ORIGINAL RESEARCH

Dentinal Microcracks after Root Canal Preparation in Primary Root: An *In Vitro* Evaluation of ProTaper Gold and Kedo-S Rotary File Systems

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Abstract

Context: There is a possibility of dentinal crack formation in primary teeth after root canal preparation using rotary files.

Aims: To evaluate and compare the effect of ProTaper-Gold and Kedo-S rotary files on crack formation after root canal preparation in primary molars.

Settings and design: A total of 120 freshly extracted mandibular primary molars (6–9 years) were randomly divided into three groups of 40 each: ProTaper-Gold, Kedo-S, and Hand H-files, respectively.

Materials and methods: The roots were covered with a snuggly fitting surgical glove and stabilized in the teeth slot of a silicone mold of mandibular mixed dentition. Dental casts were obtained in a mixture of plaster of paris and sawdust. A screw system was incorporated in the cast for stabilization of the cast into the phantom head. All the root canals were instrumented in a standard operating position till 1 mm short of the radiographic apex. All roots were then stained and sectioned perpendicular to the long axis at the furcation level and 2 mm below the furcation to obtain one section per tooth. Sections were examined under a stereomicroscope at 25× magnification for any crack formations and recorded. Data were analyzed using Wilcoxon signed-rank and Kruskal–Wallis tests ($p = 0.05$).

Results: The total number of cracks in terms of percentage following the use of ProTaper Gold, Kedo-S, and H-files were 35, 10, and 0%, respectively, on the upper surface and 15, 5, and 0% on the lower surface. Within the group, there was a statistically significant difference in ProTaper-Gold ($p = 0.001$).

Conclusion: The use of ProTaper-Gold resulted in a greater number of dentinal cracks compared to Kedo-S and H-files.

Keywords: Dentinal cracks, Hand instrumentation, Kedo-S files, ProTaper-Gold, Primary molars, Rotary instrumentation.

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Introduction

Preservation of primary teeth in the oral cavity till their physiologic exfoliation is essential in pediatric dentistry, as the early loss of primary teeth causes space loss with consequent crowding of permanent teeth, which affects mastication, phonation, and esthetics. Pulpectomy, which involves the removal of necrotic pulp tissue followed by filling the root canals with a resorbable material to maintain the tooth free of infection, promote physiologic root resorption, and hold the space for the erupting permanent tooth, is considered an effective treatment modality which is quite a time consuming and challenging in primary teeth.[1] The objective of chemomechanical preparation is to eliminate both soft and hard tissue-containing bacteria, resulting in a sterile root canal for obturation.[2.] The effectiveness of the root canal treatment is determined by the method, instrumentation quality, proper irrigation, and disinfection of the root canal.[3] As a child's behavior may change over narrow ranges of time, the uncooperative behavior of the child due to fear of pain makes the treatment more difficult.

Hand instrumentation remains the conventional method for root canal preparation, which is time-consuming. As preparation time is an important factor in pediatric patient management, rotary instrumentation in primary teeth can be a better option that allows faster procedure, improves patient cooperation by shortening treatment time, and reduces the professional's fatigue.[4] Despite various clinical advantages, the rotary has been shown to produce dentinal cracks developed by stresses generated inside the root during instrumentation.[5]

The use of rotary instruments in pediatric dentistry is a new practice despite their widespread use for root canal treatment of permanent teeth. Among these rotary systems, the ProTaper system is widely used in many countries and has also been used for primary teeth.[3] Recently, Kedo-S has been introduced as an exclusive Ni-Ti

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file for pediatric patients. The taper of these instruments is designed according to the diameter of the primary teeth with narrow and wide root canals.[2] The use of rotary Ni-Ti files in permanent teeth has been proven to cause cracks in the root dentin, as evidenced by numerous studies; however, there have been only a few studies conducted on primary teeth.

The objective of the present study was to compare and evaluate the effect of ProTaper Gold, Kedo-S rotary files, and Hand H-files files on the formation of dentinal cracks following root canal preparation in primary mandibular molar roots.

The hypothesis was tested as there is no significant difference in the dentinal cracks produced by the two systems (H0).

Materials and Methods

The study was conducted on teeth extracted from children for orthodontic reasons, after informed written consent, who reported to the Department of Pediatric and Preventive Dentistry.

Teeth indicated for extraction from children of both sexes in the age group of 6–9 years for orthodontic reasons or having grossly decayed primary mandibular molar having at least one unresorbed root present were included in the study. Severely curved roots or roots with obliterated canals and teeth exhibiting cracks and fractures were excluded from the study. A sample size of 120 fully formed roots (40 in each of the groups) of extracted primary mandibular molar was sufficient for hypothesis testing with 80% power and a 5% significance level. All the teeth were randomly divided into three groups: ProTaper Gold ($n = 40$), Kedo-S ($n = 40$), and the control group ($n = 40$).

Method of Disinfection of Teeth

All the teeth were cleaned, stored in sterile distilled water (Yucca Diagnostics, Kolhapur, India) at 37°C, then immersed in 0.5% sodium hypochlorite (Vensons, Bengaluru, India) for 10 minutes for disinfection and again stored in sterile distilled water for further use.

All the roots were observed using a stereomicroscope under 20× magnification (Labo America, Inc., Luxeo 4Z, United States of America). Roots with external defects or cracks were discarded. The roots were covered with snuggly fitting latex surgical gloves (thickness—0.32 mm) to simulate the periodontal ligament, stabilized in the teeth slot of a silicone mold of mandibular mixed dentition. Dental casts were obtained in a mixture of plaster of paris and sawdust.[6] A screw system was incorporated in the set cast for stabilization of the cast into the phantom head (Fig. 1).

Orientation of the Phantom Head and Operator's Position

A standard operator position was maintained during instrumentation to simulate the clinical condition. The support rod of the phantom head was about 20° elevated from the horizontal supine position. The occlusal surface was maintained approximately at 60° and the elbow level of the operator. The operator's back was at 11–1 o'clock positions, the height of the patient's chair was adjusted so forearms were parallel to the floor or sloping 10° upward, and the height of the operating stool was adjusted such that feet were flat on the floor, thighs slope slightly downward, and weight evenly distributed in a tripod pattern, represented by seat pan and each foot on the floor.[7]

Two trained operators performed the procedures. Procedures were allocated to two operators by block randomization.[8]

Instrumentation of Root Canal

The procedures were carried out in accordance with the manufacturer's instructions for each instrument system as follows (Fig. 2).

Group I (rotary instrumentation using ProTaper Gold files): An endodontic access opening was prepared using No 330 pear-shaped bur (Mani, Inc., Tochigi, Japan). The coronal tissue debris was removed using a No 19W Spoon excavator (Hu-Friedy Mfg. Co., LLC). The mesiobuccal and mesiolingual canals were explored with a size 10 K-file (Mani, Inc., Tochigi, Japan) and the distal canal with a size 15 K-file. A working length was determined (minimum 10 mm) using a preoperative radiograph and measured 1 mm short of the apex. Biomechanical preparation was performed using a crown-down technique with the ProTaper Gold system (Dentsply Maillefer, Ballaigues, Switzerland) with two instruments at a constant speed of 250 rpm and 3 Ncm torque in the following sequence: SX file was placed into the canal about 3 mm beyond the root canal orifice, followed by the use of S2 file till the working length.[9]

Group II (rotary instrumentation using Kedo-S files): After endodontic opening, removal of coronal tissue, exploration of the canal, and determination of working length biomechanical preparation were performed using a crown-down technique with

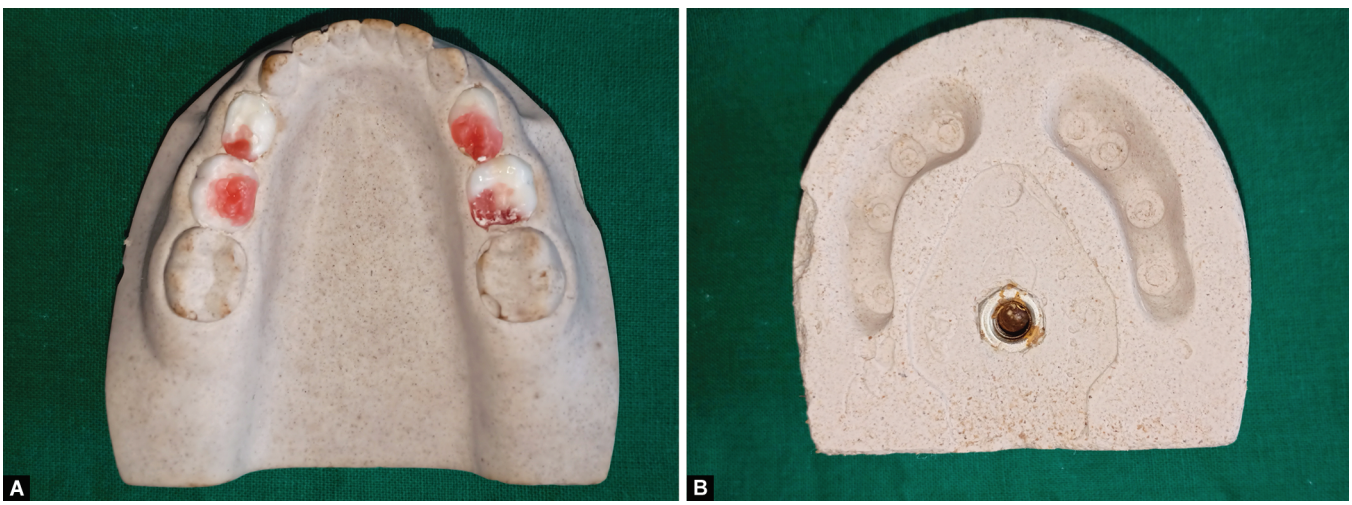
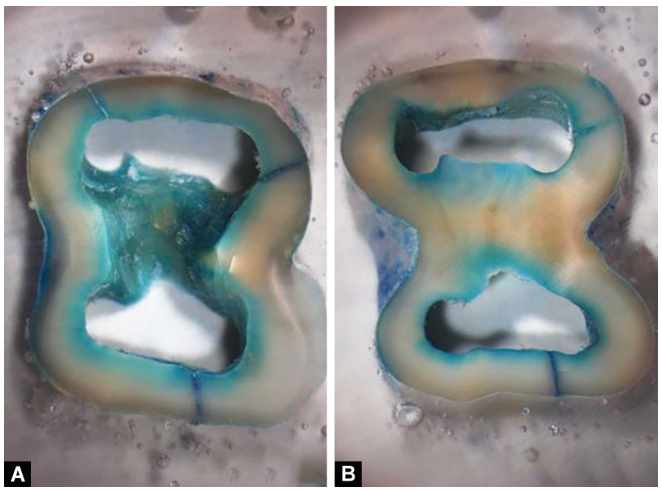


Fig. 1: Dental cast with incorporated screw system

Fig. 2: Working model with natural teeth being instrumented in standard operator's position



Figs 3A and B: Upper and lower surfaces of tooth section showing dentinal cracks; (A) Tooth section after the cut at the furcation (upper surface); (B) Tooth section 2 mm below the first cut (lower surface) (25× magnification)

Kedo-S Ni-Ti rotary instruments at 250 rpm and 3N cm torque. D1 rotary file was used to prepare the mesiobuccal and mesiolingual canals. E1 rotary file was used to prepare the distal canal.[2]

Group III (hand instrumentation using H-files): Similar to groups I and II, after endodontic opening, removal of coronal tissue, exploration of the canal, and determination of working length, biomechanical preparation was performed using a crown-down technique with H-files in rasping motion. All the canals were enlarged using precurved H-files till file number 30.

For all three groups, normal saline was used as an irrigating solution during canal preparation. RC helps (Prime Dental Products Pvt. Ltd. India), a 17% ethylenediaminetetraacetic acid (EDTA) gel used as a lubricating agent during canal preparation.

Sectioning and Microscopic Observation

After the instrumentation, the tooth was separated from the dental cast carefully and washed thoroughly using clean tap water, then immersed in 2% methylene blue solution for 30 seconds.[10] Root canals were irrigated thoroughly using a syringe with sterile water to remove excess dye if present.

All the roots were sectioned perpendicular to the long axis. Two horizontal lines were marked on the tooth surface. The first line is at the furcation level, and the second line is 2 mm below the first line. Accordingly, cuts were made. The first cut was made at the furcation level, and the second cut was 2 mm below the first using hard tissue microtome (Leica Sp 1600). Both sides of each section were examined under a stereomicroscope (Labo America, Inc., Luxeo 4Z, United States America) at 25× magnification. Using a digital camera attached to a stereomicroscope, digital images of each section were captured. Two trained operators not involved in the study examined the cracks, and the scoring was done.

Two distinct categories were made to define the formation of cracks (i.e., ''no crack'' and ''crack''). Root dentin that does not have cracks or craze lines on the internal or external surface of the root canal wall is called "no crack." All lines on the slice that either extended from the root canal lumen to the dentin or from the outer root surface into the dentin were considered to be "cracks" (Fig. 3).[5]

Statistical Analysis

The number of cracks seen on each sectioned surface of the root (i.e., upper and lower surfaces) was tabulated for 40 samples of all three groups. The results were expressed as (1) the number and percentage of cracked surfaces and also the number of cracks on upper and lower surfaces in each group; (2) within each group, the number of cracked surfaces and the number of cracks on upper and lower surfaces were analyzed with the Wilcoxon test; and (3) across the three test groups, the number of cracked surfaces and the number of cracks on upper and lower surfaces were analyzed by the Kruskal–Wallis test. The level of significance was set at 0.05.

Results

The number of cracked surfaces and the number of cracks were analyzed. Cracks originating from the lumen were only considered. The number of cracked surfaces and the total number of cracks on upper and lower surfaces for all three groups were recorded. In terms of percentage, ProTaper Gold produced a higher number of cracked surfaces and a higher number of cracks. The dentinal cracked surfaces following the use of ProTaper Gold, Kedo-S, and hand H-files were 15, 10, and 0%, respectively, on the upper surface and 10, 5, and 0% on the lower surface. The total number of cracks in terms of percentage following the use of ProTaper Gold, Kedo-S, and H-files were 35, 10, and 0%, respectively, on the upper surface and 15, 5, and 0% on the lower surface.

Table 1 shows the comparison of dentinal crack formation on the upper surface and lower surface within each group investigated. On statistical analysis, there was no significant difference in the cracked surfaces (the upper vs lower surfaces) following the use of ProTaper Gold ($p = 0.49$) and Kedo-S ($p = 0.80$). On comparing the number of cracks, there was no significant difference between upper and lower surfaces in Kedo-S ($p = 0.80$); however, the difference was significant in ProTaper Gold ($p = 0.001$).

Table 2 shows a pairwise comparison of cracked upper and lower surfaces between the groups investigated. There was no statistically significant difference between the ProTaper Gold and Kedo-S (upper surface, $p = 0.70$; lower surface, $p = 0.70$); ProTaper Gold and H-files (upper surface, $p = 0.25$; lower surface, $p = 0.44$); and also Kedo-S and H-files (upper surface, $p = 0.44$; lower surface, $p = 0.70$).

Table 3 shows a pairwise comparison of the number of cracks on upper and lower surfaces between the groups investigated. There was no statistically significant difference between the ProTaper Gold and Kedo-S (upper surface, $p = 0.70$; lower surface, $p = 0.70$); ProTaper

Table 1: Table showing the comparison of dentinal crack formation on the upper surface and lower surface within each group investigated (Wilcoxon signed-rank test)

	Group I ProTaper Gold rotary files		*Group II Kedo-S rotary files*		*Group III H-files (hand instrumented)*	
	Number of cracked surfaces	*Total number of cracks*	*Number of cracked surfaces*	*Total number of cracks*	*Number of cracked surfaces*	*Total number of cracks*
Upper surface	6 (15%)	14 (35%)	4 (10%)	4 (10%)	0	0
Lower surface	4 (10%)	6 (15%)	2 (5%)	2 (5%)	0	0
p-value	0.49 (NS)	0.001 (S)	0.80 (NS)	0.80 (NS)	–	–

Table 2: Pairwise comparison of cracked surfaces between the groups investigated (Mann–Whitney *U* test)

Groups	*Surface*	*Z-score*	*Test statistic U*	*p-value*
Group I: ProTaper Gold rotary files vs Group II: Kedo-S rotary files	Upper surface	0.38009	760.0	0.70
	Lower surface	0.38009	760	0.70
Group I: ProTaper Gold rotary files vs Group III: H-files (hand instrumented)	Upper surface	1.14989	680.0	0.25
	Lower surface	0.76499	720	0.44
Group II: Kedo-S rotary files vs Group III: H-files (hand instrumented)	Upper surface	0.76499	720	0.44
	Lower surface	0.38009	760	0.70

Table 3: Pairwise comparison of cracks on upper and lower surfaces between the groups investigated (Mann–Whitney *U* test)

Groups	*Surface*	*z-score*	*Test statistic U*	*p-value*
Group I: ProTaper Gold rotary files vs Group II: Kedo S rotary files	Upper surface	0.45707	752	0.64
	Lower surface	0.39933	758	0.68
Group I: ProTaper Gold rotary files vs Group III: H-files (hand instrumented)	Upper surface	1.14989	680	0.25
	Lower surface	0.76499	720	0.44
Group II: Kedo-S rotary files vs Group III: H-files (hand instrumented)	Upper surface	0.76499	720	0.44
	Lower surface	0.38009	760	0.70

Table 4: Table showing a comparison of dentinal cracks produced by the groups investigated on the individual surface (Kruskal–Wallis test)

		Group I ProTaper Gold rotary files	*Group II Kedo S rotary files*	*Group III H-files (hand instrumented)*	*H-statistic*	*p*
Upper surface	Number of cracked surfaces	6 (15%)	4 (10%)	0	1.3884	0.49 (NS)
	Total number of cracks	14 (35%)	4 (10%)	0	1.431	0.48 (NS)
Lower surface	Number of cracked surfaces	4 (10%)	2 (5%)	0	0.595	0.74 (NS)
	Total number of cracks	6 (15%)	2 (5%)	0	0.605	0.73 (NS)

Gold and H-files (upper surface, $p = 0.25$; lower surface, $p = 0.44$) and Kedo-S and H-files (upper surface, $p = 0.44$; lower surface, $p = 0.70$).

Table 4 shows the comparison of dentinal cracks produced on the individual surfaces (i.e., either upper surface or lower surface) across the groups studied. On statistical analysis, on comparing cracked surfaces, there was no significant difference shown by the ProTaper Gold and Kedo-S on the upper surface ($p = 0.49$) and lower surfaces ($p = 0.74$). When comparing the number of cracks, there was no significant difference shown by the ProTaper Gold and Kedo-S on the upper surface ($p = 0.48$) and lower surfaces ($p = 0.74$).

Discussion

More cracks were produced on the upper surface than on the lower surface in both groups. This could be because of the diameter, taper, and length of the files. The longer the length of the file induces more cracks. The significant difference found in comparing the number of cracks in ProTaper Gold ($p = 0.001$) could be because of the triangular cross-section of the tip and the greater taper of the file.

Kim et al. in 2010 reported that the tapered files cause increased stress on canal walls.[11] Greater taper results in reduced remaining dentin thickness, which in turn increases the risk of root fracture.[12–14]

Thus, the taper, diameter, and length of the files are influencing factors in dentinal crack formation.

In the current study, the roots were covered with snuggly fitting latex surgical gloves of thickness 0.32 mm to simulate the periodontal ligament. Dental casts were obtained in a mixture of plaster of paris and sawdust to simulate the bone density and stabilized in a phantom head to simulate the clinical situation.[6] In this study, we have followed a standard operator's position to simulate the clinical situation,[7] and the procedure was performed by two examiners to eliminate the sources of bias.

According to the manufacturer's instruction, root canals of the teeth were prepared using the respective rotary files in brushing motion at 250 rpm and 3 Ncm torque, and the torque-controlled endodontic motor (X Smart; Dentsply Maillefer) was used.

After the preparation, teeth were stained using 2% methylene blue dye for 30 seconds.[10] It has a smaller molecular size (120 nm) than the bacterium, and it penetrates more deeply than other dyes since it has a low molecular weight (318.85), which is even lower than basic fuchsin (323.45).[15]

ProTaper Gold was selected for this study, as there are reported studies on the use of the ProTaper Gold system in primary teeth. Also, it is one of the most popular rotary systems used for permanent teeth because of its advanced metallurgical features, such as resistance to cyclic fatigue and increased flexibility.

In 2018, Nishad and Shivamurthy analyzed apical root crack propagation after root canal preparation at different instrumentation lengths using ProTaper Universal (PTU), ProTaper Next (PTN), and ProTaper Gold rotary files and concluded that ProTaper Gold showed the least dentinal damage, followed by PTN and PTU owing to its manufacturing advantages and its thermomechanical treatment.[15]

The Kedo-S group produced less number of cracks compared to ProTaper Gold. This could be attributed to the length and taper of the files. In 2006, Kuo et al. stated that a new NiTi rotary file, exclusively for primary teeth with modified taper, length, and tip size, would be more advantageous.[9] The Kedo-S pediatric rotary instrumentation is developed for cleaning and shaping primary teeth to overcome the disadvantages of the existing rotary files, such as the length and taper of the file.[16] This pediatric rotary file system consists of three NiTi rotary files. The total length of the files is 16 mm. The working length of the files is 12 mm. The files are named as D1, E1, U1. All the files have a variable taper corresponding to the use in primary teeth. In this study, D1 and E1 files with tip diameters of 0.25 and 0.30 mm were used. D1 can be used in primary molars with narrow canals, and E1 can be used in wider molar canals.[2] This proves an advantage for root canal debridement of primary teeth having shorter, thinner, curved roots and ribbon-shaped morphology as compared to permanent teeth.[17] Kedo-S provides higher cervical enlargement and restricted apical preparation with progressive taper than constantly fixed taper.[18] And the flexibility of files aids in the adaptation of files to the primary canal curvature, rather than increased zipping and transportation as in hand instrumentation.[19] These features benefit efficient root canal instrumentation without over-instrumentation of thin root canal walls and reduce the chances of crack formation.[16]

However, H-files showed no cracks. In this, hand instrumentation was carried out using hand files. The mesiobuccal and mesiolingual canals were explored with a size 10 K-file (Mani, Inc., Tochigi, Japan) and the distal canal with a size 15 K-file, followed by sequential use of pre-curved H files (Dentsply Maillefer, Oklahoma, United States of America) number 15, 20, and 25 up to number 30 using rasping motion along with normal saline irrigation and 17% EDTA lubricating gel. The hand instrumentation may not induce dentinal crack formation, whereas it may impact adversely if the patient is of uncooperative behavior because of the duration of treatment.

The study has the following limitations: in this study, primary teeth indicated for extraction from children in the age group of 6–9 years were included. There could be age-related anatomical, histological, and chemical changes that take place in primary teeth, such as increased calcification leading to the narrowing of root canals and morphological changes owing to the presence of physiological or pathological root resorption.[20] The limitations of the study are applied to all the three groups investigated.

The present study evaluated dentinal cracks produced in primary teeth after rotary preparation using ProTaper Gold, which is used for permanent teeth, and Kedo-S, an exclusive pediatric rotary file. Further studies comparing the effect of the rotary on dentinal crack formation following the use of rotary files exclusively for primary teeth will aid in understanding the potential damage and efficiency of the rotary instrumentation in primary teeth.

Conclusion

Within the limitations of this study, the following conclusions can be drawn.

- ProTaper Gold resulted in a greater number of dentinal cracks on the upper surface compared to a lower surface. The difference was statistically significant.
- Kedo-S group also produced cracks on upper and lower surfaces. In terms of numbers, the difference was statistically not significant.
- Across the groups, there was no statistically significant difference in the number of cracked surfaces and the total number of cracks produced on the upper and lower surfaces by ProTaper Gold, Kedo-S, and H-files.
- The pairwise comparison showed no statistically significant difference between ProTaper Gold, Kedo-S, and H-files.
- Rotary file systems, when used with adequate care, can be a great clinical arsenal for the pediatric dentist in root canal debridement and shaping in teeth indicated for pulpectomy.

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