10.21608/ADJC.2023.200864.1276 Advanced Dental Journal
Volume 5 (2023) | Issue 2| Pages 218-229

Original Article

Assessment of the Shape and Diameter of the Root Canal and the Risk of Perforation After Using Rotary System Versus Manual Instruments in Extracted Second Primary Molars: An In Vitro Study

Asmaa Elameen Nimir [1], Rania Abdallah Nasr [1], Sarah Mohammed Kenway [2], Yasmin Mohamed Yousry [1]

[1] Pediatric Dentistry and Dental Public Health, Faculty of Dentistry, Cairo University, Egypt
[2] Oral and Maxillofacial Radiology Department, Faculty of Dentistry, Cairo University, Egypt

E-mail: yasmin.yousry@dentistry.cu.edu.eg

Abstract

Aim: To assess canal shape, dentin thickness, and risk of perforation after using rotary Fanta AF baby files versus manual Hedstrom (H) files in root canal instrumentation of extracted second primary molars. Materials and methods: Twenty-six extracted second primary molars were randomly assigned to two groups; in Group (I): Molars were instrumented by Rotary Fanta AF baby files while in Group (II): Molars were instrumented by Manual H-files. The amount of dentin removal, canal shape, and risk of perforation were evaluated by cone-beam computed tomography (CBCT) comparing the pre to post instrumentation images. Fracture resistance after instrumentation was assessed with a universal testing machine. Results: Regarding the overall comparison of the amount of dentin removal on the mesial and distal walls of the distal canal, a significant difference was present between Fanta AF baby files and H-files (P=0.013) and (P<0.001) respectively. Where H-files removed a higher amount of dentin with mean ±SD (0.10±0.04) and (0.13±0.05) than Fanta files (0.08±0.04) and (0.05±0.02). However, a non- significant difference was observed regarding the shaping ability (P=0.691), the incidence of risk of perforation (P=0.680), and the fracture resistance (P=0.189). Conclusion: The Fanta AF baby files seem to be more effective in preserving dentin thickness than H files, and it can be utilized as a better alternative in root canal instrumentation in primary molars.

Keywords: H-files, Fanta AF baby files, dentin thickness, primary molars, risk of perforation, fracture resistance

I. INTRODUCTION:

Pulpectomy is an alternative to extraction, which might maintain oral health and aesthetic, protect the space for erupting permanent teeth, eliminate speech and psychological issues, and prevent mesial drifting of permanent molars. This clarifies the necessity of preserving decayed primary teeth rather than their extraction (American Academy of Pediatric Dentistry, 2022).

When compared to permanent molars, primary molars have different anatomical structures, such as having highly divergent curved roots and thinner dentin walls. The primary teeth root canal system is complex, and this complexity can increase over time due to secondary dentin formation, narrowing of root canals, and root resorption (Fumes et al., 2014).

Microorganisms' elimination from the canal system by root canal debridement, shaping, and sealing is directly related to the effectiveness of pulp treatment. Root canal cleaning can be accomplished manually using K-files or H-files. The use of H-files is advised because they pass through the canals easily with little resistance thus prevent contaminated material from being pushed beyond the apices (Panchal and Erulappan, 2019).

Endodontics has undergone a radical transformation with the introduction of nickel-titanium (Ni-Ti) rotary systems. It has been shown that the use of rotary instruments in deciduous teeth is efficient; it reduces the time required to instrument curved root canals and is cost-effective, resulting in dependably uniform and predictable obturation (Panchal and Erulappan, 2019). Moreover, it was claimed that using manual instruments increases the amount of dentin removed during preparation, the risk of root perforation and instrument fracture. Also, it is more time-consuming, using rotary systems can solve these problems by conservative dentin removal which will decrease the risk of iatrogenic errors and will save time for both the patient and the operator (Musale, Jain and Kothare, 2019; Zameer, 2016).

Fanta AF baby file is a type of rotary files made of advanced H-wire with train cross-section that increases its flexibility, resistance to cyclic fatigue, and cutting effectiveness. Its flexibility is sufficient to avoid canal transportation and ledges formation. At the same time, its hardness is enough to achieve good cutting results, perfect surface treatment, and minimal radial contact for better cutting. Additionally, the variable cross-section of the file increases the volume for upwards debris removal, and its variable pitch can achieve efficient debris transport and reduce the screwing effect (Abdelkafy, Eldehna and Salem, 2022).

In endodontics, tooth resistance to fracture is a crucial goal since such fractures might reduce tooth long term survival rate. Also, excessive root dentin removal during instrumentation can result in tooth fracture (Ashraf et al., 2016).

Evaluation of root canal instrumentation is important to determine instruments effect on the shape of the original canal, the amount of dentin removed during preparation, and to see if the principles of root canal preparation are followed (Musale , Jain and Kothare, 2019). Cone Beam Computed Tomography is greatly precise and reproducible in linear measurements in different planes and areas of the maxillofacial region with high spatial resolution (Imaizumi , Suzuki and Murono, 2022; Moshfeghi et al., 2012). Considering the limited availability of studies on the effect of Fanta AF baby files on primary molars root canals preparation, this study aimed to assess canal shape, dentin thickness, risk of perforation using CBCT, and fracture resistance using the universal testing machine after root canal instrumentation with rotary Fanta AF baby files versus manual H-files on extracted second primary molars.

II. MATERIALS AND METHODS

A. Study setting

This in-vitro study was conducted in the Pediatric Dentistry Department, Faculty of Dentistry, Cairo university. The Faculty Research Ethics Committee reviewed the study proposal and gave its approval on 15/3 /2021 and its number is (2-1-21).

B. Sample size calculation

A power analysis was created to have adequate power to test the null hypothesis that

there is no difference between using manual instruments, and rotary system during root canal instrumentation in primary molars. Using an alpha level of (0.05), a beta level of (0.2), i.e., power=80%, and an effect size (d) of (1.15) calculated from Musale, Jain and Kothare, 2019 results, the predicted sample was a total of (26) extracted second primary molars. G*Power version 3.1.9.7 was used to calculate sample size.

C. Eligibility criteria for selected teeth

Inclusion criteria

- Extracted second primary molars with at least 2/3 of root remaining.

Exclusion criteria

- Exfoliated second primary molars.
- If pre-assessment radiograph for extracted second primary molars reveals:
- Internal or external root resorption.
- Extreme root curvature.
- Calcified canals.

D. Sample collection and preparation

Extracted second primary molars were collected from the Pediatric Dentistry clinics in the Faculty of Dentistry, and other private dental clinics. Only molars that met the eligibility criteria were included. Twenty-six molars were assigned randomly into two equal groups. Group (I): primary molars were instrumented by Rotary Fanta AF baby files while group (II): primary molars were instrumented by Manual H-files. Sequence of randomization was generated using Random.org.

Following the Occupational Safety and Health Administration's regulations and policies, the teeth were disinfected, and sequentially stored for 2 hours in a dark opaque container filled with distilled water and 0.5% sodium hypochlorite solution, then finally stored in normal saline.

For periodontal ligament simulation, the entire roots were coated with a thick silicone paste layer up to 2 mm below the CEJ. Then molars were mounted in cold cure acryl to ensure their stability during CBCT scanning and instrumentation procedures.

E. Steps for root canal instrumentation

After removing caries with a spoon excavator (LASCOD, Italy), the access cavity was prepared with a round bur (Tianjin D.M Technology Development Co., Ltd, China) using a high-speed handpiece (Foshan COXO Medical Instrument Co., Ltd, China)

Molars full working length was estimated by inserting a file until reaching the tip of the apical foramen, 1 mm short of the whole initial length which was documented for root canal preparation before molding in the acryl.

EDTA 17% (Dolo Prevest Denpro., Made in India) was used as a lubricant during files insertion, and canals were irrigated between each sequential file with 3 ml normal saline through a 31-gauge needle.

For standardization, all root canal instrumentation procedures were done by the same operator.

In group (I): Rotary System (Fanta AF baby files):

Filing was performed with 16-mm Ni-Ti Fanta AF baby rotary files (Shanghai Fanta Dental Materials Co., Ltd, China) driven by a Cicada rotary motor (Guangzhou KEDA Biological Tech Co., Ltd, China) at 350 rpm with torque 2.4N.

The coronal third of the canal was negotiated with K-file size (10) with a full working length then the orifice opener was used to prepare the coronal third to get a straight-line access.

Following that, file (#20/0.04) then file (#25/0.04) were used in a pecking motion to the full working length, and after each filing, the canal was irrigated with normal saline.

In group (II): Manual Instruments (H-files):

Root canal instrumentation was performed using H-files (Mani Inc, Tochigi, Japan) until size 30, using retraction or pulling motion in a crown-down technique. Recapitulation was done with size 10 K-file.

Each H-file was used for a maximum of five teeth to keep canal uniformity during preparation. After the last file, each canal was irrigated with 3 ml saline, and recapitulation was done with the #10 K-file.

F. Radiographic assessment of the root canal

All deciduous molars with their acrylic models were scanned twice, before and after instrumentation, at the Oral and Maxillofacial Radiology Department, Faculty of Dentistry, Cairo university, using the " "Planmeca ProMax® 3D Mid & Proface" CBCT scanner," with the following exposure parameters (kVp: 90, mA: 10, exposure time: 15 sec, operation mode: Endo-mode, voxel size: 75 μm, resolution: 0.08 mm).

- *Assessment of Dentin Thickness:*

The dentin thickness of only the distal canals of each sample was measured twice (before and after instrumentation). Two essential imaginary lines were drawn; the first "reference line" was drawn horizontally, connecting the cemento-enamel junction (CEJ) mesiodistally, while the second line was drawn starting from the previous line coronally through the center of the canal orifice till the root apex apically. The distance of this second line was measured and recorded as the "Total Root Length" (figure 1a). On CBCT coronal images, the distal root length was equally divided into three thirds; coronal, middle, and apical third as presented in figure 1b. At the center of each third, on selected axial CBCT images, the distance from the inner root canal surface to the outer root canal surface was measured at both mesial and distal wall at the level of minimum dentin thickness. After canal preparation, the mesial side of the roots' dentin removal was evaluated using the formula (A1-A2). While the distal side's dentin removal was evaluated using the formula (B1-B2) (Seema et al., 2020), as shown in figures 2 a, b and c.

- *Assessment of Canal Shape:*

On coronal CBCT images, the distal root canal taperness was evaluated by comparing pre- and post-instrumentation CBCT images. On Coronal images, the maximum mesio-distal diameter was measured at the center of each third before and after canal instrumentation figure 3a and b. Then after assessment, canals were classified as having a good or poor taper. The "good taper" was defined as the gradual reduction in canal width from coronal to apical third, while any other taperness patterns were classified as "poor taper" (Seema et al., 2020).

- *Assessment of the Risk of Perforation:*

Any discontinuity, gap, or incoherence observed on any postoperative axial CBCT image was considered a root perforation as shown in figure 4. (Seema et al., 2020)

- *Assessment of Fracture Resistance:*

Teeth were irrigated, dried, and obturated with zinc-oxide eugenol. Then the crown portion was sectioned at the CEJ using a slow- speed cutting machine (Isomet 4000, saw Buehler made in USA) to avoid any possibility of crack occurrence during cutting.

The samples were placed in the center of the lower plate beneath the plunger in the universal testing machine (SHIMADZU 5 KN AUTOGRAPH AG X PLUS Japan), at the National Research Center. In the center of the orifice parallel to the long axis of the tooth, the plunger was pushed downward at a crosshead speed of 5mm/min until the root fractured (Talreja et al., 2022). The machine stopped automatically when the fracture occurred, and the software of the machine measured the maximum force before root fracture occurrence, as shown in figure 5.

G. Statistical analysis

The chi-square test was used to assess categorical data, which were displayed as frequency and percentage values. Mean and standard deviation values were used to present numerical data. The Shapiro-Wilk test was used to check whether they were normal. The Mann-Whitney U test was used to examine the non-parametric amount of dentine removal between groups. Other numerical data were normally distributed and were examined using paired and independent t-tests for intragroup and intergroup comparisons. The level for significance in each test was set at p 0.05. R statistical analysis software 4.1.3 for Windows was used to perform the statistical analysis (R Core Team, 2022).

III. RESULTS

A. Amount of dentine removal (mm)

- *Effect on the mesial wall of the distal canal:*

For the coronal section, there was no statistically significant difference between both groups (p=0.674). H-files had a significantly higher amount of dentin removal at the middle (P<0.001) and the apical (P=0.003) section than Fanta AF files. In overall root section, there was a statistically significant difference between Fanta AF files and H-files (P=0.013), as shown in Table (1).

- *Effect on the distal wall of the distal canal:*

For the apical section, results revealed non statistically significant difference between groups (p=0.062). H-files had a significantly higher amount of dentin removal at the coronal (P<0.001) and the middle (P<0.001) section than Fanta AF files. In overall root section, a statistically significant difference was present between groups (P<0.001), as shown in Table (2).

B. Root canal shape

In group (I); 46.2% of root canals had good tapering while, 53.8% had poor tapering. For group (II); 38.5% of root canals showed good tapering, while 61.5% have poor tapering. A non-statistically significant difference was present between groups (p=0.691), as shown in Table (3)

C. Risk of perforation

A non-statistically significant difference was seen between groups regarding the incidence of perforation p=0.680), and all perforations occurred apically, as shown in Table (4).

D. Fracture resistance (N)

Molars prepared by H-files exhibited a higher fracture load with mean ±SD (729.38±110.07 newton) than molars prepared by Fanta AF files with mean ±SD (668.19±120.62 newton), with no statistically significant difference (p=0.189).

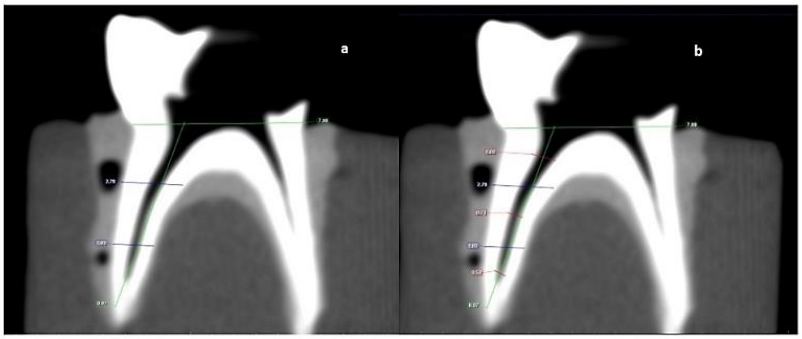

Figure (1): (a) Coronal CBCT image showing the "reference line" connecting the CEJ mesiodistally and the "Total Root Length" connecting the previous line to the root apex (b): Dividing each of coronal, middle, and apical root thirds into halves.

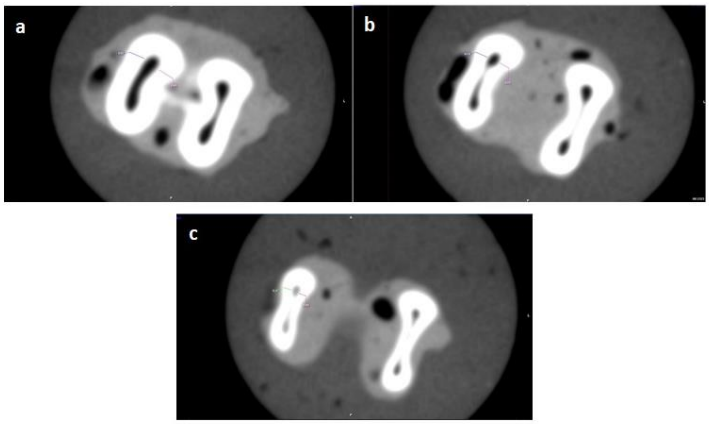

Figure (2): Axial CBCT images of the distal root canal at coronal (a), middle (b), and apical (c); showing the measured dentin thickness at the level of minimum dentin thickness.

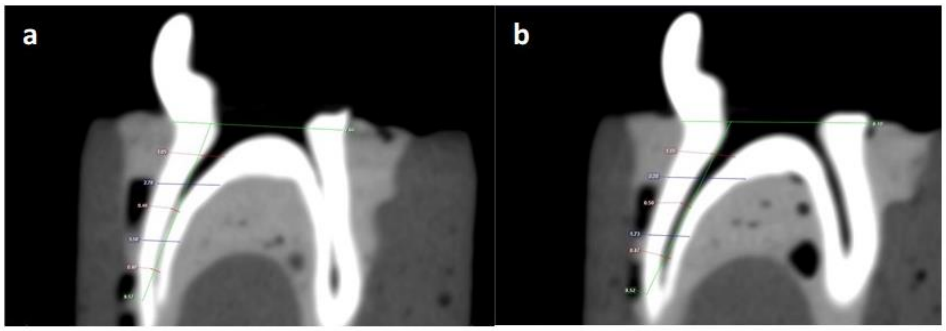

Figure (3): CBCT coronal images showing the maximum mesiodistal diameter measured at the center of each third (coronal, middle and apical) of distal canal before instrumentation (a) and after instrumentation (b).

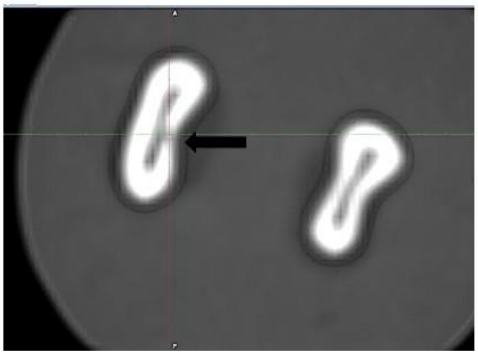

Figure (4): Axial CBCT image showing root discontinuity (black arrow) in the distal root of a primary molar after instrumentation.

Figure (5): (a) sample within the universal testing machine (b, c): samples after the applied force with the vertical fractures occurred.

Table 1: Intergroup comparisons of the amount of dentine removal (mm) for different files on the mesial wall of the distal canal

Root section	Amount of dentine removal (mm) (mean±SD)		p-value
	Fanta AF	H-files	
Coronal	0.13±0.01	0.13±0.02	0.674ns
Middle	0.07±0.01	0.12±0.02	<0.001*
Apical	0.05±0.01	0.06±0.01	0.003*
Overall	0.08±0.04	0.10±0.04	0.013*

***; significant (p ≤ 0.05) ns; non-significant (p>0.05)**

Table (2): Intergroup comparisons of the amount of dentine removal (mm) for different files on the distal wall of the distal canal

Root section	Amount of dentine removal (mm) (mean±SD)		p-value
	Fanta AF	H-files	
Coronal	0.07±0.01	0.17±0.02	<0.001*
Middle	0.03±0.01	0.15±0.01	<0.001*
Apical	0.05±0.02	0.07±0.01	0.062ns
Overall	0.05±0.02	0.13±0.05	<0.001*

***; significant (p ≤ 0.05) ns; non-significant (p>0.05)**

Table (3): Intergroup comparisons of the amount of dentine removal (mm) for different files on the distal wall of the distal canal

Tapering		Fanta AF	H-files	p-value
Good	n	6	5	0.691ns
	%	46.2%	38.5%	
Poor	n	7	8	
	%	53.8%	61.5%	

***; significant (p ≤ 0.05) ns; non-significant (p>0.05)**

Table (4): Intergroup comparisons, frequencies, and percentages of perforation incidence in different files

Level of Perforation	Lateral Perforation incidence		Fanta AF	H-file	p-value
Apical	No	n	9	8	0.680ns
		%	69.2%	61.5%	
	Yes	n	4	5	
		%	30.8%	38.5%	

***; significant (p ≤ 0.05) ns; non-significant (p>0.05)**

IV. DISCUSSION:

Nowadays rotary and manual instruments are used in root canal preparation of deciduous molars. The main aim during preparation is to achieve proper cleaning and shaping with preservation of maximum dentin thickness of the root canal. There is a direct association between the amount of dentin removed and how aggressively root canal instruments are used. If the remaining dentin thickness is decreased following root canal preparation, this can speed up tooth exfoliation, especially in primary teeth (Seema et al., 2020).

In these aspects comes the benefit of using rotary systems, which provide more effective cleaning and shaping for the root canals, decrease the risk of iatrogenic errors, increase the teeth fracture resistance , and reduce the time of treatment which will result in obvious improvement of patient cooperation when compared with manual instruments (Elheeny and Abdelmotelb, 2022). Consequently, this study aimed at assessing canal shape, dentin thickness, risk of perforation and fracture resistance after using rotary Fanta AF baby files versus manual H-files on extracted second primary molars.

According to similar previous studies, the samples utilized in this study were limited to second primary molars extracted due to gross caries, loss of bone support, or when extraction was the only option of treatment (Ramazani et al., 2016; Waly et al., 2021; Abd El fatah et al., 2022).

This study evaluated the shape, dentin thickness, and risk of perforation of the distal canal only instead of both the distal and the mesial canals since Vertucci type (IV); two separate canals in a single root was the most prevalent canal morphology among the mesial roots of lower primary second molars. While single-type (I) canal morphology was the most frequent for their distal roots (Ziya, YÜksel and Şari, 2019; Mahesh and Nivedhitha, 2020).

At the coronal part of the root, the amount of dentin removal on the mesial wall was non- statistically significantly different between Fanta AF baby files and H-files (P=0.674), while a statistically significant difference in the middle (P<0.001) and apical parts (P=0.003) was observed. In disagreement with, Seema et al., 2020 who reported that on the mesial wall of the canal at the coronal level, the K-file removed a high average amount of dentin (mean ±SD 0.31±0.21) than the Rotary Kedo-S (mean ±SD 0.19±0.10), while no statistically significant difference was present between their groups at the middle (P= 0.098) and apical levels (P= 0.204).

At the apical section of the distal wall, results showed a non- statistically significant difference between groups (P=0.062). However, at the coronal and middle sections, there was a statistically significant difference (P<0.001) and (P<0.001) respectively. These results came in contrast with Seema et al., 2020 results that revealed the absence of significant difference between K-file, Rotary Kedo-S, and Rotary Protaper files at the coronal (P=0.364), middle (P=0.228), and apical (P=0.228) levels of the distal wall.

The explanation for these dissimilar findings may be related to the variable file taper since the AF baby file system maintains a taper of 4% across the entire file length. In contrast, the Kedo-S file system has a variable taper that may reach up to 8%. Proved that the amount of dentin removed from root canal wall increases as the rotary files' taper increases (Kaya and Yigit, 2017).

In the overall comparison of the amount of dentin removal on the mesial and distal wall of the distal canal, a significant difference was present between groups (P=0.013) and (P<0.001) respectively, where H-files removed a high average amount of dentin (mean ±SD 0.10±0.04 and 0.13±0.05) than the Fanta AF baby files (mean ±SD 0.08±0.04 and 0.05±0.02). This could be attributed to the enhanced canal straightening caused by H-files, which are less flexible, as opposed to the more flexible H-wire technology used in Fanta AF baby files, allowing it to easily adapt to different canals morphology without being straighten during instrumentation of curved canals. Additionally, the amount of dentin removal had positively correlated with the aggressiveness of the used root canal instrument (Musale, Jain and Kothare, 2019; Abd El fatah et al., 2022).

Similarly, Zameer, 2016 reported a statistically significant difference between manual and rotary files (P<0.05) in which manual files removed a greater amount of dentin, and the same result was seen in other several studies. Musale, Jain and Kothare, 2019; Selvakumar et al., 2016; Eldemery et al., 2021).

Root canal taperness after preparation is mostly affected by various factors: file design and initial canal shape. Regarding the shaping ability, results showed that (4% taper) Fanta AF baby files had a better shaping ability than (2% taper) H-files, but with no significant difference (P=0.691). In accordance with previous research, no significant difference was noted between hand and rotary files in root canal

shaping in primary teeth (P=0.507), although it was reported that rotary files had better shape effectiveness than hand files (Seema et al., 2020).

A possible justification may be related to the 2% taper of the manual files that indicate that for each 1 mm of the file, canal tapering tends to increase by 0.02 mm. As a result, files with (4% taper) provide better preparation than files with 2% taper. This means that many files will be required to complete the preparation since the full length of the file will touch the entire canal wall (Mohamed, Abdelrahman and Sharaf, 2022).

Regarding the incidence of the risk of perforation, results showed that H-files caused a higher incidence of perforations (38.5%) than Fanta AF baby files (30.8%) with a non-significant difference (P=0.680), and all perforations were located at the apical root section. Similarly, Ozen and Akgun, 2013; Zameer, 2016 reported non statistically significant differences in risk of perforation between hand files and rotary files (P>0.05).

Swaminathan, Rakkesh and Haridoss, 2022 stated that most of the perforations that occurred in primary roots are located apically because the apical region has the thinnest dentinal walls and is more sensitive to perforations and should be accounted for canal instrumentation during the treatment plan.

Results showed that molars prepared by H-files had higher fracture root resistance (mean ±SD 729.38±110.07) than molars prepared by Fanta AF baby files (±SD 668.19±120.62), but without significant difference (P=0.189). This could be explained by the fact that rotary files cause more microcracks or craze lines on the dentinal walls during preparation (Panda et al., 2021).

The tooth resistance to lateral stresses is closely correlated with the thickness of the dentinal wall. Microcracks or craze lines sometimes appear on the walls because of the rotational force used to prepare root canals with rotary files. The instruments' flute shape, cross-sectional geometry, tip design, progressive or continuous taper, constant or variable pitch, and other factors all contribute to the severity of these defects (Panda et al., 2021).

In disagreement with Acharya et al., 2020 who compared hand Files, ProTaper Next, ProTaper Universal and V Taper in maxillary first premolars, results showed a statistically significant difference in vertical fracture resistance between the four groups (P≤0.05). This difference between results may arose due to variations in sample type and files used.

A limitation of this study was that outcomes evaluation was based on the assessment of the distal canals only. Further studies are needed for testing different canals in different primary molars to provide more conclusive results.

V. CONCLUSIONS

When compared to manual H-files, the use of rotary Fanta AF baby files led to significantly better dentin thickness preservation, and regardless the non-significant differences in the current results, rotary Fanta AF baby files showed superior shaping ability and lower risk of perforation incidence in most of the canals. Therefore, rotary Fanta AF baby files can be utilized as a better alternative to manual files in root canal instrumentation in primary molars.

VI. CONFLICT OF INTEREST

The authors declare that there is no conflict of interests.

VI. FUNDING INFORMATION

No funding was received for conducting this study.

VII. REFERENCES

1. Abd El fatah, Y.A.M., Khattab, N.M.A., Gomaa, Y.F., Elheeny, A.A.H., 2022. Cone-beam computed tomography analysis of primary root canals transportation and dentin loss after instrumentation with two-pediatric rotary files. BMC Oral Health 22. https://doi.org/10.1186/s12903-022-02245-8
2. Abdelkafy, H., Eldehna, A.M., Salem, N.A., 2022. Canal Transportation and Centring Ratio of Paediatric vs Regular Files in Primary Teeth. Int Dent J. https://doi.org/10.1016/j.identj.2022.09.003
3. Acharya, N., Hasan, M.R., Kafle, D., Chakradhar, A., Saito, T., 2020. Effect of hand and rotary instruments on the fracture resistance of teeth: An in vitro study. Dent J (Basel) 8. https://doi.org/10.3390/dj8020038
4. American Academy of Pediatric Dentistry, 2022. Pulp therapy for primary and immature permanent teeth. American Academy of Pediatric Dentistry 415–23.
5. Ashraf, F., Shankarappa, P., Misra, A., Sawhney, A., Sridevi, N., Singh, A., 2016. A Stereomicroscopic Evaluation of Dentinal Cracks at Different Instrumentation Lengths by Using Different Rotary Files (ProTaper Universal, ProTaper Next, and HyFlex CM): An Ex Vivo Study. Scientifica (Cairo) 2016. https://doi.org/10.1155/2016/8379865
6. eldemery, nada, Elshehawy, O., Nasr, R., badr, mahmoud, 2021. Evaluation of Remaining Dentin Thickness After Manual and Evaluation of Remaining Dentin Thickness After Manual and Rotary Instrumentation In Primary Molars Using Cone Beam Rotary Instrumentation In Primary Molars Using Cone Beam Computed Tomography. (An In-Vitro Study). future dental journal 95–98. https://doi.org/10.54623/fdj.7024
7. Elheeny, A.A.H., Abdelmotelb, M.A., 2022. Postoperative pain after primary molar pulpectomy using rotary or reciprocating single files: A superior, parallel, randomized clinical trial. Int J Paediatr Dent 32, 819–827. https://doi.org/10.1111/ipd.12959
8. Fumes, A.C., Sousa-Neto, M.D., Leoni, G.B., Versiani, M.A., da Silva, L.A.B., da Silva, R.A.B., Consolaro, A., 2014. Root canal morphology of primary molars: a micro-computed tomography study. European Archives of Paediatric Dentistry 15, 317–326. https://doi.org/10.1007/s40368-014-0117-0
9. Imaizumi, M., Suzuki, T., Murono, S., 2022. Cone beam computed tomography with oral contrast for accurate diagnosis and surgical planning of pharyngeal leakage and fistula: a case series. Braz J Otorhinolaryngol 88, S50–S57. https://doi.org/10.1016/j.bjorl.2021.08.001
10. Kaya, E., Yigit, D., 2017. Evaluation of the Self-Adjusting File system (SAF) for the instrumentation of primary molar root canals: a microcomputed tomographic study. Artificial Intelligence View project Virtual Reality Dental Simulation View project.
11. Mahesh, R., Nivedhitha, M., 2020. Root canal morphology of primary mandibular second molar: A systematic review. Saudi Endodontic Journal. https://doi.org/10.4103/sej.sej_18_19
12. Mohamed, R.H., Abdelrahman, A.M., Sharaf, A.A., 2022. Evaluation of rotary file system (Kedo-S-Square) in root canal preparation of primary anterior teeth using cone beam computed tomography (CBCT)-in vitro study. BMC Oral Health 22. https://doi.org/10.1186/s12903-021-02021-0
13. Moshfeghi, M., Tavakoli, M.A., Hosseini, E.T., Hosseini, A.T., Hosseini, I.T., 2012. Analysis of linear measurement accuracy obtained by cone beam computed tomography (CBCT-NewTom VG). Dent Res J (Isfahan) 9, S57-62.
14. Musale, P., Jain, K., Kothare, S., 2019. Comparative assessment of dentin removal following hand and rotary instrumentation in primary molars using cone-beam computed tomography. Journal of Indian Society of Pedodontics and Preventive Dentistry 37, 80–

86. https://doi.org/10.4103/JISPPD.JISPPD_210_18

15. Ozen, B., Akgun, O.M., 2013. A comparison of Ni-Ti rotary and hand files instrumentation in primary molars. Journal of International Dental and Medical Research 6, 6–8.
16. Panchal, V., Erulappan, S.M., 2019. Comparison between the Effectiveness of Rotary and Manual Instrumentation in Primary Teeth: A Systematic Review. Int J Clin Pediatr Dent 12, 340–346. https://doi.org/10.5005/jp-journals-10005-1637
17. Panda, A., Shah, K., Budakoti, V., Dere, K., Virda, M., Jani, J., 2021. Evaluation of microcrack formation during root canal preparation using hand, rotary files and self-adjusting file in primary teeth: An in vitro study. J Dent Res Dent Clin Dent Prospects 15, 35–41. https://doi.org/10.34172/joddd.2021.007
18. R Core Team, 2022. R: A language and environment for statistical computing. R Foundation for Statistical Computing.
19. Ramazani, N., Mohammadi, A., Amirabadi, F., Ramazani, M., Ehsani, F., 2016. In vitro investigation of the cleaning efficacy, shaping ability, preparation time and file deformation of continuous rotary, reciprocating rotary and manual instrumentations in primary molars. J Dent Res Dent Clin Dent Prospects 10, 49–56. https://doi.org/10.15171/joddd.2016.008
20. Seema, T., Ahammed, H., Parul, S., Cheranjeevi, J., 2020. Comparative evaluation of dentin removal and taper of root canal preparation of Hand K file, protaper rotary file, and Kedo S rotary file in primary molars using cone-beam computed tomography. Int J Clin Pediatr Dent 13, 332–336. https://doi.org/10.5005/jp-journals-10005-1787
21. Selvakumar, H., Kavitha, S., Thomas, E., Anadhan, V., Vijayakumar, R., 2016. Computed tomographic evaluation of K3 rotary and stainless steel K file instrumentation in primary teeth. Journal of Clinical and Diagnostic Research 10, ZC05–ZC08. https://doi.org/10.7860/JCDR/2016/14183.7028
22. Swaminathan, K., Rakkesh, K.M., Haridoss, S., 2022. Computed Tomographic Assessment of Remaining Dentin and Risk of Perforation after Kedo-S and Mtwo Rotary Instrumentation in Root Canals of Primary Teeth: An In Vitro Study. Int J Clin Pediatr Dent 15, S87–S91. https://doi.org/10.5005/jp-journals-10005-2217
23. Talreja, N., Shashikiran, N.D., Singla, S., Mali, S., Agrawal, N., Lohiya, J., 2022. Comparative evaluation of the vertical and horizontal root fracture resistance of primary maxillary incisors obturated with zinc oxide eugenol, vitapex, and endoflas: An in vitro study. Journal of International Oral Health 14, 273–280. https://doi.org/10.4103/jioh.jioh_206_21
24. Waly, A.S., Yamany, I., Abbas, H.M., Alsairafi, M.A.A., Bazzaz, R.M.F., Bogari, D.F., Alhazzazi, T.Y., 2021. Comparison of two pediatric rotary file systems and hand instrumentation in primary molar: An ex vivo cone-beam computed tomographic study. Niger J Clin Pract 24, 1492–1498. https://doi.org/10.4103/njcp.njcp_563_20
25. Zameer, M., 2016. Evaluation of radicular dentin remaining and risk of perforation after manual and rotary instrumentations in root canals of primary teeth: An in vitro study . Journal of Pediatric Dentistry 4, 57. https://doi.org/10.4103/2321-6646.194370
26. Ziya, M., YÜksel, B.N., Şari, S., 2019. Root canal morphology of mandibular primary molars: A micro-ct study. Cumhuriyet Dental Journal 22, 382–389. https://doi.org/10.7126/cumudj.615843