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ORIGINAL RESEARCH

Apically extruded debris evaluation with the use of ProTaper Ultimate and TruNatomy files systems with and without glider preparation in primary tooth

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Abstract

Information regarding the influence of resorption and glide paths on debris extrusion in primary teeth is lacking. Therefore, we evaluated debris extrusion with and without resorption and with and without the use of a path file in primary molar teeth prepared with ProTaper Ultimate (PTU) Prime and TruNatomy (TRN) Prime rotary file systems. Forty resorbed and forty non-resorbed primary molar teeth were collected. Both groups were divided into four subgroups ($n = 10$). The Eppendorf tubes were weighed pre-debris. The distal canals of the teeth were prepared with PTU Prime and TRN Prime file systems, with and without the use of path files. The debris-filled tubes were weighed, and the weight of only the extruded debris was calculated by subtraction. The data were analyzed using a three-way analysis of variance (ANOVA) test. The presence of tooth resorption significantly increased debris extrusion, and the use of a path file significantly decreased debris extrusion ($p < 0.001$). The binary and ternary interactions of the three evaluated parameters among the groups showed no significant differences in terms of the amount of debris extruded ($p > 0.05$). While debris extrusion was observed in all groups, the use of a glide path file in primary teeth before the preparation process resulted in less debris extrusion.

Keywords

Apically extruded debris; Glide path; Nickel titanium file; Primary teeth; Root canal preparation

1. Introduction

Primary teeth are multipurpose: they influence jawbone and muscle development, ensure the proper eruption of permanent teeth, and affect phonation [1, 2]. For this reason, preserving primary teeth within the oral cavity is of utmost importance. Irreversible infections and infected or necrotic pulp can lead to premature loss of primary teeth [2]. In such situations, endodontic treatments are routinely performed to retain primary teeth within the mouth [3]. For endodontic treatment of primary teeth, it is necessary that no more than two-thirds of the root be resorbed [4]. One of the most critical factors determining the success of endodontic treatment in primary teeth is chemomechanical preparation [5]. During chemomechanical preparation, dentin fragments, pulp tissue, and microorganisms can be transported apically and may be extruded into periarticular tissues [6]. While apical debris extrusion may influence the success of endodontic treatment, it is not the only factor.

The broad apical foramen of the primary teeth facilitates extrusion of debris into the periapical tissues [5]. This debris extrusion can harm the periapical stem cells and the permanent tooth bud located beneath the primary tooth [7]. Therefore, in shaping primary teeth, hand files or single- or multiple-file nickel-titanium (Ni-Ti) rotary systems are used. The Ni-Ti rotary systems provide faster, safer, and more effective root canal preparation while also reducing fatigue for both the patient and the clinician [8].

Glide paths are smooth paths created from the canal orifice to the apical constriction. These paths enhance the performance of Ni-Ti file systems while ensuring less apical extrusion of debris [9]. To create glide paths, both hand files and rotary files are used. Recently, the TruNatomy (TRN) rotary file system (Dentsply Maillefer, Ballaigues, Switzerland) was developed as a new type of heat-treated Ni-Ti instrument with a unique design. Due to its special thermal treatment, the TRN file is more flexible and resistant to fatigue [10]. This system includes a (17/0.02v) Glider for making the glide path and small (20/0.04v), prime (26/0.04v) and medium (36/0.03v) files for shaping. These files have a parallelogram cross-section, an off-centered design, and a variable taper. The manufacturer claims that due to the unique design of the instrument, it increases debridement during preparation [10]. Another rotary file system, the ProTaper Ultimate (PTU; Dentsply Maillefer), is the newest member of the ProTaper family. It is among the first systems to utilize crystallographic ordering through special thermal treatment, aiming for a balance between flexibility and strength [11]. This system comprises a Slider (16/0.02v) made of M-wire for making the glide path and F1 (20/0.07v), F2 (25/0.08v), and F3 (30/0.09v) files for shaping [12].

In the literature, no study has yet evaluated these file systems in terms of debris extrusion in primary teeth. Therefore, the aim of this study was to assess and compare debris extrusion in primary molar teeth during preparation using the TRN Prime and PTU Prime rotary file systems with and without the use of the glider/slider file in distal canals with and without resorption. Four hypotheses were developed as follows:

1. No significant difference in debris extrusion will be found between the main preparation files.
2. No significant difference in debris extrusion will be found between roots with and without resorption.
3. The presence of a glide path will not create a significant difference in terms of debris extrusion.
4. The binary and ternary interactions of the three parameters evaluated in the study will not be significantly different in terms of the amount of debris extruded apically.

2. Materials and methods

2.1 Sample size calculation

All study procedures were performed in Firat and Dicle University's Faculty of Dentistry's laboratories. Based on a previous study, we performed a power calculation using G*Power 3.1 software (Heinrich Heine University, Dusseldorf, Germany) that resulted in $\alpha = 0.05$, ß = 0.95 and $f = 0.746$ [7]. The calculation indicated that the total sample size should be at least 48 teeth.

2.2 Tooth preparation

For this study, we used straight-structured distal roots (<10° according to the Schneider method) of primary mandibular second molars with indications for extraction, such as persistent, orthodontic reasons and periapical pathology [13]. The teeth were stored in distilled water at 4 °C until use. Teeth with internal and external resorption, perforation, root fracture, open apex, radicular fissure, more than one canal in the root, and several apical foramens were excluded from the study. The resorption status of the teeth and the study criteria were checked using both dental operating microscopy (Zumax OMS 2360, Suzhou New District, China) at ×24 magnification and periapical radiographs. Teeth without resorption were selected from those that had a closed apex and showed no signs of resorption in the distal root. For the teeth with resorption, the distance between the cementum–enamel junction and the first visible root resorption point was measured using a digital caliper. Teeth with resorption of less than approximately one-third of the root length were included in the study.

Distal roots with a minimum length of 8 ± 0.5 mm were obtained by separation, first from the cementum–enamel junction and then from the mesial roots. Endodontic access cavities were prepared using diamond burs with a high-speed handpiece under water cooling. Canal patency was checked with a #10 K-file (Dentsply Maillefer) for roots without resorption and a #15 K-file (Dentsply Maillefer) for roots with resorption. Canals with apical foramens larger than these sizes were excluded from the study. Under a dental operation microscope (Zumax OMS 2360), in roots without resorption, a #10 K-file was placed into the canal. In roots with resorption, a #15 K-file was advanced until visible from the apex; from this point, the working length was determined as 1 mm short. All teeth meeting the inclusion criteria were divided into two main groups according to their resorption status. Then, teeth were numbered and, using a randomizer program (randomizer.org), subdivided according whether a glider/slider would be used during preparation and which main shaping file would be used (Fig. 1). To account for the potential dropout risk, 80 samples (10 per subgroup) were included in this study.

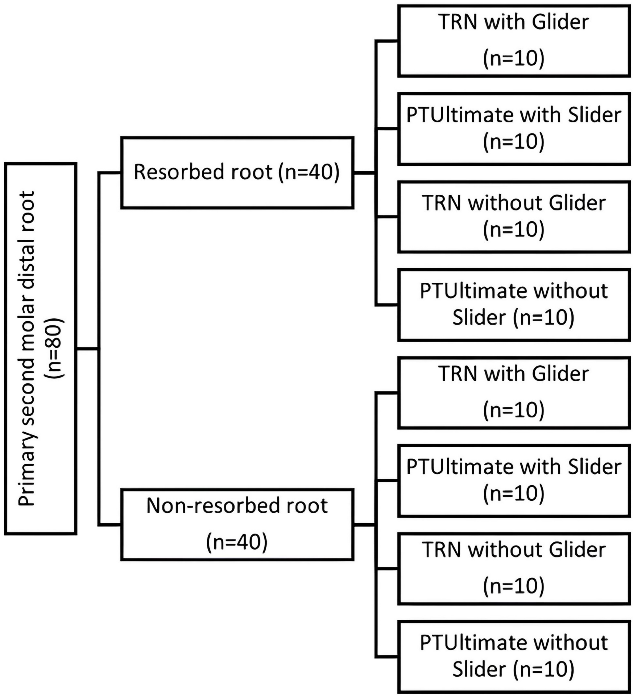

FIGURE 1. Grouping of samples based on the file used, the presence of gliders, and the presence of resorption in the teeth. TRN: TruNatomy; PTU: ProTaper Ultimate.

2.3 Root canal preparation and debris collection

In this study, the experimental model described by Myers and Montgomery was used to evaluate debris extrusion [14]. The caps of the Eppendorf tubes were removed, and the capless tubes were weighed three times using a 10^{-5} precision electronic scale (Mettler Toledo, Denver Instrument, New York, NY, USA) to determine their initial weight, which was then recorded. Holes were made in the removed Eppendorf tube caps, and each tooth was positioned up to the cementoenamel junction. The teeth were fixed to the caps using a flowable composite (Grandio Flow; Voco GmbH, Cuxhaven, Germany). A 27 G needle (Ayset, Adana, Turkey) was inserted next to the cap to equalize the pressure inside the tube with the atmospheric pressure outside. Subsequently, the cap, tooth, and needle were placed into the Eppendorf tube. To prevent the operator from seeing the debris generated during the preparation process, the tubes were placed into glass jars covered with aluminum foil. Then, including the tooth and needle, was fitted into the Eppendorf tube, and the tubes were fitted into vials.

During tooth preparation, using an endodontic motor (X-Smart Plus, Dentsply Maillefer, Ballaigues, Switzerland), 25 mm in length, the TRN Glider (17/0.02v) and Prime (26/0.04v) files were used continuously at 500 rpm and 1.5 Ncm torque, while the PTU Slider (16/0.02v) and F2 (25/0.08v) files were used at 400 rpm and 4 Ncm torque. Each file was inserted into the root canal with two or three gentle advances of 2–5 mm each. The file was withdrawn, and its flutes were cleaned with a sterile sponge. The canal was irrigated with 2 mL of distilled water using a #30 G double side vented irrigation needle (Irriflex; Produits Dentaires SA, Switzerland). The procedure was repeated until the working length was achieved. The files were used once for each tooth. A total of 20 mL of distilled water was used during the preparation process. Root canal preparations were performed using a dental operating microscope (Zumax OMS 2360, Suzhou New District, China) with ×3 magnification.

2.4 Evaluation of apically extruded debris

The preparation process was carried out by a single operator to reduce variation and eliminate bias. Upon canal preparation completion, the Eppendorf tubes were removed from the vials and rinsed with 1 mL of distilled water to collect debris adhering to the root surface. The tubes were then stored in an incubator at 70 °C for five days to allow moisture to evaporate before the debris was weighed. The average weight from three consecutive weighings of each tube was recorded. Finally, the dry weight of the apically extruded debris was calculated by subtracting the pre-preparation weight from the post-preparation weight.

2.5 Statistical analysis

The data were analyzed using SPSS version 23 (IBM Corp., Armonk, NY, USA). The normality of the distribution was determined using the Shapiro-Wilk and Kolmogorov-Smirnov tests based on the sample size. The means for the file, glider and resorption values, which showed normal distribution, were analyzed using a three-way analysis of variance (ANOVA). Multiple comparisons were assessed with Bonferroni correction. The results of the analyses were presented as mean ± standard deviation (SD). The level of significance was set at $p < 0.05$.

3. Results

Table 1 displays the main effects of the parameters and the impacts of their interactions. The primary effects of the glide paths and resorption significantly influenced the amount of debris extruded apically ($p < 0.001$). However, the primary effect of the file, as well as the dual and triple interactions of the parameters, did not significantly impact the amount of extruded debris ($p > 0.05$).

Table 2 and Fig. 2 provide descriptive statistics. The main effect of the file did not have a significant impact on the amount of overflowed debris ($p > 0.05$). In samples for which the TRN file was used, the average overflowed debris amount was 93.7 mg, while in samples for which the PTU file was used, this value was 90.2 mg. The primary effects on the amount of overflowed debris of resorption and the presence of a glide path were statistically significant ($p < 0.05$). When a glide path was used, the average amount of overflowed debris was 78 mg, but when a glide path was not used, the average amount of debris was 105.9 mg. Furthermore, using a glide path resulted in less apical debris overflow ($p < 0.001$). The average amounts of overflowed debris in the presence and absence of resorption were 102.9 mg and 81.1 mg, respectively. Teeth with resorption had significantly more apical debris extrusion compared to those without ($p < 0.001$).

TABLE 1. The effect of glider usage and presence of resorption on the amount of apically extruded debris.

	F	p	η^2
File	1.159	0.285	0.016
Glider	76.345	<0.001	0.515
Resorption	46.634	<0.001	0.393
File*Glider	0.529	0.469	0.007
File*Resorption	0.713	0.401	0.010
Glider*Resorption	0.009	0.925	0.000
File*Glider*Resorption	0.024	0.877	0.000

Adjusted R^2 = 0.60.
Three-way ANOVA.

4. Discussion

Biomechanical preparation of the root canal system is one of the most crucial stages in endodontic treatment. During this phase, debris residues, bacteria, and irrigation solutions can be extruded into periapical tissues from the root canal system [7]. Since the apical foramen of primary teeth is broader than that of permanent teeth, more material can be extruded into periapical tissues during the chemomechanical preparation process [15]. Such occurrences can lead to various complications in primary teeth, just as in permanent teeth [16, 17].

Several studies have assessed the impact of manual files and Ni-Ti file systems on apical debris extrusion in primary teeth [7, 8, 16]. In line with studies that evaluated debris extrusion in primary teeth, demonstrating that manual files cause more debris extrusion and postoperative pain compared to rotary files, this study aimed to assess the amount of debris extruded apically when preparation was performed with or without a motorized path file [18–20]. To our knowledge, no existing literature has evaluated the TRN and PTU systems and corresponding glide path files in terms of apical debris extrusion in both non-resorbed and resorbed primary teeth.

In studies on permanent and primary teeth, apical debris extrusion occurred in all methods used. In this study, debris extrusion occurred in all groups in varying amounts. According to our findings, there was no significant difference in terms of debris extrusion between the TRN and PTU files. Therefore, Hypothesis 1 was accepted. The lack of statistical

TABLE 2. Descriptive statistics by file system, glider usage and presence of resorption (mean and SD values in milligrams).

			Root resorption		
File system	Glider	n	Presence	Absence	Total
TRN					
	Absence	10	120.7 ± 15.6	97.0 ± 18.0	108.8 ± 20.4
	Presence	10	91.2 ± 9.8	65.9 ± 12.4	78.6 ± 16.9
	Total	20	106.0 ± 19.7	81.4 ± 21.9	93.7 ± 24.0
PTUltimate					
	Absence	10	112.7 ± 18.0	93.4 ± 15.4	103.1 ± 19.1
	Presence	10	86.9 ± 11.3	68.0 ± 11.4	77.4 ± 14.7
	Total	20	99.8 ± 19.7	80.7 ± 18.5	90.2 ± 21.2
Total					
	Absence	40	116.7 ± 16.9	95.2 ± 16.4	105.9 ± 19.7
	Presence	40	89.1 ± 10.5	66.9 ± 11.7	78.0 ± 15.7
	Total	80	102.9 ± 19.7	81.1 ± 20.0	92.0 ± 22.6

Abbreviations: TRN: TruNatomy; PTUltimate: Protaper Ultimate.

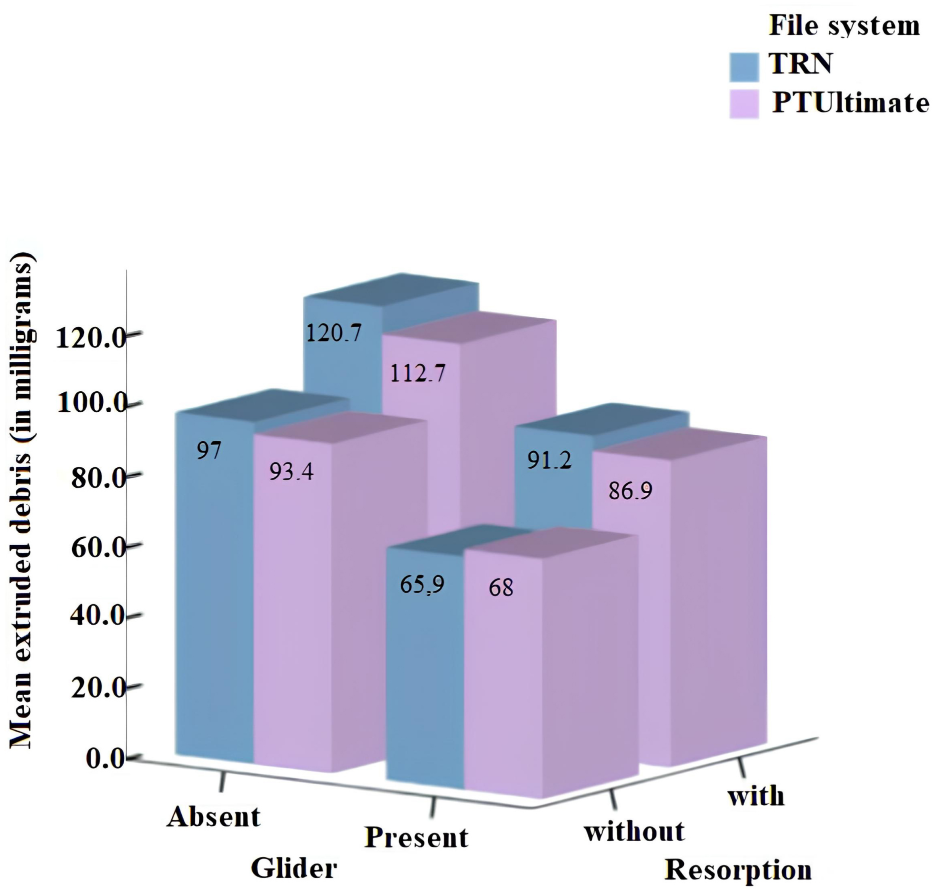

FIGURE 2. Visualization of the average amount of extruded debris based on the three parameters.

difference between the files was thought to be related to the fact that both files have similar apical diameters, off-center, cross-sectional structures (parallelograms) designed to remove debris effectively, and similar manufacturing techniques and kinematics [10, 12].

In primary teeth with resorption, it was found that the amount of apically extruded debris was significantly greater, regardless of the main shaping file and glide path file used. Hence, Hypothesis 2 was rejected. This finding may be due to the non-standardized root length and/or the selection of resorbed primary teeth according to subjective criteria. Moreover, even though care was taken to select resorbed primary teeth with an apical width not larger than a #15-K file, the stage of root resorption in the primary teeth and their complex anatomy could have been contributing factors to the result [21]. This result could also have been caused by a lack of standardization of, for example, microhardness between teeth, pulpal conditions of the teeth (necrosis, vital, *etc.*), and the presence of pulp tissue that may be present in the lateral canals, regardless of the resorption status of the teeth [22]. This situation is considered one of the limitations of our study.

Various studies have evaluated the effects of glide path files on apical debris extrusion in permanent teeth [6, 9, 23]. However, in our review of the literature, limited studies have used glide path files in primary teeth, and we did not find any studies that evaluated their effects on debris extrusion. In our study, we found that the use of a glide path file in primary teeth resulted in significantly less debris extrusion, irrespective of resorption status and the main shaping file used. Furthermore, studies conducted on permanent teeth have also indicated that the use of glide path files results in less apical debris extrusion [6, 9, 23]. The findings obtained from studies conducted using glide paths in permanent teeth are consistent with the findings of our study. Therefore, Hypothesis 3 was rejected. Using a glide path file during root canal preparation in primary teeth, as in permanent teeth, may result in less postoperative pain and less debris extrusion [9, 24]. In addition, it has been shown that the use of glide path files in primary teeth can reduce procedural errors and allow for faster preparation [25]. Furthermore, this study used the distal roots of primary mandibular second molars. The complex root canal anatomy of these teeth may have influenced the results [26]. We believe that further studies are needed to evaluate the efficacy of glide path files with different kinematics in teeth with inclined and different root canal anatomies.

In the process of root canal preparation, several factors can lead to the extrusion of debris and irrigation solution, such as the apical anatomy of the tooth, instrumentation technique, length of the irrigation needle, penetration of the needle tip to the apex, and the speed of irrigant application [22, 27]. In this study, the distal root of the mandibular primary molar tooth was used due to its single root and single canal structure. Additionally, to reduce the irrigant extrusion achieved with traditional metal needles [5], side-perforated flexible needles were used. To standardize the preparation and irrigation protocol, all procedures were performed by a single operator.

Various methods have been used to evaluate debris extrusion. In this study, the experimental setup developed by Myers and Montgomery was preferred for its practicality, repeatability, and comparison with other studies [7, 15, 16]. A limitation of this experimental setup was our ability to measure the amount of debris extruded from the apices, but not the amount of irrigation solution. In addition, in natural teeth, periapical pressure and periodontal tissues provide a natural barrier to prevent debris extrusion. Flower foam can be used to mimic clinical conditions in an experimental setup, but it was not used in our study due to its disadvantages of absorbing debris and irrigation solutions [5, 16]. In addition, sodium hypochlorite is used in various concentrations as an irrigation solution in routine endodontic treatment [28]. However, in debris studies, the potential for sodium hypochlorite to crystalize and alter debris weight, potentially affecting the results, has been pointed out in various studies. Hence, distilled water was used as an irrigation solution in our study. Additionally, to simulate *in vivo* conditions in this experimental setup, the apparatus was placed in a water bath at 35 °C [22].

Considering their pairwise and triple interactions, the three parameters evaluated in this study did not demonstrate significant differences in terms of the amount of extruded debris. Therefore, Hypothesis 4 was accepted. It should be noted that this study was conducted using only straight and single-canalled roots of primary mandibular molar teeth. The effect of apical resorption present in primary teeth on the apical extrusion of debris should be addressed in future studies. The debris extruded from a single canal may be less than that extruded from two or three canalled molar teeth. Therefore, further studies that consider both micro-computed tomography and debris extrusion measurements related to the use of file systems in resorbed and non-resorbed primary molars are needed.

5. Conclusions

Within the limitations of this study, all groups demonstrated apical debris extrusion. The least amount of debris extrusion occurred using a glide path file and a TRN file on a tooth without resorption. The use of a glide path file in the preparation procedure resulted in less debris extrusion.

AVAILABILITY OF DATA AND MATERIALS

The data that support the findings of this study are available from the corresponding author BKE, upon reasonable request.

AUTHOR CONTRIBUTIONS

BKE—contributed to the acquisition, analysis, interpretation of the data and wrote the draft. MYÖ—contributed to the statistical analysis of gathered data and contributed to acquisition of data. All authors contributed to the final version of the manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Ethical approval was obtained from the Research Ethical Committee of Firat University (Approval no. 2023/10-32). The informed consent process was completed for each participant.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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