Original Article

Evaluation of radicular dentin remaining and risk of perforation after manual and rotary instrumentations in root canals of primary teeth: An *in vitro* study

Mohammed Zameer*
Department of Pediatric and Preventive Dentistry, Navodaya Dental College and Hospital, Raichur, Karnataka, India.

ABSTRACT

The aim of the study is to evaluate the efficacy of radicular dentin removal, risk of perforation, and shape of the canal on using manual and rotary instruments in primary teeth. Sixty primary teeth selected were divided into three groups; all the teeth were then embedded into resin and sectioned for examination before and after instrumentation. H-files were used for manual technique, and 2% taper and 4% taper I-Race files were used for rotary. Dentin removal was calculated using stereomicroscope-assisted digital image viewing software. Manual instrumentation has removed overall more dentin compared with 2% and 4% taper rotary instrumentation. No statistical differences were found between 2% and 4% instrumentation with respect to the amount of dentin removed. In few specimens, root perforations were observed in areas coinciding with largest root resorption. In primary teeth without significant root resorption, the use of nickel-titanium-rotary files with 2% and 4% taper up to size 30 revealed to be safe and had prepared the root canals with greater conservation of tooth structure than manual instrumentation. However, 4% taper instrumentation had an additional advantage of providing more funnel-shaped canal desired for ideal compaction of obturating material.

Key words: H-files, I-Race, Manual instrumentation, Root perforation, Rotary instrumentation, 2% and 4% taper

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INTRODUCTION

In pediatric dentistry, pulpectomy is a preferred root canal procedure for pulp tissue that is irreversibly inflamed or necrotic. The anatomic and physiologic features of primary teeth can present challenges to the clinician wishing to undertake pulpectomy. However, with knowledge of these features and how they may impact on clinical technique, pulpectomy can be a clinically successful option.[1]

Root canal preparation techniques using manual instruments have found to be time-consuming and may lead to iatrogenic errors such as ledging, zipping, canal transportation, and apical blockage. To overcome this, much attention has been directed toward root canal preparation using nickel-titanium (NiTi)-rotary instruments. The flexibility and the instrument design of NiTi-rotary files allow it to closely follow the original root canal path. Studies have consistently shown acceptable cleaning ability of NiTi instruments and considered to be more effective way to debride the uneven walls in primary teeth.[2,3]

However, evaluation of the amount of dentin removal from the root canals of primary teeth upon using manual

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***Address for correspondence**
Dr. Mohammed Zameer, Galib Nagar, Raichur, Karnataka, India. E-mail: drmohammedzameer@gmail.com

and rotary endodontic instruments has not been much investigated yet. Therefore, the present study was opted to evaluate the amount of dentin removal and the risk of perforation when root canals were instrumented using H-file and I-Race rotary files.

MATERIALS AND METHODS

The present study was conducted in the Department of Pediatric and Preventive Dentistry at Navodaya Dental College and Hospital, Raichur. Evaluation of the study was done by the Ethical Committee of the Institute, and ethical approval was obtained before the study.

Sample size estimation

The sample size was estimated using the given formula:

$n = (Z\alpha/2 + Z\beta)2 \times 2 \times \sigma 2/d2$

$n = (1.96 + 1.282)2 \times 2 \times (0.09)2/(0.08)2 = 27 \approx 28$ (final sample size)

The total sample of this study comprised sixty human primary teeth extracted for reasons not related to the study. Mainly, teeth were donated by patients from public health-care services where tooth extraction is the only treatment available for teeth with compromised pulp and periradicular tissues. Others were extracted because they were unrestorable or taken up for treatment through serial extraction.

Inclusion criteria

a. Teeth with minimal apical resorption with the presence of at least two-third remaining root structure

b. Teeth with the absence of visual perforating resorption.

Exclusion criteria

a. Teeth with calcified root canal

b. Teeth with the presence of any visual perforation on the roots.

Study design

Based on the selection criteria, sixty primary teeth were selected and stored in formalin. Ultrasonic scaler was used to clean soft-tissue debris or calculus attached to the teeth. Teeth were divided into three groups (n = 20): Group A - 4% taper rotary, Group B - 2% taper rotary, Group C - manual. The real tooth length was established by visual observation, with 19 mm k-file size 8 or 10 until it could be seen at major apical foramen. Buccolingual and mesiodistal radiographs were taken. The working length corresponded to the real tooth length [Figure 1]. An accurate simplified Bramante muffle system[4,5]was used for the specimens. A rectangular plaster model with orientation grooves at every 2 mm was prepared. Impression was made with elastomeric material to obtain a mold opened at one end. The tooth with screws was stabilized on a modeling wax such that tooth and the screws are parallel to each other. Resin was poured into the mold, and the frame comprises tooth and screws was embedded into resin. Embedment was carried out with the tooth crown protruding to the level of cementoenamel junction, and the roots were placed parallel to the long axis of mold. After the resin had been set, screws were removed from the mold. Tooth-resin block was transversely sectioned using micromotor, with 0.25 mm thick diamond disc [Figure 2]. Following the orientation grooves at every 2 mm, the most three sections were obtained from each tooth-resin block and were labeled to indicate the section within each sample.

Image recording of the sections before instrumentation was performed under a Nikon SM225 model P2-Firl

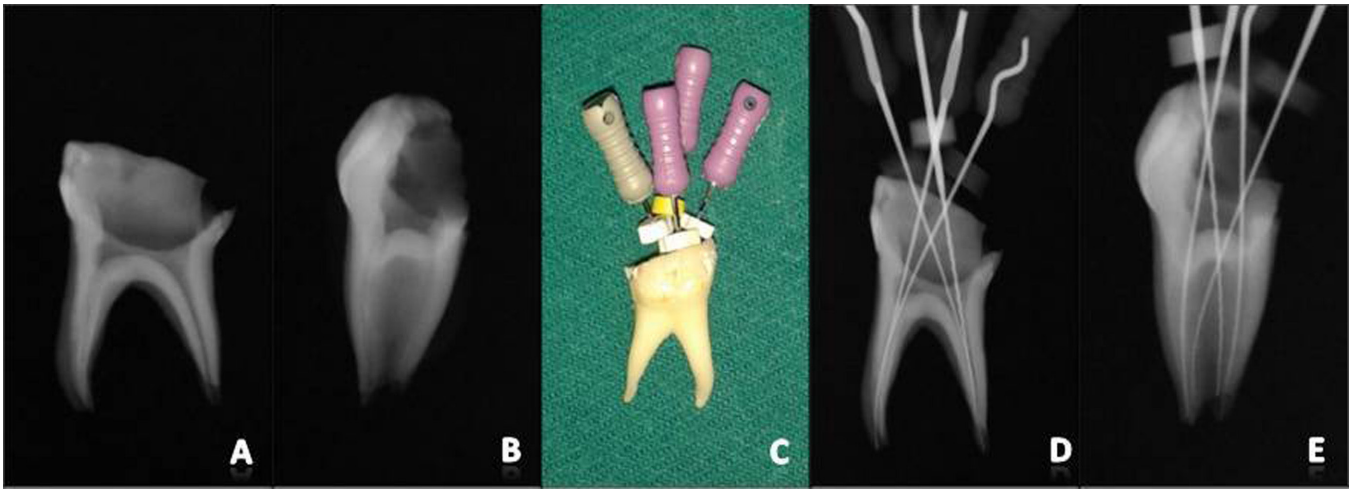

Figure 1: (a and b) Preinstrumentation radiographs, (c) real-tooth length determination, (d and e) working length corresponding to the real tooth length

stereomicroscope attached digital camera Nikon Digital Sight-Ds-Fi2-K18944, Japan [Figure 3]. Tooth surface positioning and magnification (×0.63) were standardized for all the sections.

Measurement of dentin thickness in different root wall was taken from the external limit of the root canal to the surface of the root. In each wall, the thinnest area between the canal wall and the external root surface was recorded. The total sample (n = 60) was divided into three groups; each group was equally divided to have the same type of teeth and the same number of root canals per group. Teeth were thus randomly divided into two subgroups (n = 10 in each group), maxillary molars and mandibular molars. At this time, the groups were defined and sections were repositioned for instrumentation using manual and rotary files. Protocol for instrumentation was standardized: manual (H-files) and rotary (I-Race files both 2% and 4% taper) up to size 30. All canals in both groups were copiously irrigated with 2 ml of 3% sodium hypochlorite and saline before preparation and after instrumentation using disposable syringe. Totally, 8 sets of rotary instruments were used (4 sets of 2% taper and 4 sets of 4% taper). Each instrument was used for preparation of five specimens. Totally, 4 sets of H-files were used for manual instrumentation. Each set of manual H-files comprises 4 instruments of size from 15 to 30. Each set of rotary comprises three instruments: 6% taper size 30, followed by size 25-30 for each taper group. Instrument movement followed for manual files was clockwise half-turn followed by a similar counter-clockwise motion and withdrawal. Each instrument performed nearly 15 circumferential filing movements on the root canal walls. The rotary instrumentation (n = 20 for 2% taper, n = 20 for 4% taper) was performed with I-Race system. Preparation was performed with 21 mm NiTi instruments using step-back technique following to the manufacturer

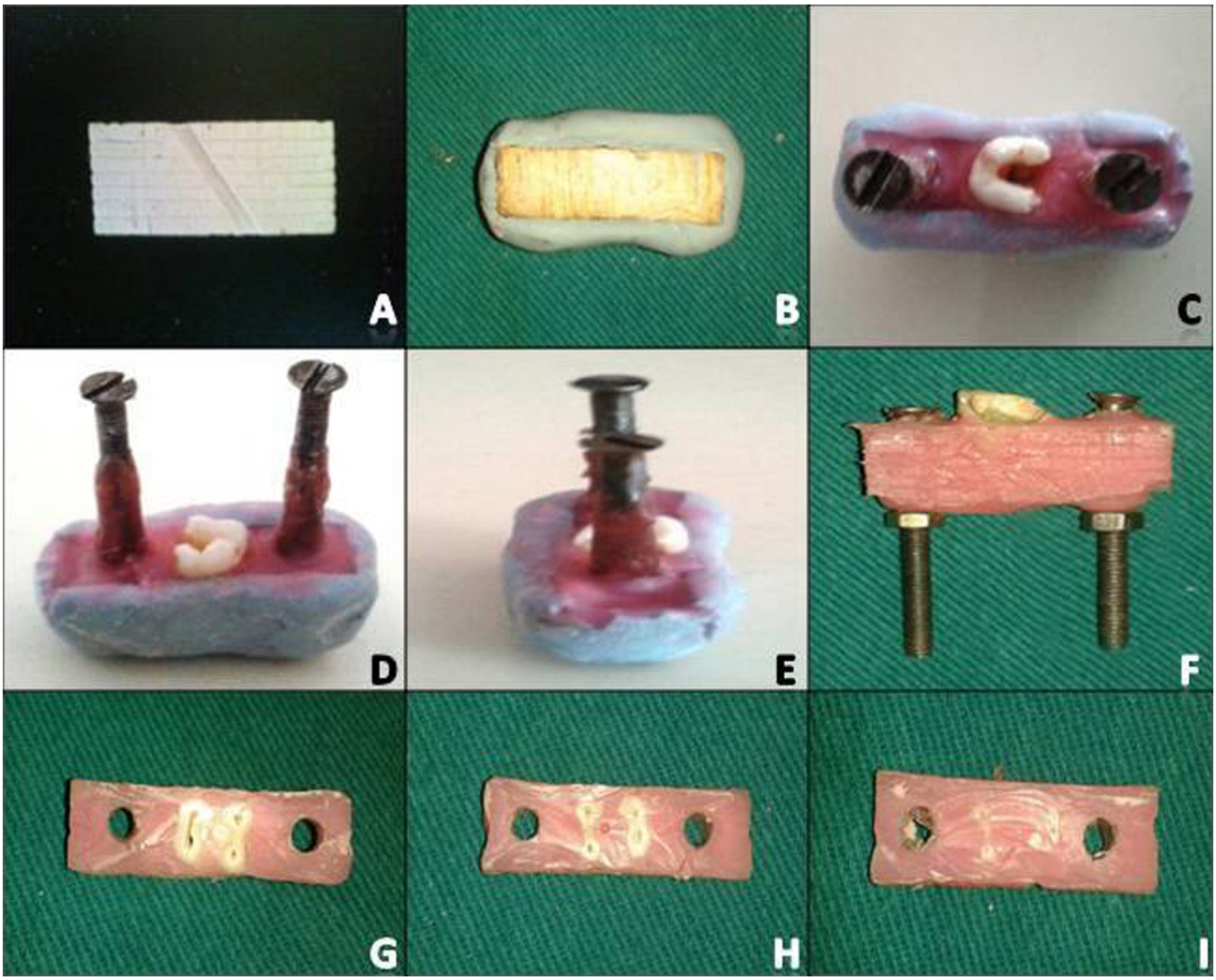

Figure 2: (a) A rectangular block with orientation grooves, (b) preparation of mold using the elastomeric impression material, (c-e) embedment of tooth with screws for building up tooth-resin block, (f) tooth-resin block with orientation grooves for sectioning, (g-i) three sections of the tooth-resin blocks ready for imaging

instruction. After completion of shaping, sections were separated and images were recorded and analyzed using image viewing software [Figure 3]. Data obtained were subjected to statistical analysis.

Statistical analysis

Descriptive statistics such as mean, standard deviation (SD), and percentage were used. Comparison between manual and rotary was done using unpaired *t*-test for normal data and Mann–Whitney test for nonnormal data. Comparison between before and after instrumentation was done using paired *t*-test. Comparison between groups of categorical data was done using Chi-square test. A $P < 0.05$ was considered statistically significant.

RESULTS

Instrument failure

There were no H-file or I-Race rotary instrument fractures during preparation.

Radicular dentin thickness

The mean and SD of root canal areas before and after instrumentation and the amount of dentin removed according to the type of instrumentation, root third, and different dental groups are summarized in [Tables 1–3].

Total sample size

Manual instrumentation removed larger amount of dentin at the coronal and middle third compared with rotary instrumentation ($P < 0.05$) at the same root thirds in all roots and dental groups, except to the apical third ($P > 0.05$)

Comparison between 2% taper and 4% taper rotary instrumentation revealed overall no statistically significant difference ($P > 0.05$) with respect to the amount of dentin removed.

Maxillary teeth

Manual instrumentation has removed a larger amount of dentin at the coronal third of mesiobuccal, distobuccal, and palatal roots of the maxillary molars compared with rotary instrumentation at the same root third ($P < 0.05$)

Comparison between 2% taper and 4% taper rotary instrumentations revealed overall no statistically significant difference ($P > 0.05$) with respect to the amount of dentin removed in all roots of maxillary molars, except the coronal and middle third of the distobuccal root ($P < 0.05$).

For standardization, the root canals of the mandibular first and second molars were combined with respect to the roots to which they belonged and were named as mesial and distal canals.

Mandibular teeth

Comparison between manual and rotary instrumentation did not show any statistically significant difference ($P > 0.05$) with respect to the amount of dentin removal in all the roots of mandibular molars, except the coronal third of the mesial root ($P < 0.05$)

Comparison between 2% taper and 4% taper rotary instrumentations revealed no statistically significant difference ($P > 0.05$) with respect to the amount of dentin removed in all the roots of mandibular molars, except the coronal third of the distal root of mandibular molars.

Root perforations

Results regarding root perforation comparing type of instrumentation, dental group, roots, and root thirds are

Table 1: Root canal areas (mm^2) before and after instrumentation and amount of dentin removed according to the type of instrumentation and root third in the maxillary and mandibular molars teeth (mean±standard deviation)

Evaluation of Radicular Dentin	Root thirds	Manual 2%	Rotary		P	
			2%	4%	Manual versus rotary	2% versus 4% rotary
Before instrumentation	CT	3.88±1.06	4.18±1.14	4.08±0.99	0.12	0.57
	MT	2.21±0.42	2.27±0.5	2.26±0.54	0.45	0.98
	AT	1.56±0.44	1.68±0.8	1.65±0.75	0.23	0.79
After instrumentation	CT	2.11±0.48**	3.21±1.5**	4.01±0.92**	<0.0001	<0.0001
	MT	1.72±0.52**	1.94±0.55**	2.12±0.87**	0.001	0.16
	AT	1.06±0.56**	1.37±0.86**	1.19±0.79**	0.03	0.23
Amount of dentin removed	CT	1.77±1.3	0.97±1.19	0.63±0.65	<0.0001	0.14
	MT	0.50±0.45	0.33±0.28	0.51±0.54	0.005	0.007
	AT	0.51±0.47	0.32±0.46	0.47±0.52	0.1	0.08

*There was statistically significant reduction in the dentin after instrument in all the three groups of study, i.e., manual, 2% taper rotary, 4% taper rotary. Statistically significant difference between before and after by paired t-test (*P<0.05, **P<0.01). CT: Coronal third, MT: Middle third, AT: Apical third

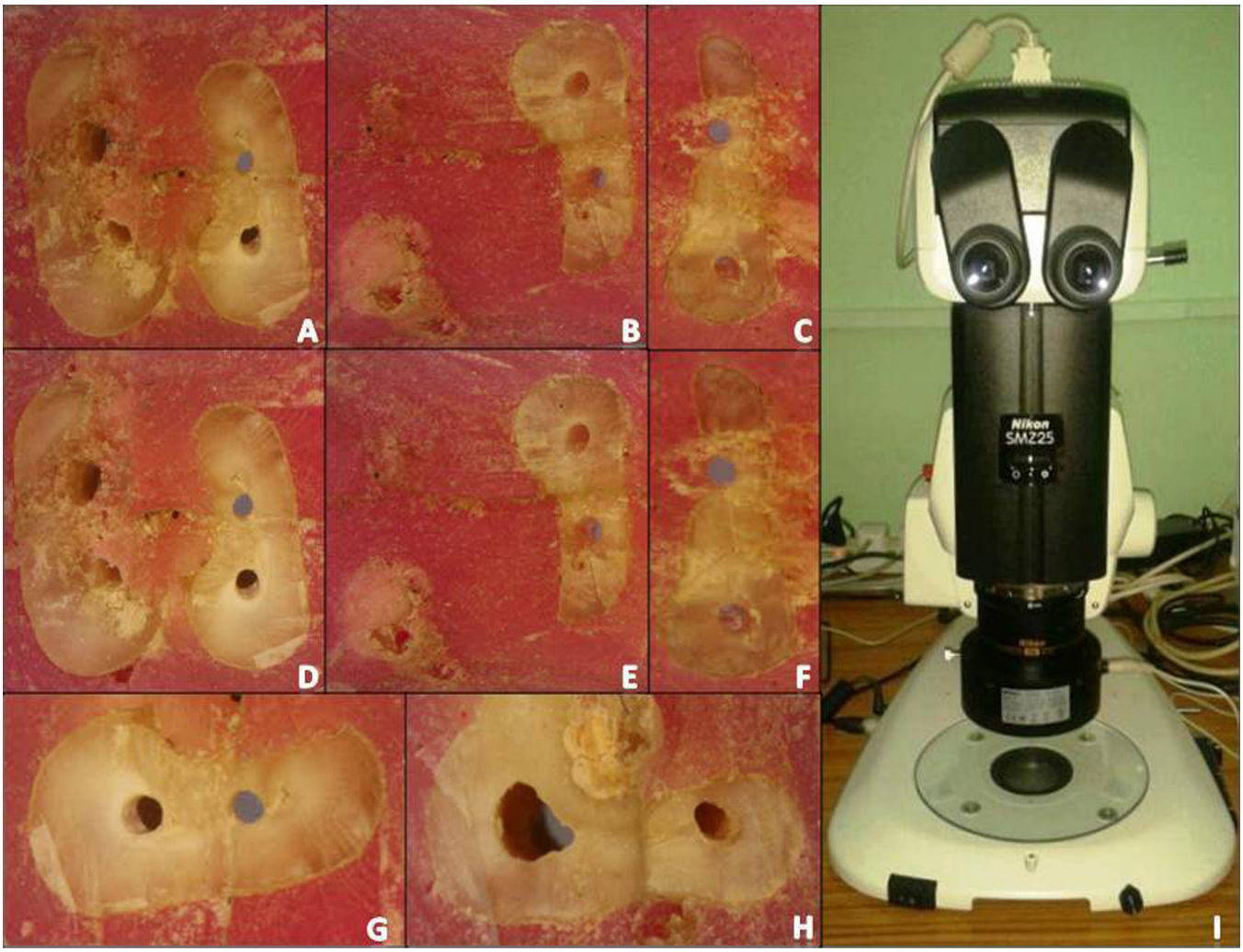

Figure 3 : (a-c) Preinstrumentation recorded images under stereomicroscope, (d-f) postinstrumentation recorded images under stereomicroscope, (g and h) comparison of shape of the canal upon using rotary and manual files, (i) stereomicroscope

summarized in [TABLE 4 and 5]. [TABLE 4] indicates no statistically significant differences between groups according to Chi-squared test ($P > 0.05$).

Canal shape

Qualitative visual analysis of images revealed achievement of more regular instrumentation with rotary technique [Figure 3g] whereas manual instrumentation usually provided more irregular shaping [Figure 3h].

DISCUSSION

Initially, root canal instruments were produced of carbon steel, stainless steel alloys, and now, the advancement is toward the use of NiTi files. These instruments have shown an enhanced flexibility and superior resistance to torsion fracture and reduced procedural errors.[6] Curvatures and irregularities of root canal walls of primary teeth have shown to be cleaned efficiently with NiTi instruments similar to the manual filing.[3] Among several methodologies developed to evaluate root canal shaping, Bramante *et al*.[4] method allows a comparison of the root canal before and after instrumentation and also provides a three-dimensional view of the preparation throughout the root canal length. In our study, we have followed a simplified Bramante muffle system.

It is generally recommended to maintain the original anatomic shape of the root canal to preserve maximum dentin thickness. Meanwhile, it is also considered to effectively enlarge the root canal, with the objective to remove its organic and inorganic contents.[7,8] However, primary teeth discourage gross enlargements of the canals due to its ribbon-shaped morphology with a narrow mesiodistal width as compared to their buccolingual dimensions. Based on the recommendations,[9,10] instrumentation till size 30 has considered to be safe in providing successful results. Therefore, in the present study, apical diameter prepared up to size 30 in both manual and rotary groups.

Table 2: Root canal areas (mm2) before and after instrumentation and amount of dentin removed according to the type of instrumentation and root third in the maxillary molars (mean±standard deviation)

Maxillary molars	Root third	Manual 2%	Rotary		P	
			2%	4%	Manual versus rotary	2% versus 4% rotary
Mesiobuccal canal						
Before instrumentation	CT	4.32±0.69	5.14±1.1	4.73±0.94	0.10	0.37
	MT	2.71±0.13	2.62±0.12	2.98±0.65	0.06	0.09
	AT	1.93±0.2	2.51±0.9	2.33±0.9	0.1	0.67
After instrumentation	CT	2.38±0.16**	4.92±1.13**	4.44±0.96**	<0.0001	0.31
	MT	1.92±0.83*	2.30±0.14**	3.05±1.19	0.03	0.08
	AT	1.48±0.21**	2.31±0.92**	1.64±1.17*	0.16	0.17
Amount of dentin removed	CT	1.94±0.53	0.22±0.08	0.29±0.09	<0.0001	0.08
	MT	0.76±0.84	0.31±0.16	1.02±1.03	0.34	0.05
	AT	0.45±0.13	0.19±0.07	0.69±0.9	0.97	0.12
Distobuccal canal						
Before instrumentation	CT	3.67±0.55	4.08±0.91	4.48±0.98	0.073	0.36
	MT	2.18±0.23	2.37±0.19	2.35±0.31	0.07	0.86
	AT	1.73±0.07	1.97±0.32	2.06±0.84	0.06	0.75
After instrumentation	CT	1.81±0.18**	3.88±0.86**	4.17±0.97**	<0.0001	0.48
	MT	1.57±0.66**	2.09±0.19**	2.92±0.67**	0.002	0.004
	AT	1.10±0.6**	1.63±0.66	1.58±0.94*	0.07	0.91
Amount of dentin removed	CT	1.86±0.55	0.20±0.06	0.31±0.07	<0.0001	0.002
	MT	0.61±0.58	0.28±0.08	0.72±0.36	0.51	0.002
	AT	0.63±0.57	0.34±0.59	0.48±0.54	0.33	0.6
Palatal canal						
Before instrumentation	CT	2.75±0.24	3.66±1.26	3.10±0.57	0.06	0.23
	MT	2.53±0.16	2.41±0.27	2.55±0.23	0.49	0.2
	AT	2.13±0.27	1.62±0.9	1.92±0.45	0.06	0.36
After instrumentation	CT	2.15±01.9**	3.45±1.21**	2.82±0.58**	<0.0001	0.16
	MT	1.90±0.2**	2.06±0.47*	2.25±0.28**	0.03	0.3
	AT	1.28±0.84**	1.13±1.0	1.56±0.4**	0.85	0.23
Amount of dentin removed	CT	0.61±0.31	0.21±0.08	0.28±0.12	<0.0001	0.13
	MT	0.63±0.25	0.34±0.38	0.31±0.12	0.007	0.77
	AT	0.86±0.76	0.49±0.78	0.35±0.11	0.13	0.59

Statistically significant difference between before and after by paired *t*-test (*P<0.05, **P<0.01). CT: Coronal third, MT: Middle third, AT: Apical third

In our study, manual root canal instrumentation was done using H-files. The advantages of using these files as reported are more positive rake angle and a blade with cutting rather than scraping angle. Furthermore, it has a unique cutting fashion that allows cutting only during pulling stroke which prevents pushing infected material through the apices.[11-15]

Barr *et al.*[2] advocated that instrumentation in primary teeth using rotary files is faster than hand files. It is not necessary to use a crown-down technique in primary teeth since the dentin cuts more easily in primary teeth than in permanent teeth. Meanwhile, care must be taken not to over instrument as perforations can easily occur in the thin dentinal walls. The manufacturer of I-Race rotary files has suggested two step-back and one crown-down operator sequence.[16] The step-back technique starts with coronal flaring using 6% taper size 30 file. (After coronal flaring) Subsequently, instrumentation for 2% taper files from size 25 to 40 and for 4% taper files from size 25 to 35 is recommended(by the manufacturer). Baumann[17] recommended instrumentation using Race rotary files at speed between 300 rpm and 600 rpm, with light apical pressure in a "pumping-pecking" motion. The protocol of instrumentation for the present study was followed as recommended by the manufacturer with I-Race rotary file of 2% and 4% taper up to size 30 in a step-back technique with pumping pecking motion.

According to the results, manual files have generated more dentin removal at coronal and middle third of all roots and groups compared with rotary files (combination of 2% and 4% taper files), except to apical third which did not show statistically significant difference. This agrees the results of the previous study.[1] The comparison of 2% taper with 4% taper I-Race rotary instrumentation

Table 3: Root canal areas (mm2) before and after instrumentation and amount of dentin removed according to the type of instrumentation and root third in the mandibular first and second molars (mean±standard deviation)

Mandibular molars	Root third	Manual 2%	Rotary		P	
			2%	4%	Manual versus rotary	2% versus 4% rotary
Mesial root						
Before instrumentation	CT	4.35±1.07	3.92±1.09	4.37±1.17	0.5	0.22
	MT	1.92±0.37	2.19±0.72	2.10±0.38	0.068	0.661
	AT	1.31±0.24	1.33±0.74	1.29±0.63	0.99	0.841
After instrumentation	CT	2.07±0.64**	2.87±1.62**	4.28±0.77*	<0.0001	0.002
	MT	1.65±0.37**	1.82±0.76**	1.72±0.55**	0.366	0.64
	AT	0.89±0.41**	1.05±0.69**	0.84±0.64**	0.695	0.344
Amount of dentin removed	CT	2.28±1.37	1.49±1.39	1.34±0.76	0.01	0.66
	MT	0.29±0.14	0.37±0.43	0.39±0.38	0.26	0.884
	AT	0.43±0.42	0.29±0.41	0.45±0.55	0.637	0.286
Distal root						
Before instrumentation	CT	3.45±1.32	3.75±0.82	4.22±0.64	0.08	0.075
	MT	2.08±0.42	2.0±0.44	1.79±0.26	0.12	0.10
	AT	1.19±0.37	1.47±0.57	1.24±0.29	0.18	0.17
After instrumentation	CT	2.16±0.58**	1.99±0.56**	4.07±0.63**	0.001	<0.0001
	MT	1.65±0.45**	1.71±0.46**	1.46±0.27**	0.636	0.08
	AT	0.83±0.45**	1.16±0.59**	0.87±0.40**	0.203	0.12
Amount of dentin removed	CT	1.29±1.45	1.75±1.25	0.38±0.38	0.56	0.002
	MT	0.44±0.26	0.30±0.08	0.33±0.26	0.06	0.68
	AT	0.36±0.26	0.30±0.32	0.42±0.27	0.99	0.28

Statistically significant difference between before and after by paired t-test (*P<0.05, **P<0.01). CT: Coronal third, MT: Middle third, AT: Apical third

Table 4: Number and percentage of perforations according to the type of instrumentation, group of teeth, and root

Type of Instrumentation	Maxillary molars (%)						Mandibular molars (%)				Total
	Mesiobuccal canal		Distobuccal canal		Palatal canal		Mesial root		Distal root		
	WP	WoP	WP	WoP	WP	WoP	WP	WoP	WP	WoP	
Manual	-	10 (100)	2 (20)	8 (80)	-	10 (100)	2 (10)	20 (80)	1 (7.7)	12 (92.3)	65
Rotary											
2% taper	-	10 (100)	1 (10)	9 (90)	1 (10)	9 (90)	1 (5)	20 (90)	-	12 (100)	63
4% taper	2 (20)	8 (80)	1 (10)	9 (90)	-	10 (100)	3 (15)	20 (70)	-	12 (100)	65
Total	2	28	4	26	1	29	6	60	1	36	193
*P**	0.1		0.58		1.00		1.00		1.00		

*No significant differences between groups according to Chi-squared test (P>0.05). WP: With perforation; WoP: Without perforation

revealed overall no statistically significant difference with respect to the amount of dentin removed in all roots and dental group. According to the previous studies, 4% taper rotary instrumentation is found to be efficient without undue aggressiveness in primary teeth and resulted in a smooth funnel-form preparation desired for ideal compaction of the pulpectomy paste.[2,18] Based on our study, it can be stated that 2% and 4% taper I-Race rotary instrumentations are safe for canal preparation with regard to the amount of dentin removal.

The present study used the actual tooth length as the working length to observe the action of endodontic instruments in the presence of cementum and dentin resorption and evaluated the possibility of instrumentation at these segments. The results revealed that root perforations coincided with areas showing largest resorption, primarily affecting middle thirds and apical thirds of the root canals of the maxillary and mandibular molars. It is because the dentinal walls in these areas were thin, creating zones susceptible to perforation, which should be taken into account during treatment planning. Instrumentation using 4% rotary files revealed maximum number of perforations compared to the manual as well as 2% taper rotary files. Five perforations were in the apical third and one was in the middle third coincided

Table 5: Number of root perforations for the different groups of teeth, roots, and thirds

Type of Instrumentation	Maxillary first molars									Mandibular molars											
										Mandibular first molars						Mandibular second molars					
	Mesiobuccal canal			Distobuccal canal			Palatal canal			Mesiobuccal canal			Mesiolingual can0l			Mesiolingual canal			Distobuccal canal		
	CT	MT	AT	CT	MT	AT	CT	MT	AT	CT	MT	AT	CT	MT	AT	CT	MT	AT	CT	MT	AT
Manual	-	-	-	-	-	2	-	-	-	-	-	1	-	-	-	-	-	1	-	-	1
Rotary																					
2% taper	-	-	-	-	-	1	-	-	1	-	-	-	-	-	-	-	-	1	-	-	-
4% taper	-	-	2	-	-	1	-	-	-	-	-	-	-	-	1	-	1	1	-	-	-

CT: Coronal third. MT: Middle third. AT: Apical third

with the areas showing largest resorption. 2% taper rotary instrumentation has shown the least number of perforations compared to manual and 4% taper rotary instrumentation accounted as only 3 perforations. All of them were found in the susceptible zone, i.e., the apical third.

The qualitative and visual analysis of the images in the present study revealed the achievement of more regular shape of the root canal of the primary molars after instrumentation with both 2% and 4% taper I-Race rotary files whereas manual instrumentation with H-files usually provided more irregular shaping. This is in agreement with the previous study done using rotary files Hero 642 and K-files for manual instrumentation.[1]

Limitations

The asymmetric root length of multirooted teeth did not allow the standardization of sections for evaluation of specimens. The root length in the apical third of some specimens was reduced due to resorption, leading to experimental errors.

The present study has shown no significant occurrence of root perforation upon using manual and rotary files. However, the anatomic features of primary teeth, particularly the ribbon-shaped canals with thin dentinal wall especially in the apical third, have a risk of root perforations with the use of 4% taper rotary instruments which further need evaluation and confirmation. Among all the groups of instrumentation, 2% taper rotary files revealed a safer and more conservative approach for the root canals of the primary teeth. The findings of the present study add on the development of safer and more conservative and faster protocols for the treatment of primary teeth with compromised pulp tissue.

CONCLUSION

In primary teeth without significant root resorption, the use of NiTi-rotary files with 2% and 4% taper up to size 30 revealed to be safe and had prepared the root canals with greater conservation of tooth structure than manual instrumentation. However, 4% taper instruments can provide more funnel-shaped canal desired for ideal compaction of obturating material.

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Conflicts of interest

There are no conflicts of interest.

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