done by a second examiner who was blinded to group assignment.

After completion of the instrumentation, the stoppers of the vial and Eppendorf tubes were removed. The surface of the root was washed with 1 mL bi distilled water into the vial to collect debris adhering to the root surface. The tubes were then stored in an incubator at 55 °C for 10 days to evaporate the distilled water before weighing the dry debris. The same electronic balance was used to weigh the tubes containing the debris. The Eppendorf tubes were weighed with the same analytical balance to obtain the final weight of the tubes including the extruded debris. Three consecutive weights were obtained for each tube. The net weight of the extruded debris was determined by subtracting the weight of the empty tube from the weight of the tube containing debris.

Statistical analysis

Data were analyzed statistically using two-way ANOVA test at 0.05 level of significance using SPSS statistical software (version 18, SPSS, Inc., Chicago, IL, USA).

RESULTS

The results indicated that all instrumentation and irrigation systems caused a measurable apical extrusion of debris. Table 1 presents the mean, minimal and maximum weights, as well as the standard deviation data of each group. Mean and standard deviations of the extruded debris amount was 0.000378±0.000168 g for Group 1 (TFA and LAI), 0.000361±0.000245 g for Group 2 (RP and LAI), 0.000338±0.000153 g for Group 3 (TFA and CNI), and 0.000353±0.000175 g for Group 4 (RP and CNI). The CNI groups extruded less debris than LAI groups with both TFA and RP systems. However, there were no significant differences between the groups at a confidence level of 95 % ($P > 0.05$).

Table 1. Amount of debris extruded apically after using the different instruments and irrigation systems (g)

Debris extrusion (gr)	Group 1 (TFA/LAI)	Group 2 (RP/LAI)	Group 3 (TFA/CNI)	Group 4 (RP/CNI)
Mean	0.000378*	0.000361*	0.000338*	0.000353*
Standard deviation	0.000168	0.000245	0.000153	0.000175
Number of samples	15	15	15	15
Minimum	0.00015	0.00011	0.00013	0.00006
Maximum	0.00081	0.00094	0.00061	0.00074

Same superscript letter indicates nonsignificant difference between the groups.

CNI: Conventional needle irrigation

LAI: Laser activated irrigation

RP: Reciproc

TFA: Twisted File Adaptive

DISCUSSION

Root canal preparation and irrigation procedures may trigger an inflammatory reaction by forcing intracanal content such as dentin, necrotic pulp tissue, or microorganisms through the periapical tissue. Therefore, apical extrusion of debris, bacteria, and irrigants during root canal treatment or retreatment with NiTi and hand files has been studied extensively because of its clinical relevance for permanent teeth [3, 7, 14-20]. This phenomenon for primary dentition is also important for permanent dentition, because the negative effects of apically extrusion of necrotic debris, microorganisms and many kinds of irrigants including NaOCl and chlorhexidine can be detrimental to stem cells [21]. The preservations of the remaining dental pulp stem cells and mesenchymal stem cells of the apical papilla (SCAPs) are important prerequisites for root canal revascularization and root maturation [22]. In addition, the root canal disinfection materials may lead to alterations in the dental germ, such as hypoplasia, morphological alteration on the dental crown or total arrest of radicular formation [23]. However, apical extrusion of debris has not been investigated on primary teeth. Because, studies have been limited to teeth with mature root morphologies. Physiologic resorption starts soon after the completion of the formation of a primary tooth. Then the dimension, shape, and position of the apical foramen continuously alter. The primary teeth have wider apical foramen than permanent teeth, because of the physiological root resorption. Thus, more intracanal materials may be easily extruded to the periapical tissue during root canal treatment. Therefore, the main purpose of the present study was to assess the apical extrusion of debris as a result of canal shaping by different NiTi instruments (RP and TFA) and irrigation techniques (CNI and LAI) in MB roots of the primary second molars. Also, our results were compared with studies performed with permanent teeth, because no study has been published on apical extrusion of debris from root canals of the primary teeth.

A previous study showed that less debris extrusion was associated with the balanced force and crown-down techniques compared with linear filing motion [24]. Thus, the Reciproc system was develeoped as a sort of mechanized balanced force technique for improving control of apically extruded debris [25]. Its better design, improved alloy, fewer number of files, and high cutting ability can also lead to better performance during the treatment [26]. However, despite its important advantages, unfortunately its disadvantages may lead negative effect in relation to its structural and procedural properties. For example, the reciprocating method uses a rigid single file of increased taper, such as 25/.08, in order to reach the apex. Therefore, a reciprocating file with a noncutting, greater tip needs more inward pressure for progressing towards the apex compared to a similar-sized rotary NiTi file, and this pressure may push the debris towards the apex [19, 20].

The TFA system has been proposed to maximize the advantages of reciprocation, while minimizing its disadvantages by using a unique, patented motion and a 2- or 3-file method. While a review of the literature revealed that no study has evaluated the extent of apically extruded debris during root canal treatment with either TFA or Reciproc systems, only one study compared the TFA system with WaveOne, another reciprocating file system [27]. The results of the present study corroborate the findings of this previous study [27]. These results could probably be explained by the same tip size (tip size of the RP system's single file and TFA system's the last file was #25), and similar kinematics (reciprocal movement can be used by both instrumentation systems) of both systems.

In this current study, 6 mL of bi-distilled water was used in each tooth. For accurate measurement, completely pure bi-distilled water was used to prevent the presence of particulate matter, which is found in other irrigants, from skewing the final values.

In the present study, both CNI and LAI were used along with different preparation methods. Although it is advisable to use LAI after each file for debriding and decontamination of the endodontic system [28] in most studies, this irrigation technique was used with different objectives, only after completion of root canal preparation [29-31]. Furthermore, these studies did not report the amount of debris extruded apically when LAI was used after each file during the root canal preparation. Thus, we evaluated the effect of LAI on apically extruded debris after each file or 3 pecking motions on primary teeth.

Although LAI resulted in more apical debris extrusion compared with CNI, the result of the current study revealed no significant difference in the irrigation systems used. This result could be because positive pressure affects both techniques. Open-ended needles have been reported to result in significantly more irrigant extrusion than closed-ended needles [32] which could be explained by higher irrigant pressure developed at the apical foramen [33]. Penetration depth is another important factor in root canal irrigation. If the needle's tip is advanced to the apical foramen, the risk of extruding irrigant and debris increases [33]. Therefore, recommendations for the use of needle irrigation include not binding the needle, not placing the needle to WL, and using a gentle expression of irrigant to avoid forcing irrigants into the periapex [34]. Similarly, the LAI is another irrigation technique with positive pressure. Laser activation of the irrigant produces cavitation and pressure waves in the root canal (Figure 1c). Cavitation is defined as the formation of vapor or a cavity that contains bubbles inside a fluid [35]. In water, a laser at ablative settings can form large, elliptical vapor bubbles. These bubbles can expand the irrigant up to 1600 times the original volume [36]. This expansion is the mechanism that generates high pressure that can facilitate 3D movement of the irrigation solutions, which might assist in cleaning the root canals [31]. Hence, this high pressure and more aggressive irrigation may cause the larger quantity of debris extruded apically by LAI than CNI, in the present study. Also, larger amount of debris extrusion with LAI may be explained by the wide apical foramen of the primary teeth. Because remaining debris after each file used may easily pushed by high pressure of the LAI. Additionally, because the root length of the primary teeth is shorter than permanent teeth the distance that the extruded debris takes is shorter in primary teeth. The diameter of the fiber is another important factor for debris or irrigant extrusion. Because the cavitation bubble size and the life time depend on the size of the fiber used. In the present study, 275 µm RFT2 fiber tip was used for laser application. However, further studies should evaluate debris extrusion using larger diameter fiber tips.

The distance between the fiber tip and apex may also affect the apical fluid pressure during laser activation in the root canal [31]. To avoid some undesirable effects of conventional laser applications (such as creation of ledges up to canal curvature, carbonization cracks, collateral damage, and apical extrusion of the irrigant and debris), the fiber tip of the laser was used only in the orifice of the root canals for LAI, as in some previous studies [28-31]. During laser irradiation, the root canal was irrigated continuously to maintain hydration. The pulp chamber served as a reservoir for the irrigant.

The amount of extruded debris was collected following the Myers and Montgomery method [13], but the debris collection apparatus was slightly modified to make it more simple, practical, and affordable using an Eppendorf supported on an vial. This method also prevents fingertip contamination throughout the entire experiment. Because the amount of extruded material is extremely low, the contact of moist or greasy fingertips may alter the weight of the extruded debris significantly [37].

In the present study, there was no pulp tissue inside the root canals, nor was there any periapical tissue that could act as a barrier against the apical extrusion of debris. This fact limits the extrapolation of our results to the clinical environment, which is considered a shortcoming in most extrusion studies [3, 14, 16].

Single-root teeth are usually used in studies on apically extruded debris mainly because of the ease in setting up the collector apparatus as well as the greater predictability of the cleaning and shaping procedures. However, mesial roots of maxillary second molars were chosen for the current study, to approximate the challenging real clinical situation. So the amount of debris extrusion was assessed during the root canal preparation of teeth with more intricate anatomy.

There is general consensus that root canal treatment is contraindicated in primary teeth displaying root resorption of more than one-third of the root [38]. Thus, primary maxillary second molars with at least two thirds of root length remaining, were used, in the current study. Also, apical foramen widening of the primary teeth is not standard, because of the physiological root resorption.

Therefore, all root canal surface of the teeth was sealed with nail varnish and a hole was created with a size 15 K-file to achieve a standard size of apical foramen.

CONCLUSION

In the present study, all instrumentation and irrigation techniques caused debris extrusion. But no significant differences were found between the instrumentation and irrigation techniques used. However, we opine that if laser activation is carried out for a longer duration using higher power with a larger diameter fiber tip, debris extrusion may increase. Therefore, the optimal laser activation time and other parameters need to be investigated to ensure minimal extrusion of debris and irrigant due to cavitation and pressure during root canal treatment.

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