Journal of Dental Sciences 19 (2024) 2126–2134

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.e-jds.com

Original Article

Comparative evaluation of the remaining dentin volume following instrumentation with rotary, reciprocating, and hand files during root canal treatment in primary molars: An *ex vivo* study

İrem Eren [a], Berkant Sezer [b*]

[a] *Department of Endodontics, School of Dentistry, Çanakkale Onsekiz Mart University, Çanakkale, Türkiye*
[b] *Department of Pediatric Dentistry, School of Dentistry, Çanakkale Onsekiz Mart University, Çanakkale, Türkiye*

Received 19 March 2024; Final revision received 2 April 2024
Available online 7 April 2024

KEYWORDS
Endodontic treatment;
Pulpectomy;
Reciprocating files;
Root canal treatment;
Rotary files

Abstract *Background/purpose:* The effectiveness of root canal treatments with different file systems in primary teeth is important in terms of clinical practice and the use of file systems that work with different principles in primary tooth pulpectomy is becoming widespread. The amount of remaining dentin in the coronal region of the root is important in terms of the prognosis of the tooth and the long-term success of the treatment in teeth that have undergone root canal treatment. The aim of this study was to evaluate the remaining dentin volume in the coronal part of the root after the use of rotary, reciprocating, and conventional hand files in primary tooth pulpectomy.
Materials and methods: A total of 30 primary molars were divided into three groups. In each group, the preparations were made with three different file types: WaveOne Gold, which works with reciprocating motion; TruNatomy, which works with rotational motion; and conventional hand files. The three-dimensional images were evaluated for remaining dentin volume in the 2-mm coronal part of the root. Group means were compared using one-way analysis of variance, and post hoc analyses were performed with the Tukey test.
Results: There was no statistically significant difference between the groups in terms of preoperative and postoperative dentin volume ($P > 0.05$). The mean difference after preparation was observed the most in the WaveOne Gold group and the least in the TruNatomy group. When the mean percentage differences were evaluated, it was observed that statistically

* Corresponding author. Department of Pediatric Dentistry, School of Dentistry, Çanakkale Onsekiz Mart University, Cumhuriyet Mah., Sahilyolu Cd., No:5, Kepez, Merkez/Çanakkale, 17100, Türkiye.
E-mail addresses: dt.berkantsezer@gmail.com, berkant.sezer@comu.edu.tr (B. Sezer).

https://doi.org/10.1016/j.jds.2024.04.003
1991-7902/© 2024 Association for Dental Sciences of the Republic of China. Publishing services by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

significantly more dentin volume was preserved after the preparation with TruNatomy than with WaveOne Gold ($P = 0.021$).
Conclusion: In primary tooth pulpectomy, file systems working with rotational motion can be preferred over file systems working with reciprocating motion in preserving the amount of dentin in the 2-mm coronal part of the root.
© 2024 Association for Dental Sciences of the Republic of China. Publishing services by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

Introduction

It is important to have primary teeth asymptomatic in the oral cavity during the primary and mixed dentition periods, as they guide the replacement of permanent teeth by preserving the arch length, providing chewing function, contributing to phonation, and contributing to aesthetics. Dental caries, which is still an important public oral health problem in industrialized countries, is a non-communicable and preventable disease.[1] Dental caries in primary teeth should be treated within the right indications and with appropriate treatment approaches, taking into account the stated importance of these teeth. Although endodontic approaches such as indirect pulp capping and pulpotomy are less invasive methods for the treatment of extensive dental caries in primary teeth, in the presence of signs of irreversible pulpitis, treatment options include pulpectomy or extraction.[2,3] Primary tooth pulpectomy aims to advance the functional status of the affected tooth in cases where the radicular pulp is non-vital or irreversibly infected by eliminating the infection in the root canals and maintaining the entirety of the periapical tissue until the physiological exfoliation period.[4,5]

Root canal preparation in primary teeth should result in the removal of vital and/or necrotic pulp tissue, infected dentin, and debris from the root canals. The entire treatment process basically consists of mechanical shaping of the entire root canal space, chemical cleaning, and obturation.[6,7] Although hand files such as reamers, K-files, and H-files have conventionally been used in primary tooth pulpectomy, the use of more effective and flexible rotary file systems is becoming more common due to time savings and a reduced possibility of iatrogenic error.[7–9] Many file systems have been developed in recent years to provide an easier, safer, and more comfortable treatment option for the patient by performing the pulpectomy in a faster and simpler way. These nickel-titanium alloy file systems are subjected to various thermal treatments to improve and optimize their properties, such as flexibility and cyclic fatigue resistance. These file systems can work with continuous rotational or reciprocating motion.[8,10] With the advancements in technology and science, reciprocating systems have been put on the market to relieve the pressure on canal files and root dentin. Considering that most file systems on the market work on the principle of full clockwise rotation, new systems continue to be developed.[11–13] In *ex vivo* conditions, it has been shown that file systems operating with continuous rotational motion have better centering ability than file systems operating with reciprocating motion.[14,15] The apical extrusion of debris containing necrotic pulp tissue, dentin and bacteria formed during root canal preparation is considered the primary cause of periodontal ligament inflammation.[15,16] Although more studies are recommended,[16] systematic reviews have shown that file systems operating with continuous rotation extrude less apical debris than reciprocating files.[15,17] On the other hand, it is reported that the use of reciprocating motion instead of continuous rotational motion increases fatigue resistance by prolonging the life of nickel-titanium rotary files.[18] In reciprocating motion, the file rotates clockwise and counterclockwise at different angles. While it moves through the root canal by cutting the dentin in the cutting direction, when it rotates in the opposite direction, the file is disengaged. This principle of action prevents the instrument from locking in the root canal, reduces the compressive forces that create elastic deformation, and reduces the risk of the instrument fracture due to fatigue.[10,19]

Due to the direct relationship between the dentin thickness in the root and the strength of the root, it is very important to preserve the radicular dentin during the chemo-mechanical instrumentation of the root canals.[7,20] If this thickness is not maintained and root dentin is excessively removed, the root can potentially weaken, leading to problems such as strip perforation, zipping, canal transportation, ledging, microcracks, and/or root fractures. Microcracks observed in root dentin can also cause vertical root fractures and eventually tooth loss. Therefore, the preparation should be done in a way that does not dangerously reduce the fracture resistance of the root.[7,21,22] In addition, the dentin thickness in the pericervical region is important in terms of the risk of crown-root fracture under chewing forces, the success of the restoration, and therefore the prognosis of the tooth and the treatment.[23,24] It is known that the remaining dentin thickness is higher after the treatment with rotary file systems in primary tooth pulpectomy compared to the treatment with hand files.[7]

The aim of this study was to evaluate the remaining dentin volume in the 2 mm coronal part of the root after the use of rotary, reciprocating, and conventional hand files in primary tooth pulpectomy. The null hypothesis of the study was that there would be no difference in terms of remaining dentin volume in primary molars after using the

rotary, reciprocating, and hand files for the pulpectomy treatment.

Materials and methods

This *ex vivo* study was approved by the Clinical Research Ethical Committee of the Çanakkale Onsekiz Mart University with approval number 2022/13−10. Children between the ages of four and 12 who applied to the Pediatric Dentistry Clinics of School of Dentistry, Çanakkale Onsekiz Mart University, between April 2022 and August 2022 were examined by a pediatric dentist who was blinded about the study, and a treatment plan was created. Detailed information about the study was given to the patients who had teeth that were indicated for extraction and met the inclusion criteria as well as their parents. After obtaining verbal consent, a detailed informed consent form was signed. The inclusion criteria for the study were mandibular second primary molars with a minimum of 7 mm root length and no evident defects or anomalous morphology.[11] The root canals of second primary molars have significantly more surface area than first primary molars.[25] This increases the accuracy of evaluating the quantitative effectiveness of the file systems used in the root canal. In addition, since more root canal variations are seen in maxillary second primary molars than in mandibular second primary molars,[26] mandibular second primary molars were preferred to increase the possibility of standardization. In addition, teeth with any root fracture, internal and/or external root resorption, prosthetic crown restoration (including stainless steel crowns), radicular caries, partial or total root canal obliteration, or previously treated with root-canal treatment were not included in the study. Tooth extraction was performed by a maxillofacial surgeon who was blinded to the study. After extraction, the residual tissues on the root surface of the extracted teeth were eliminated with a scrub under irrigation with sterile saline (Geno Technology, St. Louis, MO, USA), and the teeth were examined under reflectory light for potential perforations, fractures, developmental root anomalies, and/or caries on the root surface. The root lengths of the extracted teeth were measured using a digital caliper (Digimatic 500; Mitutoyo, Kanagawa, Japan). Teeth that met the inclusion criteria were then stored in a 0.1% thymol solution (Caelo, Hilden, Germany) until used for study within three months.

Sample size calculation

G*Power software program (G∗Power v. 3.1.9.6; Universitat Kiel, Kiel, Germany) was used to calculate the sample size. Based on the data from previous study,[27] which showed statistically significant differences between the Endogal Kids (Galician Endodontics Company, Lugo, Spain) (2.89 ± 1.26 mm^3) and Reciproc Blue (VDW, Baillagues, Switzerland) (1.22 ± 0.58 mm^3) study groups in the volume of root canal dentin removed at the coronal third of the root canal, a total sample size of 27 was calculated to be enough to achieve power of 95% at a 1.702 effect size with a significance level (α) set at 0.05. In accordance with ethical responsibilities and obligations, patients whose teeth are included in the study and their parents may request the exclusion of their teeth from the study at any stage of the study without providing any reason. Therefore, considering the 10% dropout risk, the minimum sample size of the study was determined as 10 for each group and a total of 30.

Randomization and initial imaging

Thirty primary teeth that met the inclusion criteria were grouped with 10 teeth in each group using the random integer generator tool of the random.org website. Teeth were numbered from one to 10 in each group. After caries removal (if any) with a tungsten carbide bur (#1.2) (Busch, Düsseldorf, Germany) using a low-speed handpiece (W&H International, Bürmoos, Austria), the endodontic access cavities were opened with diamond fissure (#018) and round burs (#020) (KaVo Kerr, Biberach, Germany) using an aerator (W&H International) under water cooling, and tissue debris in the pulp chamber was irrigated with 1% sodium hypochlorite (NaOCl) (Cerkamed, Stalowa Wola, Poland). Three-dimensional (3D) images of all teeth were obtained with cone-beam computed tomography (CBCT) in 3D High-Resolution (Hi-Res) denture scan mode with 100 micron voxel size and an 8×5 field of view (FOV) area (NewTom, Tokyo, Japan) at 110 kVp (kilovoltage peak), 12 mA, and 9 s exposure time after caries removal and endodontic access cavity opening (Fig. 1).

Root canal preparation

File systems that work with rotational and reciprocating motions have advantages and disadvantages compared to each other in primary tooth root canal treatment just as in permanent tooth root canal treatment. It was aimed to compare two different motion systems in order to determine which motion principle is more effective on the remaining dentin volume in the coronal part of the root. WaveOne Gold (Dentsply/Maillefer, Ballaigues, Switzerland) is a file that operates on the reciprocating motion and was launched with the claim of providing greater resistance to cyclic fatigue.[28] TruNatomy (Dentsply/Maillefer), on the other hand, is a file system that works with rotational motion and was introduced to the market with the claim of increased resistance to cyclic fatigue and flexibility.[29] The torque, speed, and order of use of the file systems, and final apical size and the taper of the canal preparations in the groups in which rotary and reciprocating systems were used were made according to the manufacturer's instructions. In the hand file group, the preparation was performed by conventional methods. All preparations were made by the same experienced endodontist and the number of uses of all instruments was limited to one tooth. Root canals were irrigated using a 27-gauge needle (27G-0.40 × 40mm) (Jiangyin Nanquan Macromolecule Products, Jiangyin, China) in all groups. A digital stopwatch (Internetservice Kummer + Oster, Buchenberg, Germany) was used to measure the working and irrigation times. Considering the safety factor, the preparation was completed 0.5 mm behind the apical foramen in all groups.[30]

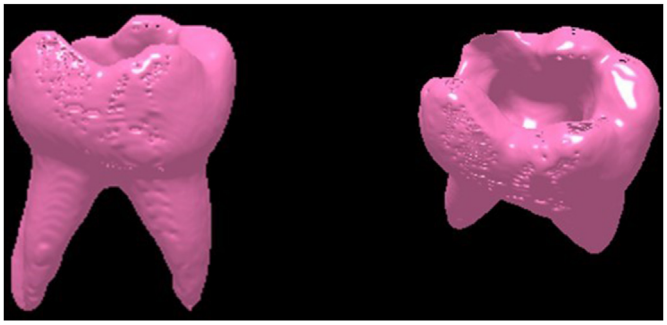


Figure 1 Three-dimensional modeling of the image obtained as a result of scanning with cone-beam computed tomography after caries removal and access cavity preparation.

- **Group 1 (Hand files):** Standard rotation and traction technique was applied for the mechanical preparation of root canals using 0.02 taper stainless steel K-files (Dia-Dent Group International, Burnaby, Canada). The instrumentation process started with size #15 file, and finished with size #35 file.[31] Irrigation with 3 ml of 2.5% NaOCl (Cerkamed) for 3 min was applied at each file change per root canal. After the preparation with the final file, irrigation was performed with 5 ml of 17% ethylenediamide tetraacetic acid (EDTA) (Cerkamed) for 3 min. Final irrigation was done with 5 ml of 0.9% sterile saline (Geno Technology). Root canals were dried with paper points (Dentsply International, York, PA, USA).[8,11]
- **Group 2 (WaveOne Gold):** The root canal was prepared using one new WaveOne Gold primary (size 25/0.07) file (Dentsply/Maillefer) activated in an endodontic motor (VDW), at the RECIPROC ALL setting, adjusted for reciprocating motion (170° counter-clockwise and 50° clockwise) at 350 rpm speed. The file was used with a slow, in-and-out pecking motion according to the manufacturer's instructions. After each cycle in the system, the root canals were irrigated with 3 ml of 2.5% NaOCl (Cerkamed) per root canal. The irrigation procedure was completed as in Group 1. Root canals were dried with paper points produced for the file system (Dentsply International). The effective working time of the file in the canal did not exceed 1 min.[32–34]
- **Group 3 (TruNatomy):** TruNatomy Orifice Modifier (size 20, 0.08 variable taper), Glider (size 17, 0.02 variable taper), Small (size 20, 0.04 variable taper), and Prime (size 26, 0.04 variable taper) files (Dentsply/Maillefer) were operated using the endodontic motor (Dentsply Sirona, Tulsa, OK, USA), adjusted at 500 rpm speed and 1.5 Ncm torque following the manufacturer's instructions. All files used with 2–3 gentle, approximately 2–5 mm length in-and-out motion in the canal. Every file was replaced with the next file upon reaching the length limit to avoid over-enlargement. The irrigation procedure was performed as in Group 2. Root canals were dried with paper points produced for the file system (Dentsply International).[34]

All three main canals of the mandibular second primary molars included in the study were prepared. Accessory, paramolar, lateral, and other extra canals that may be present other than the main canals were not prepared and therefore were not evaluated. After root canal preparations, the teeth were rescanned with CBCT (NewTom). Pre and postoperative 3D images were evaluated comparatively.

Cone-beam computed tomography assessment

All teeth were scanned again with the same parameters in 3D Hi-Res denture scan mode with 100 micron voxel size and an 8 × 5 FOV area at 110 kVp, 12 mA, and 9 s exposure time after all preparation steps were performed. Thus, 3D images were obtained before and after preparation for the teeth in all groups with the same order on the same CBCT device (NewTom) to be able to compare the obtained data before and after preparation.

Cone-beam computed tomography image analysis

The pre and postoperative 3D images of each tooth were transferred to the image processing software (3D-Doctor Modeling Software version 4; Able Software Corporation, Lexington, KY, USA) in Digital Imaging and Communications in Medicine (DICOM) format. Axial images can be processed in the image processing software in this way. Initially, cementoenamel junction (CEJ) was detected in the axial images. Then, 2 mm more apically were descended from this section, and the pericervical dentin region was selected (2 mm coronal part of the root).[24,35] The segmentation process was performed automatically by choosing a range of gray tones that encompasses the density of the dentin. Afterwards, each section in the selected region of interest was examined individually, and adjustments were made in each section to ensure that the selection completely covered the dentin. Subsequently, the adjusted field, which consists of a 2 mm coronal part of the root dentin, was modeled in 3D in "Stereolithography" (.stl) format. As a result, a 3D volumetric reconstruction image of the relevant region was obtained (Fig. 2). Thus, the volume changes due to the preparation in the 2 mm coronal part of the root were calculated. In addition, the amount of dentin reduction in the 2 mm coronal part of the root was

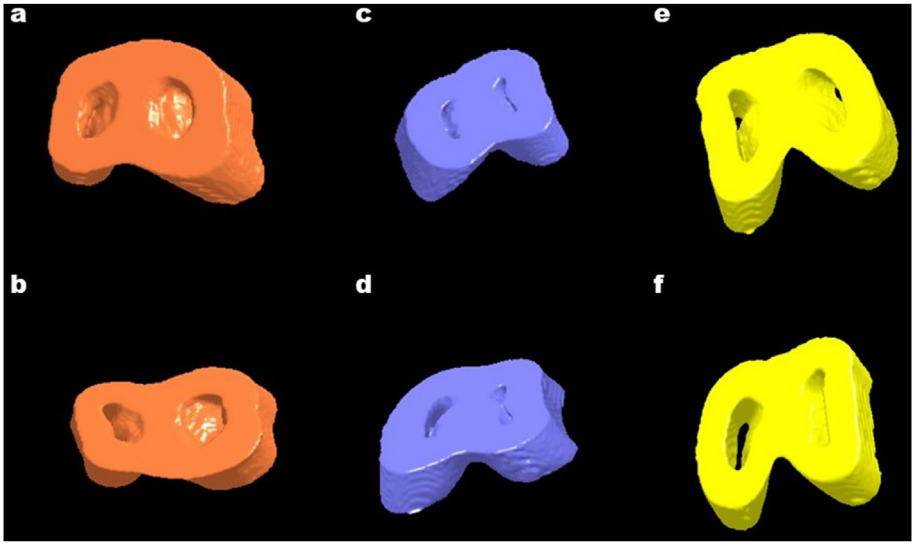


Figure 2 Three-dimensional modeling of the 2 mm coronal part of the root before and after preparation with different file systems. The top line shows the preoperative models, the bottom line shows the postoperative models. From left to right, preparations were made with hand files (**2a, 2b**), WaveOne Gold (**2c, 2d**), and TruNatomy (**2e, 2f**) file systems, respectively.

calculated as a percentage according to the dentin volume before preparation. So, the amount of weakening of the pericervical dentin was determined.

Statistical analysis

Statistical analysis software (SPSS version 26.0; IBM, Chicago, IL, USA) was used to enter and analyze the data. The normality of the data distribution was tested with the Kolmogorov–Smirnov test, and its homogeneity was tested with Levene's test. Group means were compared using one-way analysis of variance (ANOVA), and post hoc analyses were performed with the Tukey test. In all analyses, $P < 0.05$ was taken to indicate statistical significance.

Results

Preoperative and postoperative dentin volumes of groups are shown in Table 1. The mean volume differences calculated by subtracting the remaining dentin volume after preparation from the dentin volume that existed before preparation are also given in Table 1. No statistically significant difference was observed between the dentin volumes at the 2 mm coronal part before preparation in all groups used in the study ($P = 0.729$). Although there was no statistically significant difference in all groups when the mean volumes of remaining dentin after the preparation were examined ($P = 0.904$), there was a statistically significant difference between groups in the volume of mean

Table 1 The mean, standard deviation, minimum, maximum, and first and third quartile values of the preoperative and postoperative dentin volume, and mean difference for each group.

	Mean	SD	Minimum	Maximum	Q1	Q3	*P*-value[a]
Preop. dentin volume (mm^3)							
Hand files	83.14	19.43	56.90	117.71	67.23	96.28	0.729
WaveOne Gold	86.25	20.93	50.32	122.53	74.12	100.23	
TruNatomy	78.48	23.98	52.55	112.98	56.50	93.86	
Postop. dentin volume (mm^3)							
Hand files	75.18	19.23	49.75	109.39	59.88	88.65	0.904
WaveOne Gold	74.70	20.63	42.48	112.25	57.67	85.51	
TruNatomy	71.38	21.63	48.06	108.23	51.18	83.95	
Mean difference							
Hand files	7.96	1.69	5.17	10.57	7.12	8.81	**0.018**
WaveOne Gold	11.55	4.43	7.66	20.82	8.38	12.23	
TruNatomy	7.10	3.62	2.63	14.29	4.56	9.68	

SD: standard deviation, Q1: first quartile, Q3: third quartile, mm^3: cubic millimeter, Preop.: preoperative, Postop.: postoperative.
[a] One-way ANOVA. Bold value means statistical significance ($P < 0.05$).

Table 2 The percentage (%) difference of dentin volume removed from the 2 mm coronal part of the root.

Files type	% difference		
	Hand files	WaveOne Gold	TruNatomy
Sample number			
1	7.98	15.58	10.81
2	5.62	9.91	12.93
3	11.90	15.93	10.56
4	12.55	8.61	10.56
5	7.07	9.50	4.21
6	11.23	12.02	5.00
7	14.27	8.39	6.71
8	11.38	15.02	8.56
9	9.69	17.03	10.03
10	8.04	26.96	9.22
Mean % difference	9.97	13.89[1]	8.86[2]
***P*-value**	**0.021**[a]		

[a] One-way ANOVA with Tukey's post-hoc test. Different superscript numbers indicate statistical difference between groups. The mean difference is significant at the 0.016 level. Bold value means statistical significance ($P < 0.05$).

difference, which means reduction due to preparation at the 2 mm coronal part after preparation ($P = 0.018$).

Table 2 shows the percentage of dentin volume removed from the 2 mm coronal part relative to the dentin volume before preparation. The mean percentages of removed dentin at the 2 mm coronal part of the root were 9.97%, 13.89%, and 8.86% for hand files, WaveOne Gold, and TruNatomy, respectively. According to the results, there were not any statistically significant differences between the hand files and the other groups. Besides that, a statistically significant difference was found between the WaveOne Gold group and the TruNatomy group ($P = 0.021$).

The dentin volume in the 2 mm coronal part of the root before preparation and the remaining dentin volume in this region after the preparation with different file systems are shown in Fig. 2. While Fig. 2a, c, and 2e are the preoperative images taken with hand files, WaveOne Gold, and TruNatomy, respectively, Fig. 2b, d, and 2f are the postoperative 3D images in the same order.

Discussion

The development of present endodontic preparation protocols and file systems has focused on the concept of minimally invasive endodontics and the preservation of the healthy dental tissues, root, and pericervical dentin. This study compared the WaveOne Gold and TruNatomy file systems and conventional hand files for their effects on the volume of root dentin 2 mm below the CEJ of mandibular second primary molars.

The purpose of chemo-mechanical preparation of the root canals in primary teeth is to effectively prepare the root canals to preserve the original anatomical shape of the root canals and remove infected organic and inorganic contents. Considering the curved anatomical and morphological shape of the primary root canals due to the position of the permanent tooth to replace it, irrigation also plays an important role in removing debris. Ideally, at least 1 mm of dentin should be left in all root aspects along the entire length of the root after root canal preparation.[36] Therefore, instrumentation and preparation should not weaken the tooth structure while allowing the canal to expand. For this reason, the amount and volume of remaining dentin in the root, especially in the pericervical region, are important in maintaining the fracture resistance of the tooth.[7,37,38]

Although no statistical difference was observed between the success of hand and rotary files in primary tooth pulpectomy in the 24-month clinical follow-up,[39] the use of rotary file systems is recommended because it takes less time, less root dentin is removed, and it provides a more uniform root canal preparation.[40] In the current study, although it was not statistically significant, it was observed that the TruNatomy files caused less dentin removal in the 2 mm coronal part of the root than the hand files. On the other hand, it was determined that more dentin was removed from the root canal with the WaveOne Gold reciprocating file system than with the hand files. When evaluated in terms of remaining dentin volume in the coronal part of the root, although no superiority was observed between hand files and other file systems in the current study, a significant difference was observed between rotary and reciprocating file systems. Therefore, the null hypothesis of the study was rejected. Although there is no study in the scientific literature evaluating the effect of WaveOne Gold and TruNatomy file systems on the amount and volume of remaining dentin in the root after pulpectomy of primary teeth, there are a few studies that make this evaluation in permanent teeth or simulated canals. In a study comparing WaveOne Gold and TruNatomy file systems in different access cavity preparations, it was concluded that TruNatomy removed statistically less dentin in both the pericervical region and the root in all access cavity types.[41] This situation, which is similar to the findings of the present study, can be explained by the design of file systems. The design of the TruNatomy files with the reduced maximum diameter of the instrument is known to better preserve dentin in the region 2–4 mm below the CEJ.[41] It has been reported that the TruNatomy file system removed statistically significantly less resin from the canal than the WaveOne Gold file system in simulated curved canals.[42] Similarly, in the same study, TruNatomy created significantly less canal transportation than WaveOne Gold. It was also determined that the working time of Trunatomy files was less.[42] In a study evaluating apical debris extrusion using clockwise and counter-clockwise single-file reciprocation of rotary and reciprocating systems, it was stated that WaveOne Gold files removed significantly more apical debris than all tested groups, while TruNatomy and other clockwise reciprocating groups had the lowest mean values.[43] In the current study, it was determined that TruNatomy removed significantly less dentin than WaveOne Gold in the 2 mm coronal part of the root and preserved the remaining dentin structure. TruNatomy is a single-file rotary system made of a super-flexible alloy with post-production thermal process. This new file system has been introduced with the aim of transforming the canals

into a constantly thinning preparation while significantly preserving the pericervical dentin. The findings of the current study also show that TruNatomy preserves dentin at the pericervical region of the root in primary teeth compared to other file types tested.

Excessive dentin removal can increase tooth fragility and the risk of perforation. This shows that dentin should be preserved at the root. There is no consensus in the scientific literature on the amount and volume of removed and remaining dentin in the root to achieve optimal disinfection of the root canal, but this situation may be influenced by the taper and size of the files and the anatomy and morphology of the root canal of the primary tooth.[8] Some research including primary teeth found that more dentin was removed using hand files,[44,45] while others reported more dentin removed using a rotary file.[46] The findings of the present study showed that the rotary file systems, which operates with two different principles of action, does not differ significantly from hand files in terms of remaining dentin volume in the 2 mm coronal part of the root.

Given the success of endodontic treatment and the importance of root canal preparation for the differentiated root anatomy and morphology of primary teeth, the results emphasized the significance of the use of an ideal file to prevent excessive dentin removal. While choosing the file, it is necessary to maintain the resistance and strength of the root and pericervical region, taking into account the anatomical structure of the roots of the primary teeth.[7] The file system, which works with a reciprocating motion, uses the single file technique for root canal preparation. This is highlighted by the fact that the relevant file system is mostly based on opinion and simplicity rather than proven effectiveness.[47] This is supported by the fact that the WaveOne Gold file system used in our study offers a more practical application since it contains a single file. On the other hand, the TruNatomy file system, which has a rotational motion working principle, reaches the foramen faster because it has a relatively small taper and therefore stays in the root canal for a shorter time.[48] This means that these types of files constitute a safer clinical use recommendation in terms of cyclic fatigue.[48]

This study has some strengths and limitations. The selection of all teeth included in the study by following the inclusion criteria and grouping them by randomization method can be qualified as strengths. It is also important that all preparations are made by a single, trained endodontist to avoid bias. Considering the determined sample size and study findings, it was concluded that the actual power of the study was 0.974, with an alpha error probability of 0.05 and a $1 - \beta$ error probability of 0.95, so the sample size was sufficient and the study was at the optimal power level. However, there are also some important limitations that arise from the *ex vivo* methodology. This study points to the issue of choosing the ideal file, considering the differences in the anatomical and morphological structure of primary tooth roots. The findings obtained in line with the objective of the study show that in primary tooth pulpectomy, the remaining dentin volume in the coronal part of the root is preserved more by the TruNatomy file system working with rotational motion than by the WaveOne Gold file system working with reciprocating motion. This study solely focused on the dentin volume at the 2-mm coronal portion of the root without considering other factors that may influence the success of root canal treatment (such as complete root canal cleaning, sealing properties of filling materials, etc.).

Considering the importance of primary tooth pulpectomy and the remaining dentin volume in the coronal part of the root in terms of treatment and tooth prognosis, rotary file systems are preferable materials for primary tooth pulpectomy. File systems working with rotational motion can be preferred over file systems working with reciprocating motion in terms of the remaining dentin volume in the coronal part of the root. We think that new file systems developed with different working principles and new preparation and instrumentation protocols should be evaluated in future studies. In addition, we think that prospective, randomized studies should be conducted comparing different file systems to determine the file systems, preparation methods, and accordingly the amount of remaining dentin in the root in order to achieve an optimal treatment prognosis.

Declaration of competing interest

The authors have no conflicts of interest relevant to this article.

Acknowledgements

The authors thank Prof. Hakan Eren for his support and assistance in the imaging and image evaluation process.

References

1. Pitts NB, Twetman S, Fisher J, Marsh PD. Understanding dental caries as a non-communicable disease. *Br Dent J* 2021;231:749—53.
2. Xie Y, Wang Y, Ma Q, et al. Survival analysis of pulpectomy in primary molars performed under dental general anaesthesia: a two-year retrospective study. *BMC Oral Health* 2022;22:597.
3. Hadwa SM, Ghouraba RF, Kabbash IA, El-Desouky SS. Assessment of clinical and radiographic efficiency of manual and pediatric rotary file systems in primary root canal preparation: a randomized controlled clinical trial. *BMC Oral Health* 2023;23:687.
4. Elheeny AAH, Abdelmotelb MA. Postoperative pain after primary molar pulpectomy using rotary or reciprocating single files: a superior, parallel, randomized clinical trial. *Int J Paediatr Dent* 2022;32:819—27.
5. Dou G, Wang D, Zhang S, Ma W, Xu M, Xia B. A retrospective study on the long-term outcomes of pulpectomy and influencing factors in primary teeth. *J Dent Sci* 2022;17:771—9.
6. Lee SM, Yu YH, Karabucak B. Endodontic treatments on permanent teeth in pediatric patinets aged 6-12 years old. *J Dent Sci* 2023;18:1109—15.
7. Nisar P, Katge F, Bhanushali P, Deshpande S, Poojari M, Shetty S. Comparative in vitro evaluation of remaining dentine thickness following instrumentation with hand and rotary

endodontic files during pulpectomy in primary molars: a systematic review. *Eur Arch Paediatr Dent* 2023;24:15–32.
8. Shi L, Yang Y, Wan J, Xie W, Yang R, Yao Y. Shaping ability of rotary and reciprocating single-file systems in combination with and without different glide path techniques in simulated curved canals. *J Dent Sci* 2022;17:1520–7.
9. Moraes RDR, Perez R, Silva ASSD, et al. Micro-CT evaluation of root canal preparation with rotary instrumentation on prototyped primary incisors. *Braz Oral Res* 2021;35:e132.
10. Moraes RDR, Santos TMPD, Marceliano-Alves MF, et al. Reciprocating instrumentation in a maxillary primary central incisor: a protocol tested in a 3D printed prototype. *Int J Paediatr Dent* 2019;29:50–7.
11. Yüksel BN, Öncü A, Çelikten B, Bilecenoğlu B, Orhan AI, Orhan K. Micro-CT evaluation of 'danger zone' and microcrack formation in mesial root canals of primary teeth with single-file rotary and reciprocating systems. *Int J Paediatr Dent* 2022;32:109–15.
12. Panchal V, Jeevanandan G, Erulappan SM. Comparison between the effectiveness of rotary and manual instrumentation in primary teeth: a systematic review. *Int J Clin Pediatr Dent* 2019;12:340–6.
13. Abu-Tahun IH, Ha JH, Kwak SW, Kim HC. Evaluation of dynamic and static torsional resistances of nickel-titanium rotary instruments. *J Dent Sci* 2018;13:207–12.
14. Giuliani V, Di Nasso L, Pace R, Pagavino G. Shaping ability of waveone primary reciprocating files and ProTaper system used in continuous and reciprocating motion. *J Endod* 2014;40:1468–71.
15. Ahn SY, Kim HC, Kim E. Kinematic effects of nickel-titanium instruments with reciprocating or continuous rotation motion: a systematic review of in vitro studies. *J Endod* 2016;42:1009–17.
16. Puleio F, Giordano F, Bellezza U, Rizzo D, Coppini V, Lo Giudice R. Do continuous rotating endodontic instruments extrude fewer apical debris than reciprocating instruments in non-surgical endodontic retreatments? A systematic review. *Appl Sci* 2024;14:1621.
17. Caviedes-Bucheli J, Castellanos F, Vasquez N, Ulate E, Munoz HR. The influence of two reciprocating single-file and two rotary-file systems on the apical extrusion of debris and its biological relationship with symptomatic apical periodontitis. A systematic review and meta-analysis. *Int Endod J* 2016;49:255–70.
18. Erik CE, Özyürek T. Effects of etidronate, NaOCl, EDTA irrigation solutions and their combinations on cyclic fatigue resistance of nickel-titanium single-file rotary and reciprocating instruments at body temperature. *Odontology* 2019;107:190–5.
19. Grande NM, Ahmed HM, Cohen S, Bukiet F, Plotino G. Current assessment of reciprocation in endodontic preparation: a comprehensive review-part I: historic perspectives and current applications. *J Endod* 2015;41:1778–83.
20. Lim SS, Stock CJ. The risk of perforation in the curved canal: anticurvature filing compared with the stepback technique. *Int Endod J* 1987;20:33–9.
21. Elnaghy AM, Al-Dharrab AA, Abbas HM, Elsaka SE. Evaluation of root canal transportation, centering ratio, and remaining dentin thickness of TRUShape and ProTaper Next systems in curved root canals using micro-computed tomography. *Quintessence Int* 2017;48:27–32.
22. da Silva PB, Duarte SF, Alcalde MP, et al. Influence of cervical preflaring and root canal preparation on the fracture resistance of endodontically treated teeth. *BMC Oral Health* 2020;20:111.
23. Silva EJNL, Lima CO, Barbosa AFA, Lopes RT, Sassone LM, Versiani MA. The impact of TruNatomy and ProTaper Gold instruments on the preservation of the periradicular dentin and on the enlargement of the apical canal of mandibular molars. *J Endod* 2022;48:650–8.
24. Yuan K, Niu C, Xie Q, et al. Comparative evaluation of the impact of minimally invasive preparation vs. conventional straight-line preparation on tooth biomechanics: a finite element analysis. *Eur J Oral Sci* 2016;124:591–6.
25. Mohd Ariffin S, Dalzell O, Hardiman R, Manton DJ, Parashos P, Rajan S. Root canal morphology of primary maxillary second molars: a micro-computed tomography analysis. *Eur Arch Paediatr Dent* 2020;21:519–25.
26. Rahmati A, Khoshbin E, Shokri A, Yalfani H. Cone-beam computed tomography assessment of the root canal morphology of primary molars. *BMC Oral Health* 2023;23:692.
27. Faus-Llácer V, Pulido Ouardi D, Faus-Matoses I, et al. Comparative analysis of root canal dentin removal capacity of two NiTi endodontic reciprocating systems for the root canal treatment of primary molar teeth. An in vitro study. *J Clin Med* 2022;11:338.
28. Oh S, Kum KY, Kim HJ, et al. Bending resistance and cyclic fatigue resistance of WaveOne Gold, Reciproc Blue, and HyFlex EDM instruments. *J Dent Sci* 2020;15:472–8.
29. Riyahi AM, Bashiri A, Alshahrani K, Alshahrani S, Alamri HM, Al-Sudani D. Cyclic fatigue comparison of TruNatomy, Twisted file, and ProTaper Next rotary systems. *Int J Dent* 2020;2020:3190938.
30. Abdullah A, Singh N, Rathore MS, Tandon S, Rajkumar B. Comparative evaluation of electronic apex locators and radiovisiography for working length determination in primary teeth in vivo. *Int J Clin Pediatr Dent* 2016;9:118–23.
31. Topçuoğlu G, Topçuoğlu HS, Delikan E, Aydınbelge M, Dogan S. Postoperative pain after root canal preparation with hand and rotary files in primary molar teeth. *Pediatr Dent* 2017;39:192–6.
32. Caviedes-Bucheli J, Rios-Osorio N, Usme D, et al. Three-dimensional analysis of the root canal preparation with Reciproc Blue®, WaveOne Gold® and XP EndoShaper®: a new method in vivo. *BMC Oral Health* 2021;21:88.
33. Alberton CS, Tomazinho FSF, Calefi PS, Duarte MAH, Vivan RR, Baratto-Filho F. Influence of the preparation order in four-canal maxillary molars with WaveOne Gold system. *J Endod* 2020;46:1291–6.
34. Roshdy NN, Hassan R. Quantitative evaluation of apically extruded debris using TRUShape, TruNatomy, and WaveOne Gold in curved canals. *BDJ Open* 2022;8:13.
35. Nawar NN, Kataia M, Omar N, Kataia EM, Kim HC. Biomechanical behavior and life span of maxillary molar according to the access preparation and pericervical dentin preservation: finite element analysis. *J Endod* 2022;48:902–8.
36. Kuttler S, McLean A, Dorn S, Fischzang A. The impact of post space preparation with Gates-Glidden drills on residual dentin thickness in distal roots of mandibular molars. *J Am Dent Assoc* 2004;135:903–9.
37. Marchionatti AME, Wandscher VF, Rippe MP, Kaizer OB, Valandro LF. Clinical performance and failure modes of pulpless teeth restored with posts: a systematic review. *Braz Oral Res* 2017;31:e64.
38. Silva EJNL, Attademo RS, da Silva MCD, Pinto KP, Antunes HDS, Vieira VTL. Does the type of endodontic access influence in the cyclic fatigue resistance of reciprocating instruments? *Clin Oral Invest* 2021;25:3691–8.
39. Morankar R, Goyal A, Gauba K, Kapur A, Bhatia SK. Manual versus rotary instrumentation for primary molar pulpectomies: a 24-months randomized clinical trial. *Pediatr Dent J* 2018;28:96–102.
40. Coll JA, Dhar V, Vargas K, et al. Use of non-vital pulp therapies in primary teeth. *Pediatr Dent* 2020;42:337–49.
41. Vorster M, van der Vyver PJ, Markou G. The effect of different access cavity designs in combination with WaveOne Gold and

TruNatomy instrumentation on remaining dentin thickness and volume. *J Endod* 2023;49:83—8.
42. Kim H, Jeon SJ, Seo MS. Comparison of the canal transportation of ProTaper GOLD, WaveOne GOLD, and TruNatomy in simulated double-curved canals. *BMC Oral Health* 2021;21:533.
43. Predin Djuric N, Van Der Vyver P, Vorster M, Vally ZI. Comparison of apical debris extrusion using clockwise and counter-clockwise single-file reciprocation of rotary and reciprocating systems. *Aust Endod J* 2021;47:394—400.
44. Kaya E, Elbay M, Yiğit D. Evaluation of the Self-Adjusting File system (SAF) for the instrumentation of primary molar root canals: a micro-computed tomographic study. *Eur J Paediatr Dent* 2017;18:105—10.
45. Radhika E, Reddy ER, Rani ST, Kumar LV, Manjula M, Mohan TA. Cone beam computed tomography evaluation of hand nickel-titanium K-files and rotary system in primary teeth. *Pediatr Dent* 2017;39:319—23.
46. Poornima P, Disha P, Nagaveni NB, Roopa KB, Bharath KP, Neena IE. 'Volumetric analysis of hand and rotary root canal instrumentation and filling in primary teeth using spiral computed tomography' - an invitro study. *Int J Paediatr Dent* 2016;26:193—8.
47. Jamleh A, Alfadley A, Alfouzan K. Vertical force induced with WaveOne and WaveOne Gold systems during canal shaping. *J Endod* 2018;44:1412—5.
48. Dias PS, Kato AS, Bueno CEDS, et al. Comparative analysis of torsional and cyclic fatigue resistance of ProGlider, WaveOne Gold Glider, and TruNatomy Glider in simulated curved canal. *Restor Dent Endod* 2022;48:e4.