

Evaluation of self-adjusting file (SAF) damage during root canal therapy. An *in vitro* study

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Abstract

Introduction: The complex anatomy of root canal systems poses significant challenges for clinicians. In curved canals, fracture of endodontic instruments often prevents retrieval, compromising effective cleaning and shaping. The Self-Adjusting File (SAF) system was developed to enable efficient root canal preparation while reducing the risk of instrument fracture.

Aim of the research: To evaluate the incidence and nature of damage to SAF files during the preparation of human root canals.

Material and methods: Forty extracted human root canals were included. Preoperative radiographic assessment was performed. Canals were prepared following the manufacturer's protocol using the SAF system, operated in four-minute cycles. After each cycle, file integrity was assessed under 5× magnification using an operating microscope.

Results: All forty SAF files exhibited damage. A total of 34 cracks, 3 separations, and 3 other deformations were observed. Specifically, 32 strut fractures, 5 junction point failures, and 3 beam deformations were recorded. Neither canal curvature nor cross-sectional morphology significantly influenced the type or frequency of damage. The number of instrumentation cycles did not affect the timing of initial damage.

Conclusions: In this study, canal curvature, cross-sectional shape, and instrumentation time did not significantly impact SAF file damage, which predominantly involved strut fractures. Importantly, instrumentation was completed in all cases despite file damage. These results suggest that the SAF system is a safe and effective tool for root canal preparation in anatomically complex canals.

Introduction

Effective cleaning, shaping, and subsequent tight obturation of the root canal system are fundamental objectives of endodontic treatment [1]. For many years, the standard clinical approach has involved enlarging the root canal to at least three ISO sizes beyond the initial file used for canal negotiation [2]. This strategy aims to facilitate the removal of the innermost, heavily infected layers of dentin [1, 2]. Nowadays, this goal is easier to achieve, even in curved root canals, thanks to the use of rotary nickel-titanium (NiTi) files. Due to their elasticity, these files can preserve the original curvature of the root canal, achieving this more effectively compared to manual instrumentation [2, 3]. Canal cleaning and shaping can be more easily and reproducibly achieved with NiTi files, particularly in straight and narrow root canals with a round cross-section. However, it is more challenging in flat, oval-shaped, and curved root canals [4, 5]. The complex anatomy of the root canal system like isthmuses, recesses, and canal narrowings make thorough cleaning and shaping difficult. Failure to properly treat all root canal surfaces may contribute to unsuccessful endodontic outcomes [6]. Further-

more, canal curvatures increase the risk of procedural complications, which can negatively affect the overall prognosis of endodontic treatment [7].

Despite the numerous advantages of nickel-titanium instruments, intracanal failure of rotary NiTi files remains a significant clinical concern. The two primary causes of file separation are cyclic fatigue and torsional stress [7–11].

In response to the need for a simplified rotary instrumentation system that ensures effective root canal shaping while minimising the risk of uncontrolled file separation, the Self-Adjusting File (SAF) (Re-Dent Nova, Ra'anana, Israel) system was developed [12].

The SAF system represents a different perspective in endodontic file design and mechanism of action, specifically developed to address the limitations of traditional rotary instrumentation. The SAF file is constructed as a lattice-walled, compressible cylindrical structure (Figure 1). It is a hollow, thin-walled, pointed cylinder available in 1.5 or 2.0 mm diameters, fabricated from a 120-µm thick nickel-titanium lattice with high resistance to both torsional stress and cyclic fatigue [13–15]. One of the key features of the SAF file is its ability to adapt three-dimensionally to the original



Figure 1. Self – adjusting file [14]. License: Creative Commons Attribution-Noncommercial-Share Alike 3.0

morphology of the root canal, including curved and oval-shaped canals. This adaptation ensures uniform contact with the canal walls throughout the cleaning and shaping. The system consists of a self-adjusting file operated with a special RDT handpiece head and an irrigation pump (either the VATEA pump or the all-in-one EndoStation), which delivers a continuous flow of irrigant through the hollow file. Importantly, no significant pressure is generated within the canal because the pressure produced by the pump is dissipated once the irrigant enters the file lumen [15]. The SAF works in a different way than typical rotary instruments. It does not rotate in the canal and does not cut the dentin. The gentle abrasive action of the SAF file removes a layer of dentin and converts the debris into a thin powder that is continuously suspended and transported coronally by the flow of the irrigation fluid [12, 15].

Aim of the research

Given the scarcity of studies evaluating the operational safety of SAF [16–19], despite their innovative structural design, the present study aimed to assess the incidence and types of SAF file damage occurring during root canal instrumentation in extracted human teeth.

Material and methods

The study received approval from the Bioethics Committee of the Pomeranian Medical University in Szczecin, with approval number KB-0012/08/17. Each

patient was informed and provided written consent for their tooth's inclusion in the study.

Forty human extracted teeth (single-rooted teeth with one canal [$n = 20$] and the first maxillary molar palatal root [$n = 20$]) were collected accordingly, with inclusion and exclusion criteria presented in Table 1.

After extraction, the teeth were stored in a saline solution (0.9% NaCl) at a temperature of 4°C. An ultrasonic scaler was utilised to clean the teeth and remove soft tissue debris. Radiographic images were obtained using a digital radiography system, employing an X Mind Unity X-ray unit (Acteon) and a DIGORA Optime scanner (Soredex). The evaluation of root canal curvature was conducted using Schneider's scale. Only canals with a curvature between 0° and 20° were included. Root canals with an angle of 0° to 10° were classified as straight, while those between 10° and 20° were categorised as curved.

Additionally, canals were classified as oval or round based on radiographs taken in orthoradial and oblique projections. The canal diameter was measured at 7 mm from the radiological apex for this assessment. If the ratio of the orthoradial to oblique diameter was 2.5 or greater, the canal was designated as oval; if the ratio was 2.4 or less, it was designated as round.

Finally, root canals were divided into four groups ($n = 10$ each): straight, round; straight, oval; curved, round, and curved, oval.

The pulp chambers of all teeth were accessed following standard endodontic treatment protocols. After locating the canal orifices, endodontic access and canal negotiation were performed using a K-file ISO 10. Subsequently, the working length was determined by inserting the K-file ISO 10 until the tip was visible at the anatomic apex and then reducing this length by 0.5 mm. The canals were prepared to the working length with a #20 K-file and, following the SAF system requirements, tapered to 4% at size 20 using a Ni-Ti rotary file K3 (SybronEndo, Orange, CA). The K3 instrument was inserted to the full working length. Throughout the procedure, the canal was irrigated with 2% sodium hypochlorite at a flow rate of 4 ml/min during one cycle.

Table 1. Inclusion and exclusion criteria of the teeth studied

Inclusion criteria	Exclusion criteria
Permanent human teeth extracted for periodontal or orthodontic reasons	Teeth with fractures, severe structural damage, or previous endodontic treatment. Incomplete root formation or root resorption
Single-rooted teeth with one canal, or palatal canals of maxillary first molars	Teeth with more than one canal in the examined root
Availability of radiographs in both orthoradial and oblique projections	Poor-quality radiographs preventing evaluation of canal shape or curvature
Root canal curvature between 0° and 20° (Schneider's method)	Root canal curvature > 20° or non-evaluable on radiographs
Measurable canal diameter 7 mm from the radiographic apex	Presence of calcifications or obstructions impairing assessment

Table 2. Number and type of SAF file damages based on canal type, shape, and work duration

Number of SAF files used	Number of SAF files damaged	Cycle	Type of the canal		P-value	Canal shape		P-value
			Straight N = 10	Curved N = 10		Round N = 10	Oval N = 10	
40	21	1–2	7	14	0.0562	11	10	1
	19	3–4	13	6		9	10	
Type of damage								
40	34	Crack	16	18	0.9156	17	17	0.9156
	3	Separation	2	1		1	2	
	3	Other deformation	2	1		2	1	
File element damaged								
40	3	Beam	3	0	0.2998	0	3	0.1150
	32	Strut	16	16		16	16	
	5	Junction point	1	4		4	1	

Algorithm of the SAF system

Root canals inserted SAF file in the size of 1.5 and 25 mm long to verify working length. Forty SAF files were used for the study. Canals were then prepared using the following algorithm:

1. The irrigant (2% NaOCl) was delivered through the tube and into the file by the Vatea Irrigation pump with the typically recommended setting of 4 ml per minute.
2. 5000 SAF file vibrations/min with an amplitude of 0.4 mm, transformed by RDT3 micromotor from rotation to pecking motion.
3. Four-minute working time with SAF file per/cycle.
4. After each cycle, the integrity of the SAF file was verified by visual inspection using a surgical microscope Carl Zeiss OPMI Pico with 5× magnification.

Types of SAF file damage observed

The following classifications were used to describe the observed damage to SAF files:

Crack – defined as a breach of the structural integrity of a single lattice element at one end of the file, without complete detachment.

Separation – defined as the detachment of a portion of the lattice structure from the file body.

Other deformation – including visible distortion such as apical twisting of the lattice structure.

The entire endodontic procedure and evaluation of SAF damage (crack, separation, and other deformation) were performed by one operator, calibrated before the study. Intra-examiner reliability was assessed by repeating measurements after a 1-week interval. Cohen's kappa coefficient was calculated to evaluate agreement, with values above 0.80. All procedures were conducted under standardised conditions using

the same equipment, lighting, and magnification devices to minimise variability.

Statistical analysis

All data were analysed with statistical software (R version 4.0.0.). Fisher's exact test was used to reveal proportion differences. A significance level of $p < 0.05$ was adopted for comprehensive analysis. The Bonferroni correction for a multiple-comparison was used.

Results

Table 2 presents the obtained results. Every SAF instrument used in the study showed damage, 21 files after 4–8 minutes of work (1–2 cycles), and 19 files after 12–16 minutes (3–4 cycles). Of these, 85% (34 files) exhibited cracks; 7.5% (3 files) experienced separation, and 7.5% (3 files) had other deformations.

The types of damage observed included 32 cases of strut damage (longitudinal elements of the mesh), 5 cases of connector or node damage (junction points), and 3 cases of beam deformation.

In straight canals, file damage during cycles 1–2 was almost half as frequent as in cycles 3–4 (7 vs. 13, respectively). In curved canals, the number of damaged files was twice as high during cycles 1–2 compared to cycles 3–4 (14 vs. 6, respectively). This suggests that in curved canals, most damage occurred during the first 8 minutes of use, while in straight canals, damage was more common during 9–16 minutes of operation. However, the type of canal curvature (straight vs. curved) did not significantly influence the overall number of file damages ($p = 0.0562$).

When canal shape (round vs. oval) was analysed, no significant difference was observed between cycles 1–2 and 3–4 ($p = 1.0$). Cracks were the most frequent



Figure 2. Example of SAF file crack. Magnification: 2.5. OPMI Pico, Zeiss



Figure 3. Example of SAF file damage: separation. Magnification: 2.5. OPMI Pico, Zeiss



Figure 4. Example of other SAF file deformation: twisting of file tip. Magnification: 2.5. OPMI Pico, Zeiss

type of damage. Cracks accounted for 80% of all damages in straight canals and 90% in curved canals. Other types of deformation, such as file separation, occurred infrequently and were not statistically significant ($p = 0.9156$). Similarly, in terms of canal shape, cracks were the most frequently defect in both round and oval canals (85% of all damages). However, the shape of the canal did not significantly affect the number of damaged files ($p = 0.9156$).

In both straight and curved canals, the strut was the main SAF file damage, accounting for 80%. However, canal curvature did not exert a statistically significant influence on the type of damaged file component ($p = 0.2998$). Similarly, the analysis of the effect of canal cross-sectional shape on file element damage indicated that strut damage remained predominant (80% of cas-

es), but the cross-sectional shape did not significantly affect the type of damaged component ($p = 0.1150$).

Figures 2–4 show examples of SAF file damage.

Discussion

One of the most clinically relevant drawbacks of nickel-titanium endodontic instruments is their tendency to fracture unpredictably [11, 20, 21]. Critical failures, like instrument separation, typically result from torsional overload, cyclic fatigue, or a combination of both mechanisms [20, 22]. Torsional fractures occur when the torque from contact between the instrument and the canal wall exceeds the instrument's torsional strength or when the instrument tip is locked in the canal while the rest continues to rotate. It can also happen when instrument rotation slows sufficiently relative to the cross-sectional diameter. Fractures from flexural fatigue appear when a rotary endodontic instrument is stressed, particularly when the instrument is already weakened by metal fatigue [23]. Cyclic fatigue has been reported as the predominant mechanism of instrument fracture in clinical practice, accounting for approximately 70% of fractures related to flexural fatigue [24]. In contrast, torsional stress has also been identified as a slightly more frequent cause of instrument separation in some studies [20]. Nevertheless, both cyclic fatigue and torsional stress are considered major factors contributing to endodontic instrument failure [20]. A review by Plotino *et al.* [22] further highlighted the absence of standardized methods for evaluating the cyclic fatigue resistance of endodontic instruments, despite the widespread clinical use of NiTi rotary files for more than two decades.

Current studies indicate that the cyclic fatigue of NiTi files is influenced by factors such as file cross-sectional design, temperature changes during use, rotational speed, and torque [11, 24]. Fatigue resistance decreases with increasing file size due to the greater metal mass at the point of maximum stress [11, 20]. Canal anatomy – including curvature, calcification, and radius of curvature – also significantly impacts instrument failure [25–27]. Unexpected damage can also occur in SAF system files.

In an *in vitro* study on straight artificial canals, Hof *et al.* [15] observed the first mechanical fatigue failure after 29.1 ± 1.2 minutes, typically involving the detachment of an arch from its longitudinal beam. However, ADA-recommended testing showed that SAF files could operate for over 150 minutes without failure in any of the 10 files tested [15].

Akçay *et al.* [18], using metal blocks with curved canals (45° and 60°), reported no file separations; damage – again in the form of arch detachment – occurred during the second working cycle. Similarly, Farmakis *et al.* [17] observed structural distortions in all 19 SAF files after the third working cycle in extracted human teeth with 20° canal curvature. No complete fractures

were noted; damage was limited to partial detachment at one or both ends of the file's lattice structure.

In the present study, comparable results were obtained. All SAF files exhibited visible damage within the fourth working cycle, resulting in complete file disqualification after 16 minutes of use. The observed file lifespan was shorter than that reported by Hof *et al.* [15] in plastic blocks but consistent with findings from Akçay *et al.* [18], who employed metal canal models, and Farmakis *et al.* [17], who used an *ex vivo* model.

Solomonov *et al.* [19] reported a 0.6% separation rate during clinical use. In 80% of cases, fragments were successfully retrieved with a Hedström file or #30 micro debrider without additional dentin removal.

In the present study, consistent with the findings by Hof *et al.* [15], Akçay *et al.* [18], and Farmakis *et al.* [17], the most common type of damage was lattice cracking (Table 1). Three cases of fragment separation were recorded, resembling those described by Solomonov *et al.* [19]. However, the separated portions were small and always flushed out of the canal, with no fragments retained in the root dentin.

One of the most important factors influencing the cyclic fatigue resistance of NiTi files is root canal curvature [15, 17, 18, 26]. As shown by Kwak *et al.* [26], torque increases proportionally with greater canal curvature. However, research on the effect of curvature on SAF file damage is limited. Farmakis *et al.* [17] studied the performance of SAF in human teeth with varied canal anatomy but did not specify curvature angles or types of damage. Akçay *et al.* [18] tested SAF files in metal blocks with artificial canals wider than the file diameter. Their setup did not allow interruption of the file's motion, which may have biased the results. They reported a higher incidence of file damage in 60° canals compared to 45° canals ($p < 0.05$). Hof *et al.* [15] tested files in straight, plastic canals that do not reflect clinical conditions. In the present study, no significant difference in SAF file damage was observed between straight (0–10°) and mildly curved (10–20°) canals (Table 2). Thus, the findings apply only to canals with a limited curvature range.

The influence of canal cross-sectional shape on SAF file damage has been addressed in only a few studies. Paqué *et al.* [28] concluded that the SAF system is more effective in removing the smear layer from anatomically complex areas and better preserves the original canal shape compared to conventional rotary instruments. Farmakis *et al.* [17] included canals of varying anatomies but did not analyse the influence of cross-sectional shape. Similarly, Hof's study on the resistance of SAF files lacked such an analysis [15]. In the present study, no correlation was found between the canal's cross-sectional shape and the incidence of file damage.

Due to the unique structural design of the SAF system files and the distinct types of damage they may experience, the results obtained could not be compared to a control group composed of conventional

rotary endodontic files. Additionally, it was impossible to include a sufficient number of extracted human teeth with severely curved canals (curvature > 25°) because such specimens were often compromised during atraumatic extraction, rendering them unsuitable for standardisation and analysis.

Conclusions

Within the limitations of this *in vitro* study, neither the degree of root canal curvature (0–20°) nor the cross-sectional canal shape had a significant effect on the incidence of SAF file damage. The most frequently observed type of damage was cracking of the lattice structure. Despite the occurrence of file damage, instrumentation could be completed successfully in all cases. This suggests that the SAF system can be considered a safe and effective tool for root canal preparation in canals with variable morphology.

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Ethical approval

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Conflict of interest

The authors declare no conflict of interest.

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