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Apical extrusion of debris in primary molar root canals using mechanical and manual systems

ABSTRACT

Aim *Apical extrusion of debris in primary root canal treatment has not been well elucidated. The purpose of this study is to compare the amount of apically extruded debris during the preparation of primary molar root canals using ProTaper, ProTaper Next, Self-adjusting File (SAF) and hand files.*
Methods *One hundred sixty extracted primary mandibular molar teeth were assigned to 2 groups: Group 1: Resorbed (n=80) and Group 2: Non-resorbed (n=80) and randomly to four subgroups (n=20 teeth for each subgroup) according to the instruments used, ProTaper, ProTaper Next, SAF, and hand file. The apically extruded debris was collected and dried in preweighed Eppendof tubes. The dry weight was calculated by subtracting the preoperative weight from the postoperative weight. Statistics: Data were analysed statistically using the ANOVA and the Bonferroni post hoc t-test.*
Results *The amount of apically extruded debris was significantly less for the non-resorbed group compared to the resorbed group (P<0.05). Regardless of the resorption groups, ProTaper Next and SAF extruded significantly less debris than did the ProTaper and hand files (P<0.05), while no statistically significant difference was found between ProTaper Next and SAF (P>0.05).*
Conclusion *All instruments caused apically extruded debris in primary teeth.*

Keywords *Apical extrusion; Paediatric endodontics; Primary teeth; Rotary systems.*

Introduction

Root canal treatment is indicated for primary teeth displaying signs of irreversible pulpitis or pulp necrosis [Aboujaoude et al., 2015]. In traditional paediatric endodontics, root canal preparation is performed with hand instruments. However, this manual technique may lead to canal aberrations, perforations, inadequate cleaning, transportation, instrument failure, and long chair time for children [Canoglu et al., 2006; Oznurhan et al., 2014]. Since its development, nickel titanium (NiTi) rotary instrumentation is widely used in adult endodontics as an efficient technique [Peters, 2004]. Using the NiTi rotary instruments in primary teeth—which Barr et al. [2000] initiated and others [Canoglu et al., 2006; Crespo et al., 2008; Pinheiro et al., 2012; Silva et al., 2004] have elaborated since then—there has been an increase in examining the use of NiTi instruments in paediatric endodontics. Barr et al. [2000] stated that using NiTi instruments for root canal preparation in primary teeth is faster, cost effective, and has resulted in uniform and predictable fillings. According to Silva et al. [2004], the reduction of the instrumentation time with NiTi files is an important clinical factor for paediatric endodontic therapy since it allows for faster, safer and more effective root canal preparation, additionally reducing the fatigue of the patient and the dental team.

The complete debridement of the entire root canal through chemomechanical preparation is one of the major aims of contemporary root canal treatment [Barbizam et al., 2002]. However, it is a relevant issue for the success of primary teeth root canal treatments, especially during root resorption of the primary teeth [Coll and Sadrian, 1996]. Several studies reported that all preparation techniques and root canal instruments cause the extrusion of debris, irrigants and microorganisims from the apical foramen, thus resulting in postoperative inflammation, pain and failure [Koçak et al., 2013].

New developments in NiTi rotary instruments have led to new design concepts that efficiently create smooth, original canal forms with minimal risk of iatrogenic errors [Kim et al., 2012; Peters, 2004]. ProTaper rotary instruments (Dentsply Maillefer, Ballaigues, Switzerland) have a convex triangular cross-section that improves cutting efficiency and core strength. This design decreases the rotational friction between the instrument and dentin, increases the cutting efficacy, and improves safety more than instruments with a radial-landed design do [Peters, 2004]. ProTaper Next (Dentsply Maillefer, Ballaigues, Switzerland), recently developed as a successor of the ProTaper system [Elnaghy and Elsaka, 2014], has an off-centered rectangular design that provides shaping advantages through the convergence of a variable tapered design on a single file, m-wire alloy and a unique offset mass of rotation [Capar et al., 2014]. These percentage tapers reduce contact between the file and the dentin, resulting in a decrease in the effect of the screw and harmful taper lock. The m-wire alloy improves the resistance to cyclic fatigue, decreases the potential for broken instruments and increases flexibility [Elnaghy, 2014]. Moreover, this design increases debris removal compared with an instrument with a centered mass and axis of rotation [Capar et al., 2014].

The self-adjusting file (SAF) is a hollow file composed of a thin NiTi lattice and featuring a 1.5 mm diameter that can easily be inserted into a canal that has previously been prepared by a size #20 K-file [Metzger et al., 2010]. The SAF provides three-dimensional adaptation during root canal preparation. It adapts itself to the canal's shape, both longitudinally and along the cross-section. The SAF removes a uniform layer of dentin from the entire root canal system [Metzger et al., 2010]. Due to its use of a single file with continuous irrigation, the SAF can clinically reduce the preparation and treatment time in primary teeth, which is an important clinical issue during children's treatments.

The rationale for this study was based on the argument that although several studies [Bürklein and Schäfer, 2012; Capar et al., 2014; Ferraz et al., 2001; Koçak et al., 2015; Koçak et al., 2013; Kuştarcı et al., 2008] have assessed the apical extrusion of debris in permanent teeth, the endodontic treatment technique for primary teeth differs from adult therapy since primary teeth exhibit anatomical differences from permanent teeth in terms of size, internal and external morphology [Ahmed, 2013], and morphological changes owing to the presence of physiological or pathological root resorption [Harokopakis-Hajishengallis, 2007]. Thus, the resuts obtained in permanent teeth cannot be routed to primary teeth. Moreover, even if the working length is carefully determined and the instrumentation does not extend beyond the apex, the possible damaging effect of apically extruded material on the underlying permanent tooth is still present [Topçuoğlu et al., 2015]. Limited data concerning the use of NiTi files in paediatric endodontics are available [Barr et al., 2000; Silva et al., 2004; Topçuoğlu et al., 2015]. The apical extrusion of debris in primary root canal treatment has not been well elucidated. However, in a recent *in vitro* study, Topçuoğlu et al. [2015] used three rotary systems and hand files in primary molar roots and concluded that all instruments cause extruded debris.

The aim of this *in vitro* study was to compare the amount of apically extruded debris during the preparation of primary molar root canals using ProTaper, ProTaper Next, SAF and hand files. The null hypotheses tested were that (a) no difference exists between the amounts of apically extruded debris associated with various NiTi systems and hand files, and (b) no difference exists between the amounts of apically extruded debris associated with the presence of the resorption of primary molar roots.

Material and methods

Sample selection

Ethical approval was obtained from the Health Ethics Committee of the University of Cumhuriyet, Sivas, Turkey (ID: 2016-06/11). The sample for each group consisted of 20 teeth, and the power analysis revealed P = 0.87145 by using the values based on a previous study [Topçuoğlu et al., 2015] and $\alpha = 0.01$, $\beta = 0.10$, $1- \beta = 0.90$.

Human primary mandibular second molars that had recently been extracted were collected from patients aged 5-8 years, for periapical pathology and orthodontic reasons, and stored in distilled water at 4°C. Buccal and mesiodistal preoperative radiographs were taken to determine root curvature of less than 30°C using the Schneider method [Schneider, 1971], and the presence of the single, noncomplicated canals of distal roots. The determination of the amount of root resorption was performed using the formula that Rajan et al. [2014] described, which is based on the argument that the percentage of the total root length with resorption can be calculated using Kramer and Ireland's data [1959], where the root length of the mesial root is 11.37 mm and that of the distal root is 10.55 mm. The distal roots were examined under an operating microscope (Zeiss, Oberkochen, Germany) for any visible resorption. The distance between the cemento-enamel junction and the first point of visible root resorption was recorded using a digital caliper. Teeth with <33% of their root lengths affected by resorption were included in the study since primary root canal treatment is indicated where pathologic root resorption involves less than one-third of the root. The mesial roots of each tooth were removed with a diamond bur under water cooling. Coronal access was prepared using diamond burs. Canal patency was controlled with a size #10 K-file (Dentsply/Maillefer, Ballaigues, Switzerland) in the nonresorbed roots, and a size #20 K-file in the resorbed roots. Canals with larger apical foramen than these dimensions were excluded from the study. Finally, 160 teeth met all of the inclusion criteria and were randomly divided into two groups; Group 1- Nonresorbed (n = 80) and Group 2- Resorbed (n = 80) and four subgroups: (a) ProTaper (n = 20), (b) ProTaper Next (n = 20), (c) SAF. (n = 20) and (d) hand files (n=20). The homogenity of the groups in terms of root length was comfirmed by analysis of variance (ANOVA). A size #10 K-file was inserted into the root canal until it was visible apically under a magnifying loupe to determine the working length (WL), which is 1 mm less than the real length.

Root canal preparation

ProTaper Universal

ProTaper Universal instruments were used according to the manufacturer's instructions using a slow in-and-out brushing motion with an endodontic motor (NSK, Shimohinata, Japan) at a rotational speed of 300 rpm. The instrument sequence was SX at two-thirds of the WL, S1 and S2 at 1 mm beyond the WL, and F1 and F2 at the WL.

ProTaper Next

ProTaper Next files were used in the sequence of X1, X2 and X3 (full WL) with the same endodontic motor at a rotational speed of 300 rpm and 200 gcm torque. Each file was used with a gentle in-and-out brushing action.

SAF

To confirm a glide path, a size #20 K-file was inserted into the WL, and the samples were prepared with this hand file. Then, a 1.5-mm-diameter and 25-mm-length SAF was used in the canal using an RDT3 head (ReDent-Nova) with the same endomotor at a frequency of 5,000 vibrations/min and an amplitude of 0.4 mm. The total time spent on the instrumentation was 4 minutes. Continuous irrigation with bidistilled water was applied throughout the procedure at a rate of 2 mL/min using a special irrigation device (VATEA, ReDent-Nova).

Hand file

In the nonresorbed group, a step-back technique with stainless K-files at Wl was used. The preparation sequence was as follows: size #15.02, #20.02, #25.02, #30.02 and #35.02 files. In the resorbed group, the sequence began with size #25.02, followed by size #30.02, #35.02, #40.02 and #45.02.

Each instrument was used to prepare three canals only. Once the instrument had reached the full length of the canal and had rotated freely, it was removed. Except for the SAF groups, each root canal was irrigated with a total of 2 ml of bidistilled water using a 27-gauge needle between each instrument change. A single operator performed all instrumentation to facilitate consistent instrumentation protocols, while a blinded second examiner assessed the amounts of extruded debris.

Debris collection

The experimental model that Myers and Montgomery [1991] described was used in this study. The stoppers of Eppendorf tubes were removed, and tubes without stoppers were weighed using an electronic balance (Precisa, Dietikon, Switzerland) with an accuracy of 10-4 g to determine the initial weight. Three consecutive measurements were taken for each tube, and the mean values were calculated. A hole was drilled in each stopper of the tubes, and each tooth was forcibly inserted up to the cementoenamel junction. A 27-gauge needle was placed alongside the cover as a drainage cannula to equalize the internal and external air pressure. Then, each unit, including the stopper, tooth and needle, was fixed to its Eppendorf tube. The tubes were fitted into vials to hold the device during preparation. The vials were covered with aluminum foil to prevent the examiner from seeing the extruded debris. After preparation, the teeth were separated from their vials and eppendorf tubes, and the surface of the root was washed with 1 mL of bidistilled water to collect the debris adhering to the root surface. The tubes were then stored in an incubator at 70°C for 5 days to let the moisture evaporate before the dry debris was weighed. The mean value for each tube obtained from three consecutive weights was recorded. The dry weight of the apically extruded debris was calculated by subtracting the preoperative weight from the postoperative weight.

Statistical analysis

Data were analysed statistically using the ANOVA and the Bonferroni post hoc t-test at a significance level of $P<0.05$. All data were processed by SPSS 15.0 software (SPSS Inc., Chicago, IL).

Results

The mean values and standard deviations of the amount of apically extruded debris (g) for all groups are shown in Table 1. The results showed that all instrumentation techniques caused a significant amount of extruded debris. The amounts of apically extruded debris were significantly less for the non-resorbed group compared to the resorbed group ($P<0.05$). Regardless of the resorption groups, the ProTaper Next and SAF extruded significantly less debris than did the ProTaper and hand files ($P<0.05$), while no statistically significant difference was found between ProTaper Next and SAF ($P>0.05$).

Discussion

Since its introduction, the rotary system has been regarded as an ideal techniquie for endodontic procedures [Peters, 2004]. Various studies have examined the use

	Instrumentation			
Groups	Hand files	ProTaper	SAF	ProTaper Next
(1) Non-resorbed	0.001112 ± 0.000203[a]	0.001224 ± 0.000627[a]	0.000650 ± 0.000271[b]	0.000581 ± 0.000254[b]
(2) Resorbed	0.001601 ± 0.000592[a]	0.001561 ± 0.000606[a]	0.000821 ± 0.000335[b]	0.000705 ± 0.000286[b]
The same superscript letters indicate statistically no significant values. Values are shown as Mean ± SD.				

TABLE 1 Mean and standard deviation of the amounts of apically extruded debris (g) for all groups.

of NiTi rotary systems in terms of various issues, such as preparation time, cleaning efficacy, perforation, canal formation and apical extrusion [Bürklein and Schäfer, 2012; Canoglu et al., 2006; Koçak et al., 2015; Pinheiro et al., 2012]. Most root canal preparation instruments, especially working in the coronoapical direction, cause the apical extrusion of intracanal debris, irrigants and microorganisims [Capar et al., 2014]. These extruded materials can have toxic effects on the underlying permanent tooth [Topçuoğu et al., 2015].

Several methodologies have been developed to evaluate the amount of apically extruded debris [Myers and Montgomery, 1991; Tanalp and Güngör, 2014]. In this study, we have used the method described by Myers and Montgomery [1991], which is the most-used method in the dental literature [Tanalp and Güngör, 2014]. In our study, *in vivo* conditions, exhibiting the presence of periapical tissue, were not simulated since *in vivo* simulations using materials to close the apical foramen may lead to the absorption of the irrigant and debris, thus leading to different results [Bürklein and Schäfer, 2012]. Although sodium hypochlorite (NaOCl) is the most-used irrigant in endodontic treatments [Topçuoğu et al., 2015], we have used bidistilled water as an irrigant in the present study to avoid the possible crystallization of NaOCI, thus resulting in an intense affiliation with debris as described previously [Koçak et al., 2013].

Although several studies have reported that all instruments used in root canal preparation, including hand files and NiTi rotary systems (either using a single-file or multiple-file system), produce apically extruded debris in permanent teeth [Bürklein and Schäfer, 2012; Ferraz et al., 2001; Koçak et al., 2013; Kuğarcı et al., 2008; Tanalp and Güngör, 2014], to the best of our knowledge, no previous study has compared the amount of apically extruded debris with SAF, ProTaper and ProTaper Next in primary teeth. However, in a recent *in vitro* study, Topçuoğu et al. [2015] assessed the amount of apically extruded debris using Revo-S, Mtwo, ProTaper Next and hand files in primary molars with at least two-thirds of the root, and they concluded that all instruments are associated with the apical extrusion of debris. Similar to our study, they found that ProTaper Next significantly extruded less debris than hand files did. However, we also concluded that ProTaper Next extruded significantly less debris than did the ProTaper and hand-file group, while no statistically significant difference was found between ProTaper Next and SAF. This result is consistent with the previous studies [Bürklein and Schäfer, 2012; Capar et al., 2014; Koçak et al., 2013]. Koçak et al. [2015] assessed the amount of apically extruded debris using ProTaper and ProTaper Next in permanent teeth and determined that ProTaper Next files extruded significantly less debris than did ProTaper. Capar et al. [2014] assessed the amount of apically extruded debris using ProTaper, ProTaper Next, Twisted File Adaptive and HyFlex instruments and concluded that ProTaper Next and Twisted File Adaptive instruments extruded less debris compared to the ProTaper and HytFlex systems. Contrary to our study, Kocak et al. [Koçak et al., 2013] compared the amount of apically extruded debris using SAF, a reciprocating single-file, Revo-S and ProTaper and concluded that although ProTaper extruded the highest amount of debris, no statistically significant difference was found among the groups.

The findings of the present study could be attributed to the cross-sectional design, working mechanism and number of instruments used. ProTaper instruments have a convex triangular cross-section and multiple increasing percentage tapers over the length of the cutting blades with a brushing action. ProTaper Next has an off-centered rectangular design with a snake-like swaggering movement. This design increases debris removal through the canal compared with a file with a centered mass and axis of rotation. Similar to our study, Koçak et al. [2015] reported that ProTaper Next extruded significantly less debris than did ProTaper. SAF is a single-file system that has a hollow design where dentin removal is performed like a grinding action. However, SAF provides all dimensional root canal preparation with relatively uncontrollable apical preparation. Koçak et al. [2013] stated that apical enlargements may differ with the SAF system because of its uncontrolled apical preparation. This may be why SAF extruded more debris than ProTaper Next did, contrary to its single file use, in the current study.

In terms of the number of instruments used in each canal, we used five files in the ProTaper groups, a single file in the SAF groups, three files in the ProTaper Next group and five files in the hand-file group. Using so many intruments caused an increase in the diameter of the apical patency, thus resulting in increased apically extruded debris [Albrecht et al., 2004]. ProTaper Next extruded less debris compared with the multiple-file systems.

Pretreatment root resorption, owning to pathological or physiological root resorption, is an important factor in pediatric pulpectomy. Coll and Sadrian [Coll and Sadrian, 1996] stated that in the absence of pretreatment pathologic resorption, the pulpectomy success rate was 91.7%. In this study, we experimentally assessed primary molar root canals with or without resorption, as the roots of primary teeth vary clinically due to the resorption degree. The physiological resorption of the roots of primary teeth begins by the process of the eruption of the permanent teeth. Sometimes if a permanent tooth does not erupt owning to several reasons, the roots of the primary tooth are not resorbed. Concerning this clinical variation, we tested the hypothesis that no difference exists between the amount of apically extruded debris associated with or without the resorption of primary molar roots. The results of this study showed the rejection of this hypothesis. We found that all instruments caused significantly more extruded debris in roots with resorption than in roots without resorption. This result is consistent with the previous study [Grover et al., 2013], which reports that resorption can affect dental hard tissues, but it can also involve soft tissue and foreign materials, such as necrotic pulp tissue or materials used in root canal treatment that have been extruded through the apical foramen. Another possible explanation for this result is the presence of increased apical patency in the root canals of primary teeth with resorption compared with roots without resorption [Ahmed, 2013]. This anatomical difference can easily cause more debris extrusion from an enlarged apical foramen.

Conclusions

In conclusion, the null hypotheses were rejected, as significant differences were found among the instruments used and between the roots with or without resorption. Within the limitations of the present *in vitro* study, all instrumentation systems extruded debris. However, ProTaper Next and SAF extruded significantly less debris than did ProTaper and hand files, while no statistically significant difference was found beween ProTaper and hand files. In addition, significantly more extruded debris was found in the resorbed group than in the nonresorbed group.

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