RESEARCH ARTICLE

Effect of Different Preparation Techniques on Root Canal Geometry: An *In Vitro* Study

Pooja Bheda[1], Adesh Kakade[2], Vilas Takate[3], Akansha Juneja[4], Kishor Dighe[5], Bharat Gupta[6]

Abstract

Aim and objective: To compare and evaluate canal preparation using hand stainless steel files, hand ProTaper files, and rotary ProTaper files for change in root canal geometry in terms of surface area and volume changes assessed by computed tomography.

Materials and methods: The present study was conducted in Nair Hospital and Dental College, Department of Pediatric and Preventive Dentistry in collaboration with insight CBCT, imaging technologies. A total of 36 extracted human primary mandibular second molars were collected from the Department of Pediatric and Preventive Dentistry. All the teeth were scanned using cone-beam CT (i-CAT CT Scanner Next Generation, Imaging Sciences International) preoperatively and postoperatively to assess the mean absolute change in surface area and mean change in the volume of all the canals at different levels with the use of hand stainless steel files, hand ProTaper and rotary ProTaper files.

Results: ProTaper instruments, both hand ProTaper and rotary ProTaper caused significant changes in the surface area in the coronal thirds and middle thirds of the canal when compared to hand stainless steel files. No difference was found in surface area and volume changes between hand ProTaper and rotary ProTaper instrumentation.

Conclusion: Use of ProTaper instruments for preparation of deciduous teeth can render benefit of an improved canal preparation to facilitate better obturation and successful root canal therapy.

Keywords: CBCT, Hand ProTaper files, Rotary ProTaper files, Surface area and volume of primary canals.

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Introduction

Endodontic instrumentation serves two purposes: it removes all pulp tissue, microorganisms, and necrotic tissue from the canal, and it shapes the canal sufficiently to promote placement of obturating materials that seal the canal and inhibits bacterial marginal leakage. All dentinal surfaces should be clean, and the root canal should have a continuous tapered shape that enhances obturation. It is also a good idea to make a final apical cross section within its limits.

The preparation of root canals has conventionally been done with hand instruments. Nickel–Titanium (Ni–Ti) hand files and rotary instruments have become popular in endodontics since Walia et al.[1] introduced them due to their supremacy in handling curved canals. Prof Pierre Mactou,[2] Dr Cillford Ruddle,[3] and Prof John West[4] developed the ProTaper system (Dentsply), which represents a generation of Ni–Ti instruments. The new ProTaper files have a taper that gradually increases in size, a convex triangular cross-section, and a redesigned leading tip. The use of rotary Ni–Ti instruments for biomechanical preparation in the primary root canal system is still being studied. There have only been a few in vitro studies evaluating their effectiveness in cleaning and shaping the canals in primary teeth.

Scanning electron microscopy,[5] radiographic evaluation,[6] photographic assessment[7] and computer manipulation[8] for comparative evaluation were previously used methods for assessing canal instrumentation. These techniques, however, are intrusive, and precise repositioning of pre- and post-instrumented specimens is difficult.[9] They are also time consuming, and there is a risk of specimen loss. CT, a nondestructive imaging technology capable of producing extremely accurate and measurable cross-sectional and 3D images, has recently been recommended for pre- and post-instrumentation canal analysis.[10]

There is only a small amount of research on using CT to analyze canal preparation in primary dentition. The primary goal of this trial was to compare and evaluate hand stainless steel files, hand ProTaper files, and rotary ProTaper files for variations in root canal geometry as measured by CT in terms of volume and surface area changes. The null hypothesis stated that no significant differences in volume and surface area of canal preparation would exist between hand steel files, hand Protapers, and rotary Protapers.

[1]Department of Paediatric Dentistry, NMC Royal Medical Centre, Karama, Abu Dhabi

[2]Department of Pediatric Dentistry, Nair Hospital Dental College, Mumbai, Maharashtra, India

[3,5]Department of Pediatric Dentistry, Government Dental College and Hospital, Mumbai, Maharashtra, India

[4]Department of Pediatric Dentistry, Jamia Millia Islamia (a Central University), New Delhi, India

[6]Department of Periodontolgy, MGM Dental College and Hospital, Mumbai, Maharashtra, India

Corresponding Author: Vilas Takate, Department of Pediatric Dentistry, Government Dental College and Hospital, Mumbai, Maharashtra, India, Phone +91 7588096747, e-mail: vilastakate@gmail.com

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Materials and Methods

The present trial was conducted in Department of Pediatric and Preventive Dentistry, Nair Hospital and Dental College, in collaboration with Insight CBCT, Imaging Technologies. The department collected 36 extracted human primary mandibular second molars, that were used in the present trial. The present study received ethical approval from the institution's ethics committee. The inclusion criteria were–primary mandibular second molars extracted due to orthodontic purposes in children of age 8–12 years, primary mandibular second molars with four negotiable canals—mesiobuccal, mesiolingual, distobuccal, and distolingual, intact furcation–clinically and radiographically, absence of external or internal surface root resorption, teeth with minimum 8 mm of root length, absence of any root fracture seen clinically or radiographically, and absence of any developmental anomaly. The exclusion criteria were primary mandibular second molars with clinical or radiographic furcation involvement, excessive external or internal surface root resorption, teeth with less than 8 mm of root length, presence of any root fracture seen clinically or radiographically, and presence of any developmental anomaly.

Scanning of Samples before Root Canal Preparation

Before the procedure, all the teeth were scanned using cone-beam CT (i-CAT CT Scanner Next Generation, Imaging Sciences International). The CT scans were performed at 120 KV and 37.07 mA, with a 0.25 mm voxel size and an 8 X 8 cm display field of view. The specimens were fixed using beam incidence at the device's central portion. Each scan took 27 seconds to complete. Depending on the length of the root canal, 8–11 stages were chosen for CT assessment. Sectioning was performed at the coronal orifice of the canals up to the apex at every 1 mm.

Surface Area Measurements

The surface area measurements were made at every 1 mm starting from the coronal orifice up to the apex for all four canals using Anatomage *In Vivo* 5.1 software. Three readings were obtained at each level. The mean of these three measurements were considered as the surface area of that level to avoid bias.

Volume Measurements

Volume measurement was done for every canal using method given by Mayo et al.[11] From the coronal orifice to the apex, each canal's root canal system was divided into 1 mm sections. The height was multiplied by the mean of the apical and coronal area for each section (1 mm). The total canal volume was calculated by adding the volumes of all the 1 mm sections of each canal.[11] The images were saved on the computer's hard drive to allow for a more detailed comparison of pre- and post-instrumentation information.

Instrumentation

Thirty-six primary mandibular second molars with four negotiable canals (mesiobuccal, mesiolingual, distobuccal, and distolingual canals) were randomly divided into three groups of 12 each.

- Group A: Prepared with hand stainless steel files (Kerr-files).
- Group B: Prepared with ProTaper (Ni–Ti) hand files.
- Group C: Prepared with ProTaper rotary files.

Group A

Stainless Steel K-files (Mani Inc, Japan) from size 10 till 35, 21 mm length were used for the instrumentation of the canals performing a conventional technique. Instruments were coated with EDTA (Glyde File Prep, Dentsply Maillefer) prior to use in the canals for lubrication. Instrumentation was performed to the working length in each canal. Recaptiluation was done after use of each file. One set of file was used to instrument only three teeth before being replaced or if they showed any obvious deformation whichever being first. Five percent NaOCl was used to irrigate the canals after each instrumentation

Group B

Root canals were prepared with hand operated ProTaper files of 21 mm designed for use with the balanced force technique. Before starting with preparation with ProTaper files, each canal was enlarged to size #15 stainless steel K-file and patency of the canal was established. For instrumentation with hand ProTaper, files were rotated counter clockwise, about one-quarter to half a turn to engage the blades into the canal wall. Enough apical pressure was applied to prevent the instruments from ˝backing out˝ from the canal while rotating it clockwise for one complete turn. Files were rotated clockwise gently by about 45 degrees to load debris onto the flutes and retrieve; canals were irrigated with 5 % NaOCl. Instruments were coated with EDTA (Glyde File Prep, Dentsply Maillefer) prior to use in the canals for lubrication. One set of files was used to instrument only three canals before being replaced or if they showed any obvious deformation whichever being first.

Group C

The crown down technique was used to prepare root canals with rotary ProTaper files of 21 mm and an Endo-motor (Axis Endo 08, 50:1, MicroMega). Each canal was enlarged to size # 15 stainless steel K-file and canal patency was established before beginning rotary preparations. The S1 shaping file was used first, and it was apically moved 2 mm from the working length. Following that, Sx files were used sequential manner until resistance was experienced (4–5 mm from the working length), at which point S1, S2, F1, and F2 files were used to the working length. There was no active pressure used. The instruments were cleaned with a wet sponge after being irrigated with 5% NaOCl. Instruments were coated with EDTA (Glyde File Prep, Dentsply Maillefer) prior to use in the canals for lubrication. One set of files was used to instrument only three canals before being replaced or if they showed any obvious deformation whichever being first.

Post-preparation Scanning

The teeth were repositioned in the same orientation as the first scan after root canal preparation. Postoperative scans were obtained. Surface area and volume measurements were made in a manner similar to preoperative manner. The surface area measurements were made at the same levels at which preoperative readings were made for each canal.

Evaluation of Surface Area

For evaluating and comparing the surface area, measurements were compared at 3 levels:

- Coronal third: The surface area measurements at the coronal orifice were considered for measurement of coronal third of the canals.
- Middle third: Surface area measurement at 5 mm was considered for measurement of middle thirds of the canals.
- Apical third: The surface area measurements at the apex were considered for measurements at the apical third.

The increase in surface area was calculated by subtracting the mean preoperative surface area from the mean postoperative surface area and this was marked as absolute change in surface area. This absolute change in surface area was calculated at three levels—cervical third, middle third, and apical third for all the four canals of all the 36 teeth.

Evaluation of Volume

For each of the 36 teeth's four canals, the volume increase was calculated by subtracting the mean preoperative volume from the mean postoperative volume. This was the absolute change in the volume.

Statistical Analysis

The results obtained were tabulated and following statistical tests were applied–mean, standard deviation, ANOVA test, and Tukey test. SPSS version 16.0 statistical analysis software was used to analyze the data.

Results

The mean absolute change in surface area of all the canals, at different levels is depicted in Tables 1 to 7 and Figures 1 to 12. The mean change in volume of all canals, at different levels is depicted in Tables 8 to 16 and Figures 13 to 16.

Discussion

Pulpectomy procedures in primary teeth can be classified as a complex procedure due to the effort involved in effectively cleaning and shaping the root canals in order to facilitate removal of necrotic and infected pulp tissue and necrotic dentin containing microorganisms. Traditionally, hand instruments have been used for this procedure. Ni-Ti rotary instruments have been used in the primary teeth with greater efficiency and excellent success. The goal of this trial was to compare the effectiveness of rotary *vs* hand instrumentation in cleaning and shaping the root canals of primary mandibular second molars.

The current study used extracted human primary mandibular second molars. Only primary mandibular second molars with four negotiable canals were selected for this study as it reduced variability in the root anatomy, curvature, and angulation as well as canal morphology. Primary teeth are both physiologically and pathologically resorbable and therefore for standardization, only primary mandibular second molars with minimum root length of 8 mm were selected for the study. In the present study, the hand stainless steel file group (Group A), instrumentation was performed up to size 35 and recaptiuated till size 30 in all canals. Group B and Group C were prepared with hand ProTaper and rotary ProTaper files ,respectively using the crown down technique. The crown down concept is to step apically by using a sequence of files while lowering instrument size or taper.

Tachibana and Matsumoto[11] investigated the use of Computerized Tomography in endodontics. They came to the conclusion that this method allowed them to observe the morphology of the root canals, roots, and the appearance of the tooth from every angle. The computer could analyze, alter, and reconstruct the images. It has been reported that using CT to assess the quality of root canal preparation leads to better outcomes than other methods such as radiographic imaging, cross-sectioning, and longitudinal cleavage. By changing the viewing parameters, it was possible to display images with more or less tooth density and detail in the CT imaging system. Once the images have been

Table 1: Mean surface area (mm^2) and standard deviation of mesiobuccal canal

	Before instrumentation						*After instrumentation*						*Absolute change*					
	Coronal third		*Middle third*		*Apical third*		*Coronal third*		*Middle third*		*Apical third*		*Coronal third*		*Middle third*		*Apical third*	
n = 12	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Group A	0.523	0.080	0.346	0.051	0.090	0.013	1.030	0.146	0.505	0.074	0.187	0.043	0.507	0.068	0.160	0.023	0.097	0.027
Group B	0.493	0.158	0.317	0.092	0.097	0.046	1.293	0.254	0.597	0.161	0.202	0.095	0.800	0.134	0.280	0.069	0.105	0.052
Group C	0.505	0.142	0.316	0.073	0.103	0.009	1.348	0.296	0.594	0.131	0.210	0.025	0.843	0.169	0.278	0.058	0.107	0.017
					ANOVA test applied						F		3.655		19.532		1.025	
											p		0.037 (S)		0.00 (S)		0.081 (NS)	

$p < 0.05$ = Significant (S = significant; NS = nonsignificant)

Table 2A: Intergroup statistical significance of surface area at coronal third (mesiobuccal canal)

All pairwise multiple comparison procedures (Tukey test)		
Comparison	p < 0.05	Only this group difference is significant
Group A vs Group B	Yes	
Group A vs Group C	Yes	

Table 2B: Intergroup statistical significance of surface area at middle third (mesiobuccal canal)

All pairwise multiple comparison procedures (Tukey test)		
Comparison	p < 0.050	Only this group difference is significant
Group A vs Group B	Yes	
Group A vs Group C	Yes	

Table 3: Mean surface areas (mm^2) and standard deviation of mesiolingual canal

	Before instrumentation						*After instrumentation*						*Absolute change*					
	Coronal third		*Middle third*		*Apical third*		*Coronal third*		*Middle third*		*Apical third*		*Coronal third*		*Middle third*		*Apical third*	
n = 12	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Group A	0.481	0.086	0.344	0.048	0.098	0.014	0.985	0.148	0.502	0.070	0.193	0.025	0.504	0.068	0.158	0.022	0.095	0.012
Group B	0.488	0.162	0.319	0.078	0.096	0.045	1.409	0.219	0.600	0.146	0.204	0.098	0.922	0.117	0.280	0.071	0.108	0.055
Group C	0.505	0.159	0.322	0.081	0.118	0.050	1.319	0.373	0.600	0.141	0.236	0.052	0.814	0.134	0.278	0.071	0.118	0.049
				ANOVA test applied							**F**		4.18		16.859		1.005	
											p		0.0105 (S)		0.00 (S)		0.16 (NS)	

$p < 0.05$ = Significant (S= significant; NS= nonsignificant)

Table 4A: Inter-group statistical significance of surface area at coronal third (Mesiolingual canal)

All pairwise multiple comparison procedures (Tukey test)		
Comparison	p < 0.05	Only this group difference is significant
Group A vs Group B	Yes	
Group A vs Group C	Yes	

Table 4B: Inter-group statistical significance of surface area at middle third (Mesiolingual canal)

All pairwise multiple comparison procedures (Tukey test)		
Comparison	p < 0.05	Only this group difference is significant
Group A vs Group B	Yes	
Group A vs Group C	Yes	

Table 5: Mean surface areas (mm^2) and standard deviation of distobuccal canal

	Before instrumentation						*After instrumentation*						*Absolute change*					
	Coronal third		*Middle third*		*Apical third*		*Coronal third*		*Middle third*		*Apical third*		*Coronal third*		*Middle third*		*Apical third*	
n = 12	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
Group A	0.804	0.093	0.510	0.059	0.100	0.047	1.546	0.157	0.743	0.086	0.196	0.098	0.742	0.067	0.233	0.027	0.096	0.051
Group B	0.806	0.156	0.481	0.099	0.090	0.040	1.852	0.395	0.908	0.168	0.199	0.085	1.046	0.248	0.427	0.075	0.109	0.046
Group C	0.796	0.148	0.490	0.078	0.099	0.005	1.883	0.325	0.907	0.133	0.212	0.006	1.087	0.182	0.418	0.056	0.113	0.001
				ANOVA test applied								**F**	12.896		44.853		0.572	
												p	0.00(S)		0.00 (S)		0.567 (NS)	

$p < 0.05$ = Significant (S= significant; NS= nonsignificant)

Table 6A: Inter-group statistical significance of surface area at coronal third (Distolingual canal)

All pairwise multiple comparison procedures (Tukey test)		
Comparison	p < 0.05	
Group A vs Group B	Yes	Only this group difference is significant
Group A vs Group C	Yes	

Table 6B: Inter-group statistical significance of surface area at middle third (Distolingual canal)

All pairwise multiple comparison procedures (Tukey test)		
Comparison	p < 0.05	
Group A vs Group B	Yes	Only this group difference is significant
Group A vs Group C	Yes	

Table 7: Mean surface areas (mm^2) and standard deviation of distolingual canal

	Before instrumentation						*After instrumentation*						*Absolute change*					
n = 12	*Coronal third*		*Middle third*		*Apical third*		*Coronal third*		*Middle third*		*Apical third*		*Coronal third*		*Middle third*		*Apical third*	
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
Group A	0.401	0.089	0.253	0.058	0.051	0.033	0.837	0.152	0.402	0.084	0.114	0.060	0.436	0.065	0.149	0.026	0.063	0.027
Group B	0.402	0.146	0.254	0.087	0.053	0.012	1.175	0.276	0.478	0.167	0.132	0.027	0.773	0.117	0.224	0.080	0.079	0.015
Group C	0.409	0.106	0.264	0.066	0.050	0.003	1.201	0.174	0.482	0.117	0.127	0.003	0.791	0.092	0.218	0.051	0.077	0.001
				ANOVA test applied							**F**		4.313		6.344		0.8711	
											p		0.0115(S)		0.005(S)		0.35(NS)	

$p < 0.05$ = Significant (S= significant, NS= nonsignificant)

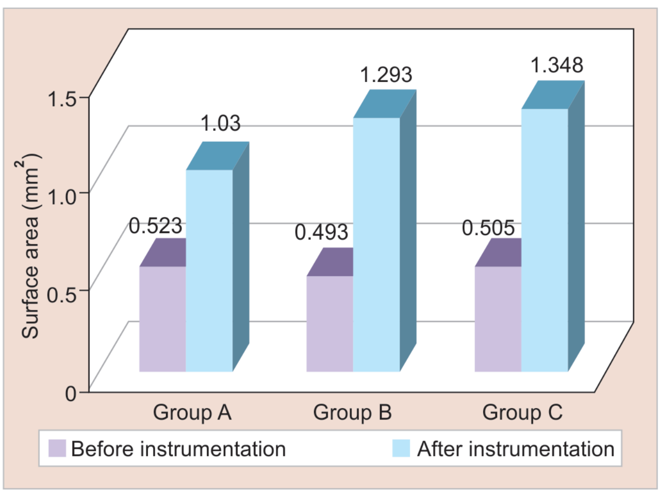

Fig. 1: Change in surface area at coronal third of mesiobuccal canal

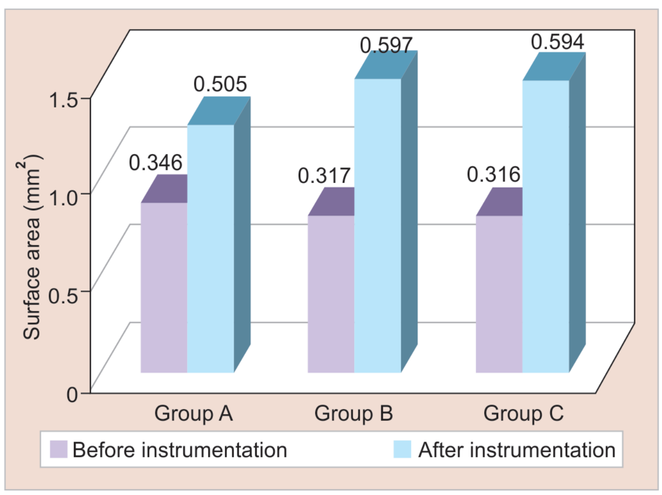

Fig. 2: Change in surface area at middle third of mesiobuccal canal

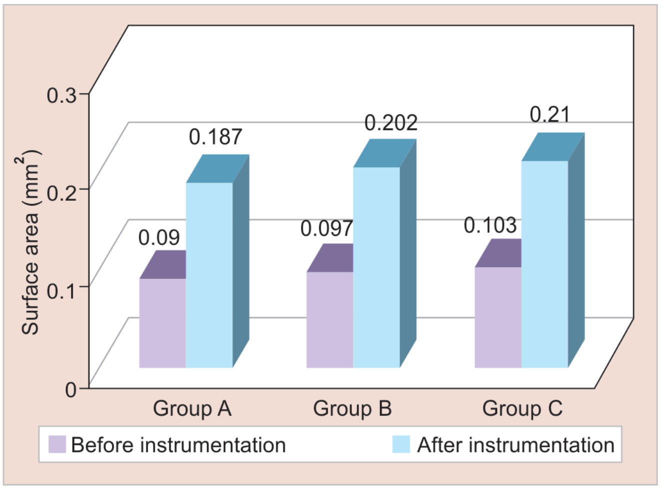

Fig. 3: Change in surface area at apical third of mesiobuccal canal

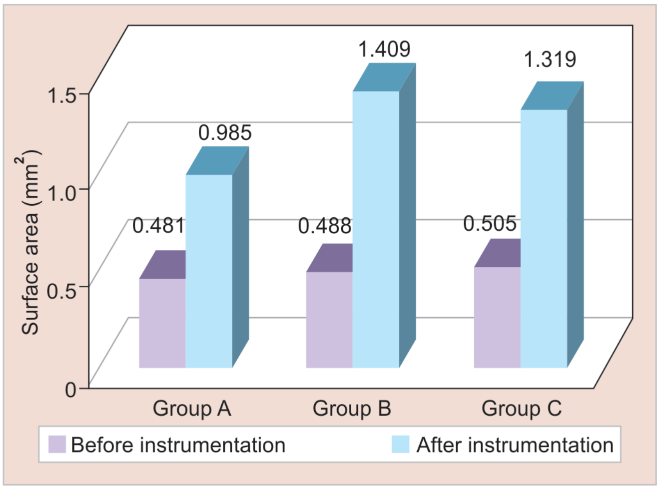

Fig. 4: Change in surface area at coronal third of mesiolingual canal

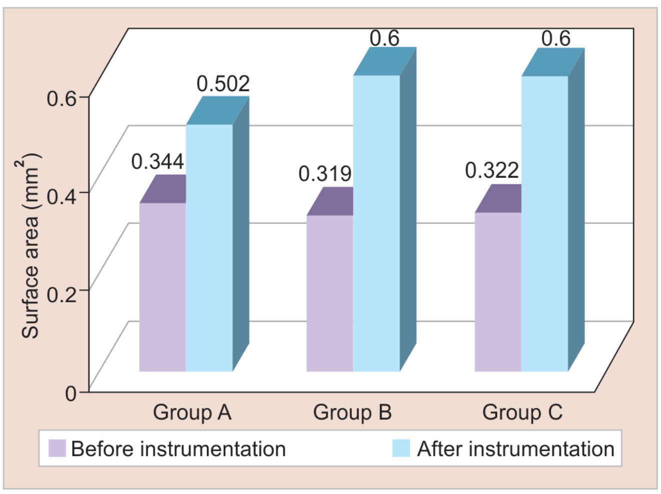

Fig. 5: Change in surface area at middle third of mesiolingual canal

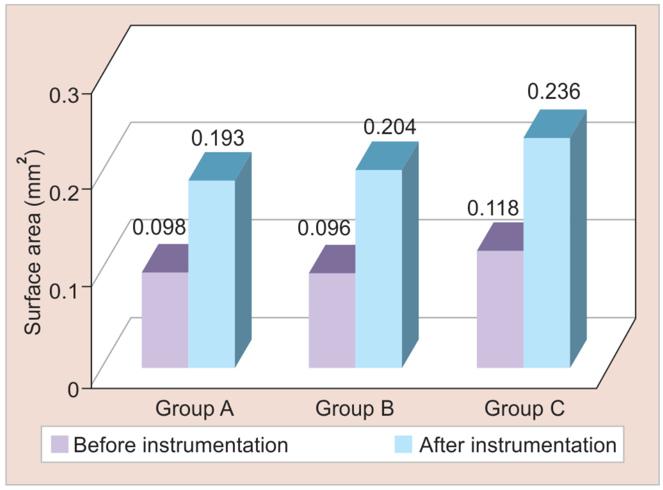

Fig. 6: Change in surface area at apical third of mesiolingual canal

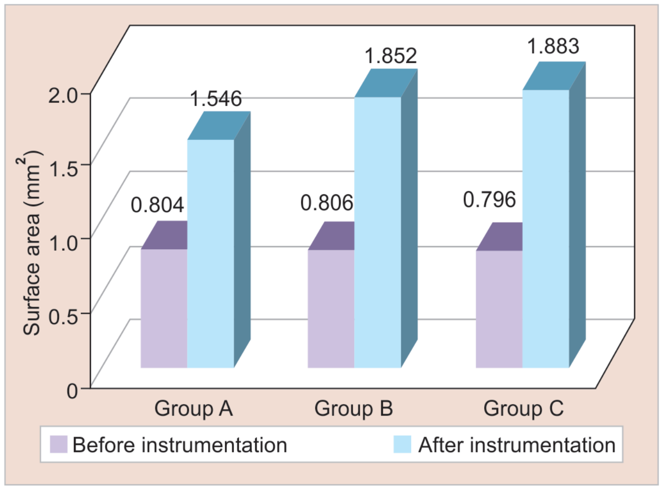

Fig. 7: Change in surface area at coronal third of distobuccal canal

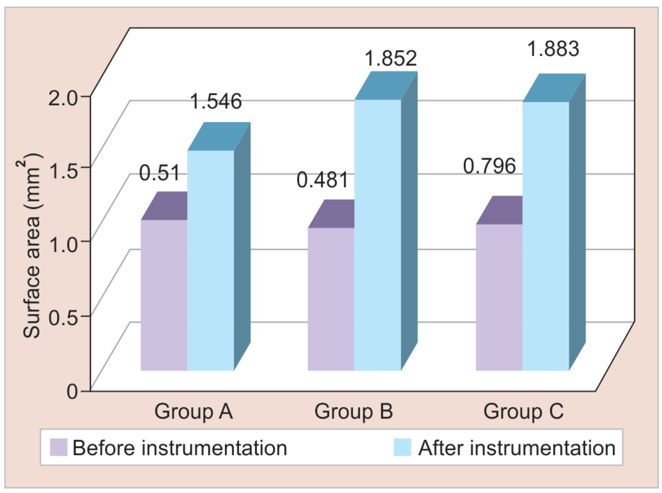

Fig. 8: Change in surface area at middle third of distobuccal canal

digitalized, they can be manipulated and viewed in an infinite number of ways. CT scans can provide a noninvasive vision of the canal systems of teeth. The 1 mm thick CT slices used in this study provided a practical and nondestructive method for assessing canal morphology before and after shaping. The surface area parameter was investigated in the present study at 1 mm intervals from the canal's coronal orifice to the apex.[12]

In present trial, statistically significant difference was observed in the coronal third when Group A (hand K files) was compared with Group B (hand ProTaper files) as well as Group C (rotary ProTaper

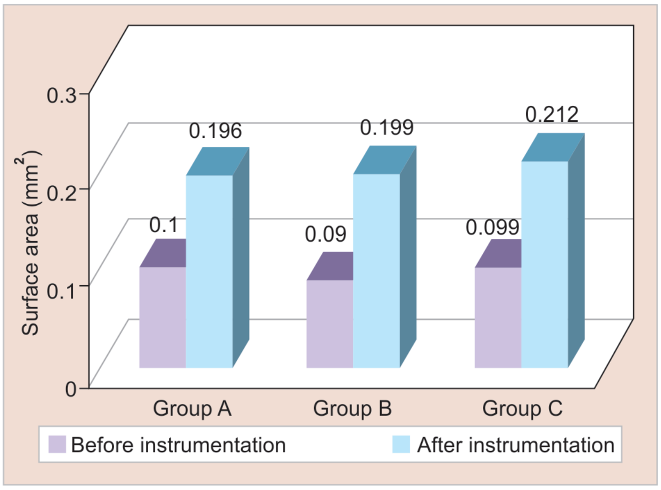

Fig. 9: Change in surface area at apical third of distobuccal canal

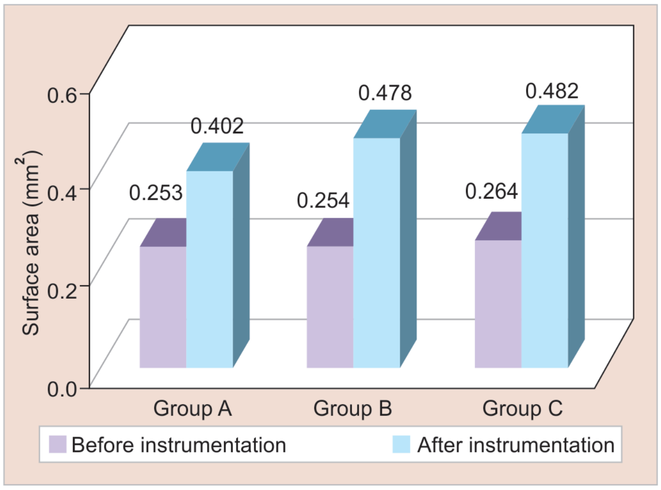

Fig. 11: Change in surface area at middle third of distolingual canal

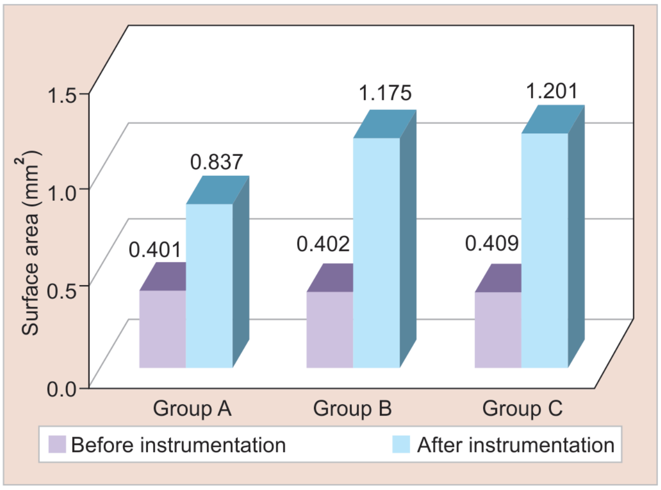

Fig. 10: Change in surface area at coronal third of distolingual canal

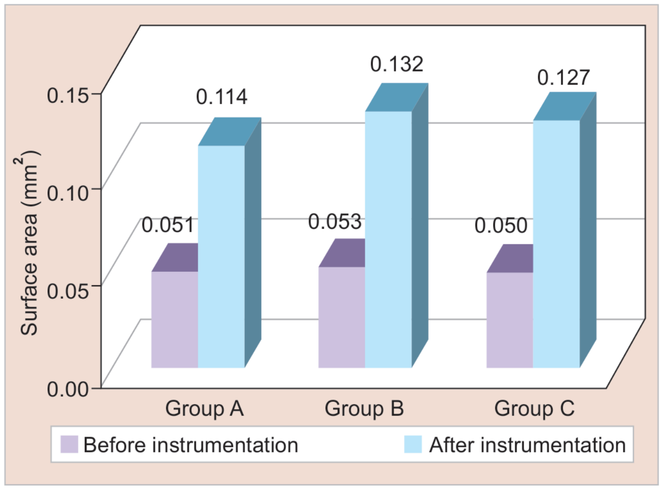

Fig. 12: Change in surface area at apical third of distolingual canal

Table 8A: Intergroup statistical significance of surface area at middle third (Distobuccal canal)

All pairwise multiple comparison procedures (Tukey test)		
Comparison	p < 0.05	Only this group difference is significant
Group A vs Group B	Yes	
Group A vs Group C	Yes	

Table 8B: Intergroup statistical significance of surface area at middle third (Distobuccal canal)

All pairwise multiple comparison procedures (Tukey test)		
Comparison	p < 0.05	Only this group difference is significant
Group A vs Group B	Yes	
Group A vs Group C	Yes	

Table 9: Mean Root canal volumes (mm³) and standard deviation of mesiobuccal canal

	Before instrumentation		*After instrumentation*		*Absolute change*	
n = 12	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
Group A	3.526	0.52	6.092	0.89	2.566	0.37
Group B	3.272	0.88	7.105	1.62	3.833	0.93
Group C	3.149	0.71	6.847	1.40	3.698	0.81
	ANOVA test applied			F	7.014	
				p	0.003 (S)	

p < 0.05= Significant (S= significant; NS= nonsignificant)

Table 10: Intergroup statistical significance of absolute change of volume of mesiobuccal canal

All pairwise multiple comparison procedures (Tukey test)		
Comparison	p < 0.050	Only this group difference is significant
Group A vs Group B	Yes	
Group A vs Group C	Yes	

Table 11: Mean root canal volume (mm^3) and standard deviation of mesiolingual canal

	Before instrumentation		*After instrumentation*		*Absolute change*	
n = 12	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
Group A	3.493	0.51	6.074	0.86	2.582	0.35
Group B	3.272	0.83	7.283	1.53	4.011	0.97
Group C	3.224	0.88	6.887	1.70	3.663	0.83
	ANOVA test applied			F	6.694	
				p	0.004 (S)	

p < 0.05= Significant (S= significant; NS= nonsignificant)

Table 12: Intergroup statistical significance of absolute change of volume of mesolingual canal

All pairwise multiple comparison procedures (Tukey test)		
Comparison	p < 0.050	Only this group difference is significant
Group A vs Group B	Yes	
Group A vs Group C	Yes	

Table 13: Mean root canal volumes (mm^3) and standard deviation of distobuccal canal

	Before instrumentation		*After instrumentation*		*Absolute change*	
n = 12	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
Group A	5.392	0.61	9.305	1.06	3.913	0.46
Group B	5.002	0.95	10.497	2.01	5.495	1.08
Group C	4.775	0.71	10.071	1.52	5.295	0.81
	ANOVA test applied			F	13.116	
				p	< 0.001 (S)	

p < 0.05= Significant (S= significant; NS= nonsignificant)

Table 14: Intergroup statistical significance of absolute change of volume distobuccal canal

All pairwise multiple comparison procedures (Tukey test)		
Comparison	p < 0.050	Only this group difference is significant
Group A vs Group B	Yes	
Group A vs Group C	Yes	

Table 15: Mean root canal volume (mm^3) and standard deviation of distolingual canal

	Before instrumentation		*After instrumentation*		*Absolute change*	
n = 12	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
Group A	3.341	0.57	5.740	0.95	2.399	0.38
Group B	2.583	0.94	5.797	1.84	3.214	1.03
Group C	2.486	0.61	5.590	1.15	3.104	0.70
	ANOVA test applied			**F**	40.684	
				p	< 0.001 (S)	

p < 0.05= Significant (S= significant; NS= nonsignificant)

Table 16: Intergroup statistical significance of absolute change of volume distolingual canal

All pairwise multiple comparison procedures (Tukey test)		
Comparison	p < 0.050	Only this group difference is significant
Group A vs Group B	Yes	
Group A vs Group C	Yes	

files). This difference may be due to difference in the instrument design of K files and ProTaper files. K files, which have a 2% taper while ProTaper files have a progressively increasing taper ranging from 3.5 to 19%. The coronal third was prepared by Sx files in Group B and Group C. The teeth used in this study had canal lengths in the range of 8–11 mm. Sx was inserted into the canal 3–4 mm short of the apex. Thus a significant difference was found in the coronal thirds prepared by ProTaper files when compared to hand Stainless Steel K files.[13] No significant difference was found between Group B (Hand ProTaper files) and Group C (Rotary ProTaper files) because of the same instrument design of hand and rotary ProTaper.

Similarly, statistically significant difference was found in the middle third when Group A (hand K files) was compared with Group B (hand ProTaper files) as well as Group C (rotary ProTaper files). This difference can also be attributed to the instrument design. The S2 file is intended to shape the root canal system's middle section. S2 has a taper that increases from 4% on D1 to 11.5 % on D14.[14] Following ProTaper instrumentation, the remaining root dentin in some teeth was significantly thinner at the mid-root and coronal level sections. A progressive tapered design combined with a triangular convex cross-sectional design could have contributed in extremely aggressive cutting.[15]

When the same hand and rotary ProTaper instrument design was used, there was no statistical difference between Group C and Group B. At the apical levels, however, no significant difference was found between the three groups.This could be attributed to the ProTaper's noncutting modified safety tip. Even though no statistically significant was found between Group B and Group C, there was variability in the values between the two groups despite the same instrument design. This difference can be explained by the variability in preparation with hand leading to over or under preparation at times and also some walls may be prepared more than the others. Rotary files on the contrary were introduced in the canal once or maximum twice, if required. Each file was maintained in the canal for not more than a 1 second contact.

Volume of the individual canals of each tooth was measured before and after preparation for each group. In our study volume was measured using the method explained by Mayo et al.[10] Each tooth was radiographed at different angles. By combining all views, a mathematically determined 3D representation of the canal was obtained. Using this relevant data, the diameters of each root canal system and access cavity preparation were calculated at various distances from the anatomical apex. The computer cut each tooth's root canal system into 1 mm sections from the apical foramen to the flattened occlusal surface. The height was multiplied by the mean of each section's apical and coronal cross-sectional areas (1 mm). The total canal system volume was calculated by adding the volumes of the 1 mm sections of each tooth. The volume was

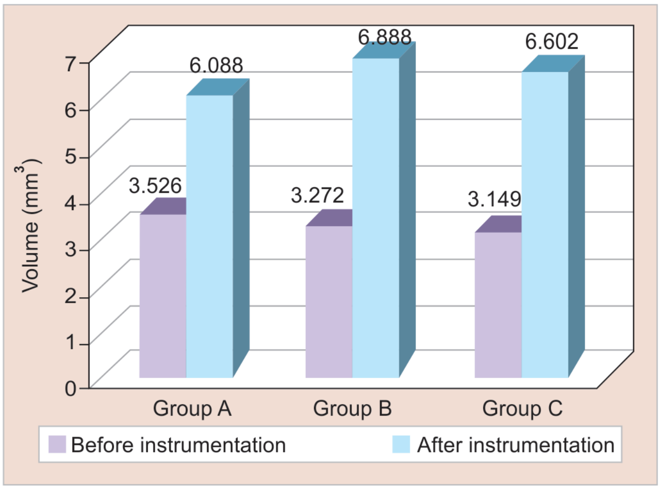

Fig. 13: Change in volume of mesiobuccal canal

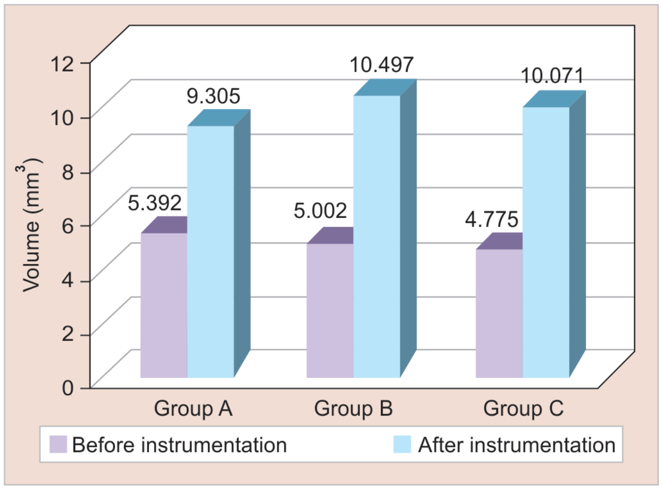

Fig. 15: Change in volume of distobuccal canal

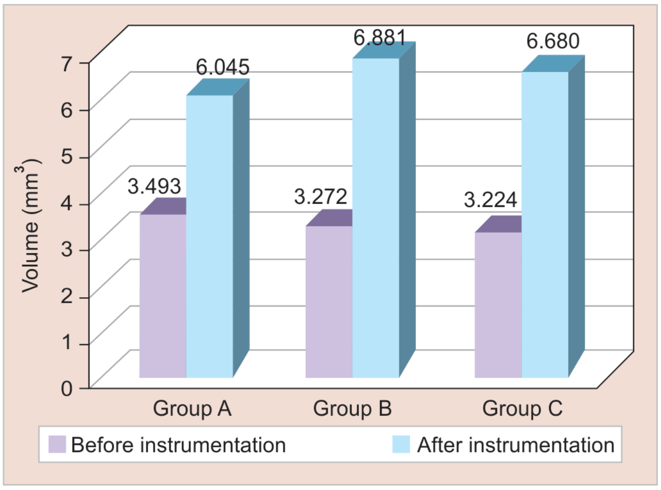

Fig. 14: Change in volume of mesiolingual canal

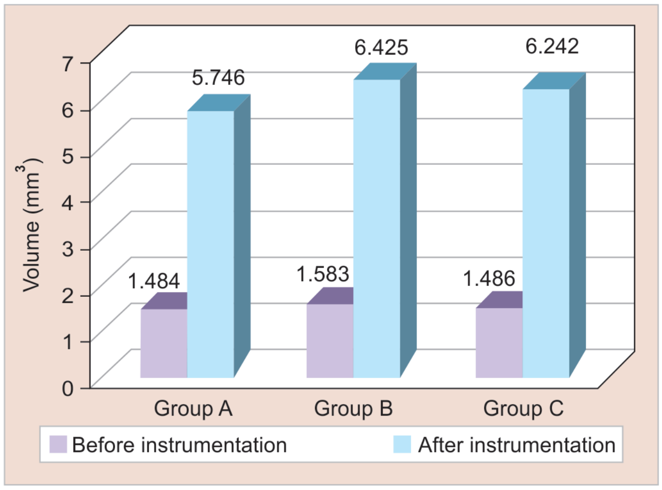

Fig. 16: Change in volume of distolingual canal

compared to the actual tooth measurement. They claimed that this method appears to be very accurate in determining root canal system. Previously, fractal geometry was used to try to quantify the cross-sectional geometry of root canals (Bjorndal et al.[16]). This method appraises outlines such as the outer root contour and the root canal cross-section; however, because the current trial focused on root canal geometry, fully 3D features such as volume and surface area were used. (Peters et al.[17]).

In present study, statistically significant difference in change in volume of the canals was found in all the four canals when group A (stainless hand K files) was compared with Group B (hand ProTaper files); also when Group A (stainless steel hand files) was compared with Group C (rotary ProTaper files. However, no statistically significant difference was detected in volume change between Group B (hand ProTaper files) and Group C (rotary ProTaper files). This finding was consistent with previous research, which reported mean volume gains of 3.725 mm3 (Rhodes et al.[18]) and between 26% and 58% (Nielsen et al.[19]). However, there is no definition for the volume of interest explored. The trials conducted earlier are all on permanent dentition. We did not come across a study for assessing volume changes after root canal preparation in deciduous dentition. Thus, our study was conducted to assess change in volume after different preparation techniques in deciduous teeth. O.A. Peters et al.[20] investigated the response of four preparation methods on canal volume and surface area in extracted human permanent maxillary molars. They revealed that by instrumenting the canals, they were able to increase their volume and surface area. O.A. Peters et al.[21] compared the performance of ProTaper Ni-Ti instruments in shaping root canals. They also observed that volume and surface area had substantially enhanced. Nagaraja et al.[22] obtained similar results. They used CT to compare canal preparation with hand Ni-Ti K files and ProTaper rotary Ni-Ti instruments in thirty mesiobuccal roots of maxillary molars. In the middle and coronal thirds, hand Ni–Ti K-files were found to have greater dentin thickness than the rotary ProTaper technique, and this difference was highly significant. There was no statistically significant difference in the amount of apical root dentin that remained.

Contrasting results were found by Kummer et al.[23] who conducted an *ex vivo* study on 80 primary teeth. They observed that in all groups, manual instrumentation removed more dentin from coronal, middle, and apical compared with apical. This can be explained as the rotary instrument used in their study was 2% and 4% Hero Shaper system compared to the ProTaper system used in our study. Interestingly, previous research found contradictory results in the metric assessment of root canal volumes and surfaces (Nielsen et al., 1995[19]). They demonstrated a reduction in surface area after canal preparation in one specimen (84.25 mm^2 *vs.* 79.30 mm^2). In the current study, two teeth in Group B and one tooth in

Group C had thinning canal walls on the furcal side. A progressive tapered design combined with a triangular convex cross-sectional design could have contributed in extremely aggressive cutting. The amount of dentin removed by manual and rotary instrumentation was revealed by the difference in mean area before and after instrumentation. The presence of physiologic or pathologic root resorption[24] can drastically alter the anatomic features of deciduous teeth's root canals, resulting in root wall thinning and root perforations. Root perforations, according to the findings, corresponded with areas of the maximum resorption, affecting mainly the middle and apical thirds. This was predicted due to the thin dentin walls in those areas, resulting in perforation-prone areas that should be considered during therapeutic interventions.

Conclusion

The present study concludes that–

- ProTaper instruments, both hand ProTaper and rotary ProTaper caused significant changes in the surface area in the coronal and middle thirds of the canal when compared to hand stainless steel files.
- Apical third preparations showed no significant difference in the increase in surface area between the three groups.
- Significant volume changes in the canal were obtained with ProTaper instruments compared to hand stainless steel files.
- No difference was found in surface area and volume changes between hand ProTaper and rotary ProTaper instrumentation.

Use of ProTaper instruments for preparation of deciduous teeth can render benefit of an improved canal preparation to facilitate better obturation and successful root canal therapy. However, ProTapers should be used judiciously, especially in primary teeth. ProTaper instruments can be advocated in the primary teeth for pulpectomy procedure with strict individual case selection and proper use of the technique. More research should be conducted to achieve better instrument design, methods of preparation, and methodologies used to assess the action of endodontic instruments in primary dentition.

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