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Evaluation of the Self-Adjusting File system (SAF) for the instrumentation of primary molar root canals: a micro-computed tomographic study

ABSTRACT

Aim *The Self-Adjusting File (SAF) system has been recommended for use in permanent teeth since it offers more conservative and effective root-canal preparation when compared to traditional rotary systems. However, no study had evaluated the usage of SAF in primary teeth. The aim of this study was to evaluate and compare the use of SAF, K file (manual instrumentation) and Profile (traditional rotary instrumentation) systems for primary-tooth root-canal preparation in terms of instrumentation time and amounts of dentin removed using micro-computed tomography (μCT) technology.*

Materials and methods *Study Design: The study was conducted with 60 human primary mandibular second molar teeth divided into 3 groups according to instrumentation technique: Group I: SAF (n=20); Group II: K file (n=20); Group III; Profile (n=20). Teeth were embedded in acrylic blocks and scanned with a μCT scanner prior to instrumentation. All distal root canals were prepared up to size 30 for K file,.04/30 for Profile and 2 mm thickness, size 25 for SAF; instrumentation time was recorded for each tooth, and a second μCT scan was performed after instrumentation was complete. Amounts of dentin removed were measured using the three-dimensional images by calculating the difference in root-canal volume before and after preparation. Data was statistically analysed using the Kolmogorov-Smirnov and Kruskal-Wallis tests.*

Results *Manual instrumentation (K file) resulted in significantly more dentin removal when compared to rotary instrumentation (Profile and SAF), while the SAF system generated significantly less dentin removal than both manual instrumentation (K file) and traditional rotary instrumentation (Profile) ($p<.05$). Instrumentation time was significantly greater with manual instrumentation when compared to rotary instrumentation ($p<.05$), whereas instrumentation time did not differ significantly between the Profile and SAF systems.*

Conclusion *Within the experimental conditions of the present study, the SAF seems as a useful system for root-canal instrumentation in primary molars because it removed less dentin than other systems, which is especially important for the relatively thin-walled canals of primary teeth, and because it involves less clinical time, which is particularly important in the treatment of paediatric patients.*

Keywords *Dentin amount; Instrumentation; Primary teeth; Root canal; Self-Adjusting File system (SAF).*

Introduction

With the increasing importance given to the retention of primary teeth until the eruption of permanent ones, endodontic treatment has become one of the most common procedures used in treating primary teeth. However, the morphology of the root canals of primary teeth makes endodontic treatment difficult [Mc Donald et al., 2011]. As treatment success is dependent upon the complete removal of necrotic material and sterilisation of the root canal, the process of cleaning and shaping the canal system is the most important aspect of endodontic treatment [Mc Donald et al., 2011; Waterhouse and Whitworth, 2015].

Root canal instrumentation of primary and permanent teeth differ due to differences in morphology [Waterhouse and Whitworth, 2015; Carrotte, 2005], with primary molar roots more widely divergent and curved to allow for the development of succedaneous teeth. These curves increase the chance of perforation of the apical portion of the root or the coronal one-third of the canal into the furcation during instrumentation [Mc Donald et al., 2011; Waterhouse and Whitworth, 2015;

Carrotte, 2005; Goerig and Camp, 1983]. In addition, preparation using larger instruments can weaken the tooth structure by excessively reducing dentin thickness [Goerig and Camp, 1983]. Finally, variations in the root canal system make it difficult to completely remove necrotic tissue from primary molars by instrumentation alone; rather, disinfection with irrigants such as 1% sodium hypochlorite and/or chlorhexidine is strongly recommended to help dissolve the necrotic tissue left behind by routine instrumentation and ensure optimal bacterial decontamination of the canals [Goerig and Camp, 1983; AAPD, 1984].

The literature describes various techniques for root canal preparation in primary teeth, including manual instrumentation with stainless steel hand files, rotary instrumentation with nickel-titanium (Ni-Ti) devices, and ultrasonic instrumentation [Pinheiro et al., 2012; Silva et al., 2004; Canoglu et al., 2006]. Although manual instrumentation is widely used in primary teeth, it is time consuming and often causes fatigue in the dentist as well as the paediatric patient [Katge et al., 2014]. Devices that reduce clinical time are of great value in paediatric dentistry, and the majority of studies comparing rotary and manual instrumentation have reported canal preparation with rotary files to be noticeably quicker and easier [Sonntag et al., 2003; Vaudt et al., 2009]. However, traditional rotary instrumentation, which utilises Ni-Ti files attached to a low-speed handpiece, also has a number of disadvantages, namely: the absence of simultaneous irrigation; the potential for over instrumentation in primary tooth roots because of the relatively thin canal walls; and difficulties in fully instrumenting flat, oval, curved and irregularly shaped canals due to the Ni-Ti rotary files' positioning in the center of the root canal, which causes the files to lose contact with the canal walls in some places [Peters, 2004]. These limitations are particularly important in primary teeth, which require the removal of smaller amounts of dentin from the root canal walls [Pinheiro et al., 2012; Barr et al., 2000].

The self-adjusting file (SAF) (ReDent- Nova, Ra'anana, Israel) has recently been proposed as a means of overcoming the inherent problems of traditional Ni-Ti rotary instruments to achieve better cleaning and shaping. The SAF system, which uses a single instrument to prepare the canal space, is able to remove an even dentin layer from all around the root canal, adapting to canal morphology and, by operating with continuous irrigation, allowing for better cleaning with minimal dentin removal and minimal invasive procedures [Metzger et al., 2010; Peters et al., 2001; Solomonov, 2011]. Metzger et al. [2010] used three-dimensional micro-computed tomographic (µCT) analysis to compare the quality of root canal preparation with rotary versus SAF instrumentation and concluded that SAF provided better cleaning and shaping than rotary files. Although the literature includes numerous reports on the use of the SAF system for permanent teeth [Silva et al., 2004; Metzger et al., 2010; Peters et al., 2001; Solomonov, 2011], the system has yet to be evaluated for use with primary teeth. Therefore, this study aimed to compare the instrumentation time and amounts of dentin removed from primary molar canals with SAF system, manual instrumentation with K files and Ni-ti rotary instrumentation (Profile) using µCT technology.

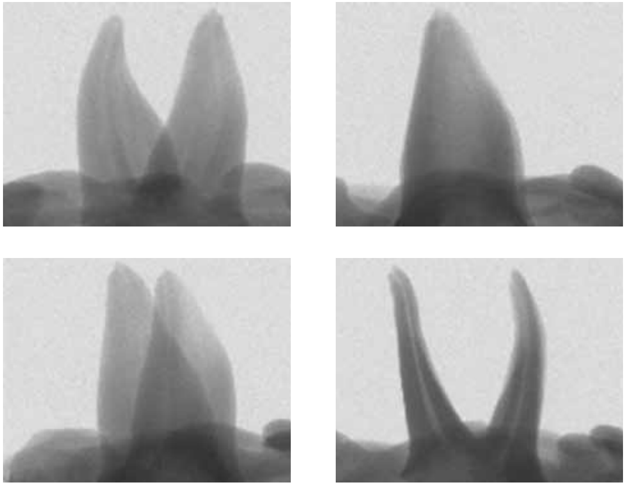

FIG. 1 µCT scanned images in TIF Format (a total of 514 images obtained for sample).

Materials and methods

The study protocol was approved by the Ethics Committee of Kocaeli University (KOU KAEK 2014/195). A total of 60 primary mandibular molars were selected from a random collection of teeth extracted due to pulpal abscesses, chronic infection and various orthodontic reasons and stored in distilled water at 4°C until the experiment.

Inclusion criteria were as follows.

- Mandibular primary second molars with at least two-thirds of the root intact and a length of 7–12 mm.
- Absence of external and/or internal pathological root resorption.
- Absence of perforation in the internal and/or external furcation area.
- Absence of root anomaly or calcified root canal.
- Moderate root angulations of primary molar distal root.

Primary mandibular second molar distal roots were preferred due to their generally large, curved, single canal; uniform canal outline; and relatively fewer intracanal ramifications when compared to mesial roots. Prior to preparation and scanning, each tooth was mounted in an acrylic block to allow for exact repositioning in the µCT scanning system (SkyScan 1172 Micro-CT, Bruker, Belgium).

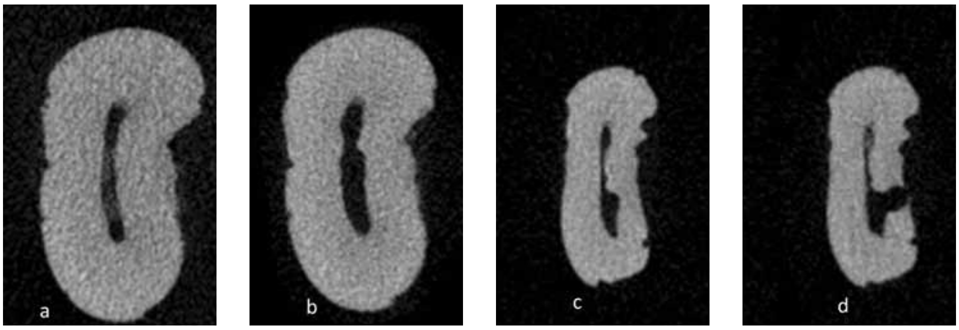

FIG. 2 Cross-sectioned images before and after preparation: A) coronal part of the tooth before preparation; B) coronal part of the root after preparation with K File; C) apical part of the root before preparation; D) apical part of the root after preparation with K File.

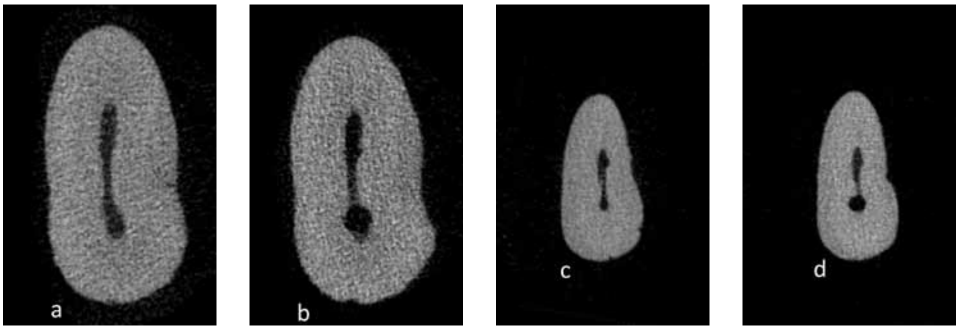

FIG. 3 Cross-sectioned images before and after preparation: A) coronal part of the tooth before preparation; B) coronal part of the root after preparation with ProFile; C) apical part of the root before preparation; D) apical part of the root after preparation with ProFile.

Specimens were scanned before instrumentation using the following parameters:

- filter: aluminum and copper;
- X-ray voltage: 95kW;
- X-ray current: 104mA;
- rotation: 360^0;
- time: 170 ms;
- Image pixel size: 19.7 µm;
- rotation step deg = 0.700:
- frame Averaging = on;
- random Movement = on.

For each sample, 514 raw images were obtained and saved in TIF format (Fig. 1a-d) and then reconstructed using the NRecon software (SkyScan NRecon version 1.6.6, Bruker Micro-BT, Kontich, Belgium) and saved as BMP files. For each sample, 614 cross-sections on the axial plane were obtained (Fig. 2a, c, Fig. 3a, c, Fig. 4a, c).

After initial scanning, spherical diamond burs (Kendo, VDW GmbH, Germany) were used to gain endodontic access, and working length was set at 1 mm short of the apical foramen. Then, teeth were assigned into 3 separate groups (N=20/group) – 1 for manual instrumentation (K file) and 2 for rotary instrumentations (Profile and SAF). All canals were irrigated with 10 ml 2.5% NaOCl before instrumentation.

In Group 1 (K file): Mechanical preparation was performed by hand in a step-back manner using K-files up to Size 30 at the apical foremen. Irrigation with 2 ml 2.5% NaOCl was performed between instruments, and canals were flushed with 10 ml 2.5% NaOCl and 10 ml distilled water when instrumentation was complete.

Group 2 (Profile): Canal preparation was performed using a crown-down technique with Ni-Ti rotary Profile.04 (Dentsply/Tulsa Dental, Tulsa, USA) instruments up to a size .04/30 file in strict accordance with the manufacturer's recommendations. Files were activated using the VDW Silver Reciproc Endomotor system (VDW Silver Reciproc, VDW, Germany). Irrigation was performed as described for Group 1.

Group 3 (SAF): Initial preparation of a glide path was performed to working length using size 15 and 20 K-files. Cleaning and shaping of all samples were carried out using the SAF system 2 mm thickness size 25 (ReDent-Nova, Raanana, Israel) following the manufacturer's recommendations. A Kavo Gentle low-speed handpiece (Kaltenbach & Voigt GmbH, Biberach, Germany) was connected to the RDT3 head (ReDent Nova, Ra'anana, Israel) at a frequency of 5,000 rpm and an amplitude of 0.4 mm. Continuous irrigation with 2.5% NaOCl was applied throughout the procedure at 5 mL/min for a total of 4 min using the VATEA irrigation device (VATEA, ReDent, Ra'anana, Israel) included with the SAF system. Final irrigation was performed as described for Group 1.

All intrumentation precedures were performed by the same investigator.

A stopwatch was used to record instrumentation time (sec). Active instrumentation (i.e. the use of files in the canal) as well as time spent on irrigation was included in the total instrumentation time; however, time spent changing files and adjusting working length was excluded. Once preparation was completed, samples were scanned and scanned images were reconstructed as described above (Fig. 2b, d; Fig. 3b, d; Fig. 4 b, d).

The amount of dentin removed was determined by measuring the volume of the distal root canal of each sample before and after preparation using the NRecon

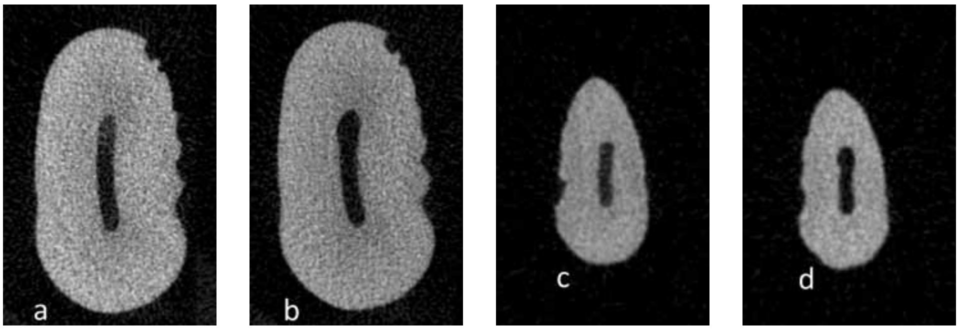

FIG. 4 Cross-sectioned images before and after preparation: A) coronal part of the tooth before preparation; B) coronal part of the root after preparation with SAF; C) apical part of the root before preparation; D) apical part of the root after preparation with SAF.

software programME and calculating the difference.

Data for instrumentation time and amounts of dentin removed were statistically analyzed using Kolmogorov-Smirnov and Kruskal-Wallis tests. The level of significance was set at $p < .05$.

Results

Intrumentation time, amounts of dentin removed and changes in root canal volume before and after preparation using three different intrumentation techniques were evaluated in 60 distal root canals of primary mandibular molars.

Mean instrumentation times for the K file, Profile and SAF groups were 14.95, 5.68 and 5.98 minutes, respectively. The instrumentation time was significantly higher in the K file manual group ($p < .05$), whereas there was no significant difference between the Profile and SAF groups (Table 1).

Mean amounts of dentin removed from primary molar distal root canal walls in the K file, Profile and SAF groups were 183.44 mm^3, 97.75 mm^3 and 31.36 mm^3, respectively (Table 2). Mean changes in volume between before and after preparation were 40.6%, 14.7% and 5%, respectively. All differences among groups were statistically significant (Table 2, Fig. 5).

Discussion

The results of the present study show that the time required for root canal instrumentation as well as the amounts of dentin removed from primary teeth root canals were significantly reduced by rotary instrumentation when compared to manual instrumentation; moreover, amounts of dentin removed were also significantly lower with rotary instrumentation using the SAF system when compared to the Profile system.

Root canal preparation can be performed using files, reamers, burs, sonic instruments, endodontic broaches and Ni-Ti rotary file systems [Pinheiro et al., 2012; Silva et al., 2004; Canoglu et al., 2006]. Although manual instrumentation is widely used in primary teeth, it is time consuming and involves iatrogenic risks (i.e. ledging, zipping, canal transportation and apical blockage) [Silva et al., 2004; Barr et al., 2000]. Ni-Ti rotary instruments were developed to address these risks and are now widely and successfully used for instrumentation of permanent teeth; however, there are no clear guidelines related to the use of Ni-Ti rotary systems for primary teeth [Kummer et al., 2008]. Barr et al. [2000] recommended that primary root canal preparation be performed using Profile .04 tapered instruments, which the authors found efficient yet non-aggressive. The present study also used Profile .04 taper instruments, given the risk of over-instrumentation and perforation of the thin dentin walls of primary-tooth canals.

Recently, a single-file system was proposed as a means of simplifying instrumentation protocols and avoiding risks of cross-contamination [Peters and Paque, 2010]. One single-file system currently available is the SAF system with a unique, hollow file design [Metzger et al., 2010]. The SAF file is designed to compress itself when it encounters a narrower section of the canal and then expand to its original dimensions when the canal

	K file	ProFile	SAF	p values		
				K File-ProFile	K File-SAF	SAF-ProFile
Mean ±std	14.95±1.24	5.68±0.96	6.00±0.35	.000*	.000*	.261
Median	14.53	5.39	5.98			
(25-75) %	13.81-15.69	5.03-6.25	5.70-6.40			
*Statistically significant difference (p<.05), Kruskal Wallis test						

TABLE 1 Comparison of the istrumentation time of K File, ProFile and SAF techniques (minutes).

	K file	ProFile	SAF	p values		
				K File-ProFile	K File-SAF	SAF-ProFile
Mean ± std	183.44 ± 78.65	97.75 ± 47.73	31.36 ± 18.68	.001*	.000*	.013*
median	165.14	90.05	27.83			
25-75%	125.08-199.24	63.29-121.10	16.31-49.21			
*Statistically significant difference (p<.05), Kruskal Wallis test						

TABLE 2 Comparison of the dentin removal amount of K File, ProFile and SAF techniques (volume change before and after preparation) (mm^3).

space widens. Thus, the SAF can also adapt itself to the cross-section of the canal, not merely longitudinally to a curved canal, like most other Ni-Ti rotary files. These characteristics of the SAF make it possible to apply continuous, delicate pressure to the walls of the canal and to maintain its original shape [Metzger et al., 2010]. Moreover, the SAF is designed so that the irrigant flows continuously through the hollow file and is constantly activated by the file's vibrating motion, which prevents deposition of a dentinal smear layer and necrotic material inside the canal [Metzger et al., 2010; Solomonov, 2011]. Finally, if a SAF file should break during instrumentation, the components remain intact, making it possible to remove the instrument in its entirety, with no part of the file left in the canal [Hof et al., 2010]. These characteristics would appear to offer particular advantages for the instrumentation of primary teeth canals.

The literature includes several studies showing rotary systems to require shorter instrumentation time than manual techniques [Silva et al., 2004; Nagaratna et al., 2006; Crespo et al., 2008]. This is particularly relevant in paediatric dentistry, because it reduces fatigue for the patient as well as the clinician. In the first controlled study to evaluate the instrumentation time of Ni-Ti rotary systems on primary teeth, Silva et al. [2004] stated that instrumentation with the Profile 0.4 system was quicker than with K files and this was confirmed in studies by Nagaratna et al. [2006] and Crespo et al. [2008]. The present study also found mean instrumentation time for rotary instrumentation (Profile and SAF) to be shorter than for manual instrumentation, which is in line with previous studies on primary [Pinheiro et al., 2012; Silva et al., 2004; Katge et al., 2014; Kummer et al., 2008; Nagaratna et al., 2006; Crespo et al., 2008] as well as permanent teeth [Peters et al, 2001; Paque et al., 2010]. However, the present study found no significant differences in instrumentation time between the Profile and SAF systems. No comparisons can be made among study findings in this regard, as no previous study has examined the instrumentation time of both the Profile and SAF systems.

It has been previously reported that there is less unnecessary removal of sound dentin in permanent teeth with the SAF system when compared to traditional Ni-Ti rotary files [Metzger, 2014]; however, this is the first study to be conducted using SAF in primary teeth, so it is not possible to compare results. Moreover, there is limited information available about dentin removal from primary teeth canals using traditional Ni-Ti rotary files. In the present study, K files and SAF system were found respectively to remove the highest and the least amount of dentin. In contrast to these findings, Canoğlu et al. [2006] found no significant differences in dentin removal from the distal roots of primary second molars using Profile, ultrasonic and K-file instruments. However, their study used 2-dimensional digital radiographs to determine the amount of dentin removed, whereas the present study used high-resolution 3-D images; thus, the difference in methodologies alone complicates direct comparisons between the two studies. Kummer et al. [2008] compared the amounts of dentin removed from primary teeth with K files and the Hero 642 Ni-Ti rotary system by using 2-dimensional digital images

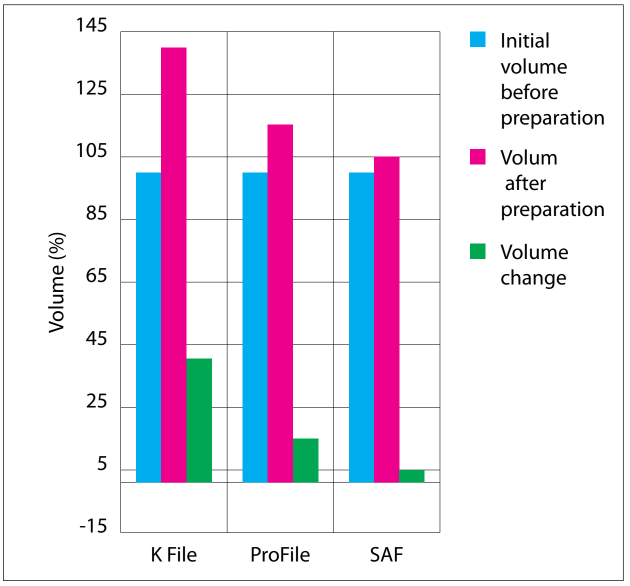

FIG. 5 Mean changes in volume between before and after preparation: 40.6%, 14.7% and 5% for K File, ProFile and SAF, respectively.

recorded before and after instrumentation. They stated that manual instrumentation removed more dentin compared with rotary instrumentation. These results are in line with our findings, although different methods were used to assess dentin removal.

Several methodologies have been developed to evaluate root canal preparation with different instruments through clinical as well as experimental endodontic studies [Kummer et al., 2008; Paque et al., 2010; Bramante et al., 1987]. Due to its high resolution, μCT is considered to be the gold standard of non-destructive methods for evaluating root canal instrumentation [Peters et al., 2001]. Other advantages of μCT include the ability to define scanning parameters (e.g. sample thickness, number of cross-sections, quantity of scans), convert images to 3-D models, and use a variety of analytical tools to examine the scanned images [Peters et al., 2001]. While the literature includes several studies using μCT technology to evaluate dentin removal in permanent teeth [Peters et al., 2001; Paque et al., 2010; Zhao et al., 2014] , the present study is the first to use μCT technology in the evaluation of dentin removal from primary root-canal walls. Further studies using μCT technology and SAF systems are needed to better understand the performance of different endodontic instruments in primary dentition.

Conclusion

Under the conditions of this study, the following can be concluded.

1. Profile and SAF rotary systems required similar instrumentation time and significantly less time than manual instrumentation with K Files.

2. Differences in the amount of dentin removed from canal walls varied significantly among the three systems, with SAF removing the smallest amounts and K files removing the largest amounts of dentin.

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