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The Contribution of the Self-adjusting File in Debris Removal in Root Canal Retreatment: A Systematic Review and Meta-analysis of *in Vitro* Studies

Salma El Abbassi [a*], **Majid Sakout** [b]

a Department of Endodontics and Restorative Dentistry, Faculty of Dental Medicine, Mohammed V University in Rabat, Rabat, Morocco; b Military Teaching Hospital Mohammed V, Rabat, Morocco

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Corresponding author: Salma El Abbassi, Department of Endodontics and Restorative Dentistry, Faculty of Dental Medicine, Mohammed V University in Rabat, Rue Mohammed Jazouli, BP 6212 Madinat Al Irfane, Rabat, Morocco.

E-mail: salma_elabbassi@um5.ac.ma

Abstract

Introduction: To assess the benefit of the adjunctive use of the Self-adjusting File (SAF) system as a final step in root canal retreatment for the removal of residual filling material. **Materials and Methods:** A systematic review of *in vitro* studies was conducted on extracted mature permanent teeth undergoing endodontic retreatment, comparing residual canal debris before and after supplementary use of the SAF system. The electronic search was performed across nine databases: MEDLINE (*via* PubMed), the Cochrane Library, Scopus, EBSCOhost, Elsevier, ScienceDirect, Web of Science, LILACS, and Google Scholar. Data from the included studies were extracted and analyzed, and key findings were summarized alongside a risk of bias assessment. A random-effects meta-analysis was performed using Hedges' g as the effect size measure. Studies were stratified into three subgroups according to canal morphology: oval-shaped, curved mesial, and severely curved canals. All statistical analyses were conducted in JASP software using restricted maximum likelihood (REML) estimation. **Results:** From an initial pool of 517 identified records, 16 studies met the inclusion criteria. No retreatment method achieved complete debridement of the root canal system. Nevertheless, the adjunctive use of the SAF system significantly improved debris removal in eight of the included studies. **Conclusion:** The adjunctive use of the SAF system following root canal filling removal improves canal cleanliness in anatomically challenging canals, particularly oval-shaped and severely curved configurations. However, the available evidence remains insufficient to support its routine clinical application, and its use should be guided by root canal morphology.

Keywords: Residual Debris; Retreatment; Self-adjusting File

Introduction

Orthograde endodontic retreatment is indicated in cases of persistent symptoms and signs suggestive of an underlying endodontic infection. The primary objective of retreatment is to address deficiencies of the initial treatment and to establish favorable conditions for periapical healing [1].

Complete removal of root canal filling material is an essential prerequisite for:

- Gaining access to the contaminated portions of the canal system (whether due to persistent infection or contamination resulting from coronal microleakage);
- Eliminating filling materials that may serve as a substrate for microorganisms and bacterial toxins;
- Establishing patency of the apical third, which is often neglected during initial endodontic treatment.

Several methods have been described for the removal of root canal filling materials. Regardless of the technique employed with or without solvents, manual or mechanized, or hybrid approaches combining multiple systems studies consistently indicate that complete removal of all filling material is difficult, if not unachievable [2].

The reported percentage of residual debris ranges from 0.02% to 43%, with most studies reporting values below 10% [2]. Even

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minimal residual debris may harbor bacteria and compromise the integrity of the subsequent root canal obturation.

This underscores the necessity of achieving not only effective but also thorough removal of all filling material. Since no single retreatment system has proven universally sufficient for this purpose, supplementary instrumentation steps have been proposed to optimize canal cleanliness after bulk filling removal, including sonic and ultrasonic activation, laser techniques, and the XP-endo Finisher system. A micro-CT study [3] confirmed that such supplementary instrumentation significantly enhances debridement in the apical third of curved canals, further supporting the need for an additional step following bulk filling removal.

The Self-adjusting File (SAF) system (ReDent Nova GmbH & Co. KG, Berlin, Germany), by virtue of its unique design and mechanism of action, has been proposed as a final step for the removal of residual filling material. Its use is supported by several rationales [4-6]:

- Upon insertion into the canal, the SAF file recovers its original cylindrical shape, expanding to conform to the canal morphology in both the transverse and longitudinal dimensions. As a result, the instrument contacts a greater proportion of the canal wall surface, which is particularly advantageous in oval, flat, or C-shaped canals.
- The outer surface of the nickel-titanium lattice comprising the SAF file is mildly abrasive. Combined with its vibratory motion, this abrasiveness produces a "*sandpaper-like*" effect along the canal walls, thereby enhancing mechanical debridement and disinfection, an effect further potentiated by the system's continuous irrigation capability.

In light of the above, the present systematic review and meta-analysis were conducted to evaluate the benefits of the SAF system as a supplementary final step following root canal filling removal.

Materials and Methods

Search strategy

A comprehensive literature search was conducted in accordance with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines [7]. The review was prospectively registered in the PROSPERO database (ID: CRD42021278914). The primary aim of this work was to address the following question:

Does the additional use of the Self-adjusting File (SAF) system following root canal retreatment improve debris removal and canal cleanliness?

The study selection was guided by the PICO (Patient/Problem, Intervention, Comparison, Outcome) framework:

- **Population:** Extracted mature permanent teeth.
- **Intervention:** Additional use of the Self-adjusting File (SAF) system following conventional root canal retreatment.
- **Comparison:**

(i) Canal retreatment performed without the SAF system.

(*ii*) Canal retreatment that includes an additional cleaning step with the SAF system.

- **Outcome:** Evaluation of the SAF system's contribution to the quality of canal cleanliness at the end of retreatment.

The electronic databases PubMed, Web of Science, Scopus, Cochrane, LILACS, EBSCOhost, Google Scholar, and ScienceDirect were searched comprehensively for relevant studies published up to September 2024. No date or language restrictions were applied.

Search terms and combinations

- Retreatment OR retrieval OR removal OR remnant OR remaining OR cleanliness
- Gutta-percha OR sealer OR paste OR sealant OR filling OR obturation
- Root canal OR endodontics OR endodontology
- Self-Adjusting File OR SAF OR Self-Adjustable File
- **Search Combination**
- #1 AND #2 AND #3 AND #4 **(adjusted per database syntax);**
- **Examples of search equations:**

- **MEDLINE-PubMed:** *((gutta-percha) OR (gutta percha) OR sealer OR paste OR sealant OR obturation OR filling) AND (removal OR remaining OR cleanliness OR retreatment OR retrieval OR remnant) AND ((root canal) OR endodontics OR endodontology) AND ((self-adjusting file) OR (self-adjusting-file) OR (SAF) OR (self-adjustable file))*
- **SCOPUS:** *((TITLE-ABS-KEY ("root canal" OR endodontics OR endodontology)) AND (TITLE-ABS KEY (removal OR remaining OR cleanliness OR retreatment OR retrieval OR remnant)) AND ("gutta-percha" OR "gutta percha "OR sealer OR paste OR sealant OR obturation OR filling)) AND (TITLE-ABS-KEY ("self-adjusting file" OR "self- adjusting-file" OR "SAF" OR "self-adjustable file"))*

The search strategy was adapted to the specific syntax requirements of each database. In addition, the reference lists of all included studies were manually screened to identify any relevant articles not captured by the electronic search.

Screening and selection of the studies

Study selection

Two reviewers independently screened the titles and abstracts of all

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retrieved articles against the predefined inclusion criteria. When the title and abstract provided insufficient information to determine eligibility, the full text was retrieved and assessed. Only studies fulfilling all inclusion criteria were included in the final review.

The included studies met the following criteria:

- **Type of study:** *In vitro* studies conducted on mature extracted permanent teeth requiring retreatment.
- **Comparison:** Studies comparing the amount of residual canal debris before and after the supplementary use of the SAF system within the same sample.

Data Extraction

Data extraction was performed independently by two reviewers using a standardized form, and the extracted data were categorized into three main groups: study characteristics, methodology, and outcomes.

- **Study characteristics** included: authors, publication year, sample size, and tooth type.
- **Methodology** included: system/technique used for initial canal shaping, irrigants used during initial shaping, master apical file size, obturation techniques and materials, storage period, system/technique used for root canal filling removal, use of solvent, irrigation protocol during retreatment, and details of SAF file usage.
- **Outcomes** included the main findings of the studies.

Risk of bias assessment

The methodological quality of the included studies was assessed using criteria adapted from previously published systematic reviews of in vitro studies [8, 9]. The following parameters were evaluated:

- Sample size calculation.
- Randomization of samples.
- Standardization of samples based on canal curvature.
- Standardization of samples based on root canal anatomy.
- Presence of a control group.
- Quality assessment of the root canal filling (obturation).
- A specification that all procedures were performed by a single operator.
- Adherence to the manufacturer's recommended protocol.
- Blinded evaluation of the outcomes.
- Comprehensive reporting of relevant data.

Each parameter was scored as "Yes" (Y) if clearly reported and addressed, or "No" (N) if not. The overall risk of bias for each study was categorized as follows:

- **High risk:** 1–3 parameters scored "Yes".
- **Medium risk:** 4–6 parameters scored "Yes".
- **Low risk:** 7–10 parameters scored "Yes".

Meta-analysis

Studies were eligible for inclusion if they met the following criteria: the outcome was the volume of residual root canal filling material, expressed either as an absolute value (mm^3) or as a percentage of the initial filling volume, and micro-computed tomography (micro-CT) was used as the evaluation method. Studies were excluded if outcomes were expressed as two-dimensional surface area measurements or if the evaluation method was not clearly described.

Effect sizes were expressed as standardised mean differences using *Hedges' g*. A negative Hedges' g value indicates less residual filling material in the SAF group. All analyses were conducted in JASP (Jeffreys's Amazing Statistics Program, version 0.18; University of Amsterdam, Amsterdam, Netherlands) using a random-effects model with restricted maximum likelihood (REML) estimation. Heterogeneity was quantified using Cochran's Q statistic and the between-study standard deviation τ. Studies were stratified into three pre-specified subgroups based on canal morphology: oval-shaped canals, curved mesial canals, and severely curved canals.

Results

Selection of studies

A PRISMA flow diagram summarizes the study selection process, including the results of the electronic database search and the subsequent screening and selection procedure (Fig. 1).

Eleven studies were assessed as having a moderate risk of bias, while five presented a low risk of bias. The detailed risk-of-bias assessment of the included studies is presented in Table 1.

Characteristics of studies

The stratified forest plot shows that the benefit of the SAF as a supplementary retreatment step is modulated by root canal morphology (Fig. 2). The characteristics of the included studies are summarized in Table 2. In oval-shaped canals, the SAF demonstrated a statistically significant advantage over conventional rotary instruments (g=−0.55, P=0.041). In curved canals, the pooled effect did not reach statistical significance (g=−0.27, P=0.210). In severely curved canals, the strongest and most consistent effect was observed (g=−1.06, P=<0.001; τ^2=0.00), suggesting particular benefit in this morphology. Overall, the full dataset confirmed a significant moderate effect in favour of the SAF (g=−0.50, P=0.002), with acceptable between-study heterogeneity (τ=0.28), supporting its use as a supplementary step during endodontic retreatment.

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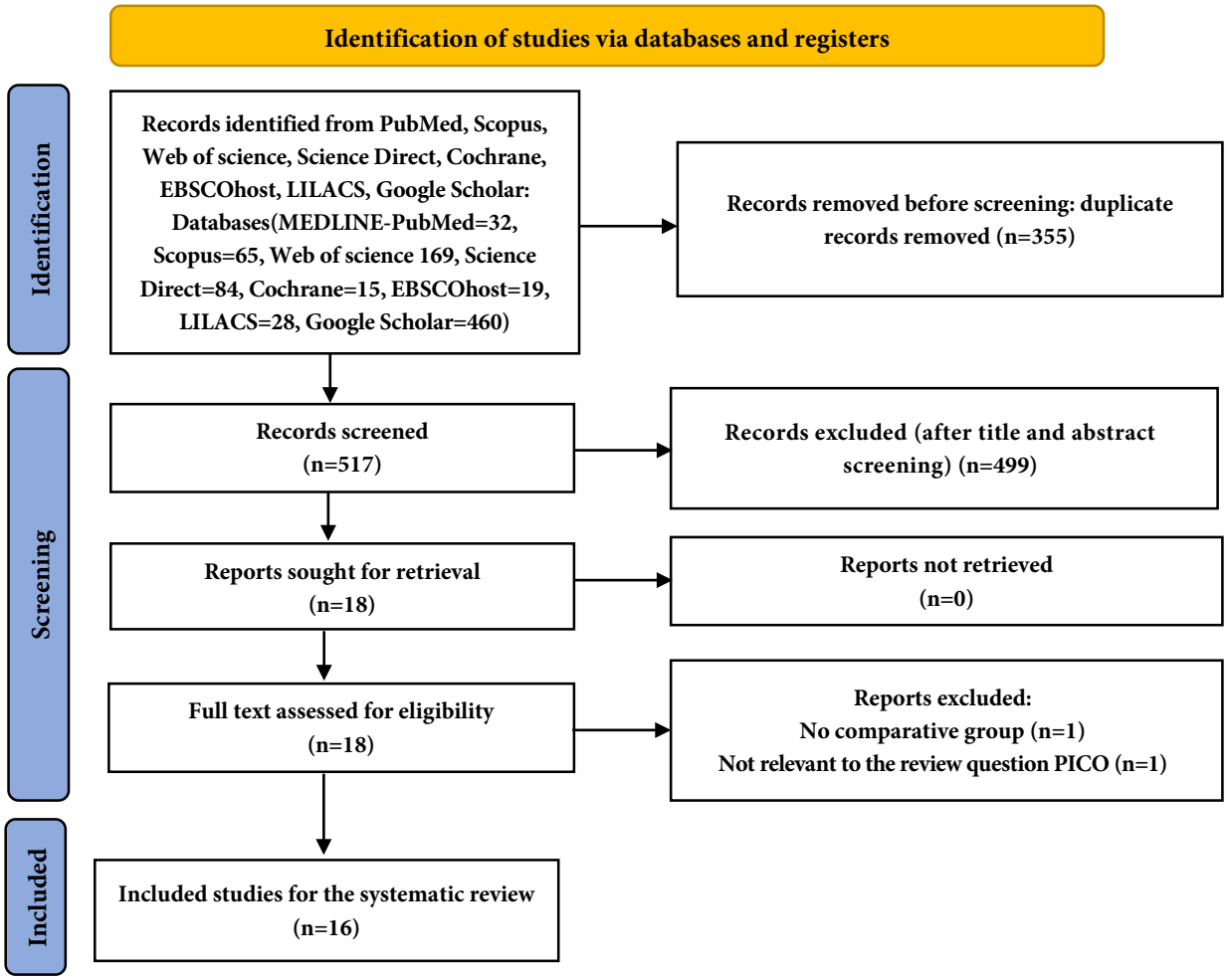

Figure 1. PRISMA flow diagram for study selection

Table 1. Risk of bias assessment of the included in vitro studies

Study	Sample size	Randomization	Root Curvature standardization	Root canal shape Standardization	Control group	Obturation quality assessment	Single operator	Manufacturer protocol	Blinding	Data available	Risk of bias
Abramovitz *et al.* [10]	N	N	Y	Y	Y	Y	N	Y	N	Y	Medium
Solomonov *et al.* [11]	N	Y	Y	Y	N	Y	N	Y	N	Y	Medium
Voet *et al.* [12]	N	N	Y	Y	Y	N	N	Y	N	Y	Medium
Alves *et al.* [13]	N	N	Y	Y	Y	Y	N	Y	Y	Y	Low
Keleş *et al.* [5]	N	Y	N	Y	Y	Y	Y	Y	N	Y	Low
Keleş *et al.* [14]	N	Y	N	Y	N	Y	Y	Y	N	Y	Medium
Simsek *et al.* [15]	N	N	Y	Y	N	Y	Y	Y	N	Y	Medium
Yürüker *et al.* [16]	N	Y	Y	Y	N	Y	N	Y	N	Y	Medium
Aslan *et al.* [17]	N	Y	Y	Y	N	Y	N	Y	N	Y	Medium
Pawar *et al.* [18]	N	Y	N	N	N	Y	N	Y	N	Y	Medium
Keleş *et al.* [19]	N	Y	Y	Y	Y	Y	Y	Y	N	Y	Low
Machado *et al.* [20]	N	Y	Y	Y	N	N	Y	Y	N	Y	Medium
Kumar *et al.* [21]	N	Y	Y	Y	N	Y	N	N	N	N	Medium
Silva *et al.* [22]	N	N	N	Y	N	Y	N	Y	Y	Y	Medium
Kiraz *et al.* [23]	Y	Y	Y	Y	N	Y	Y	Y	N	Y	Low
Zhekov *et al.* [24]	N	Y	Y	Y	Y	Y	N	Y	N	Y	Low

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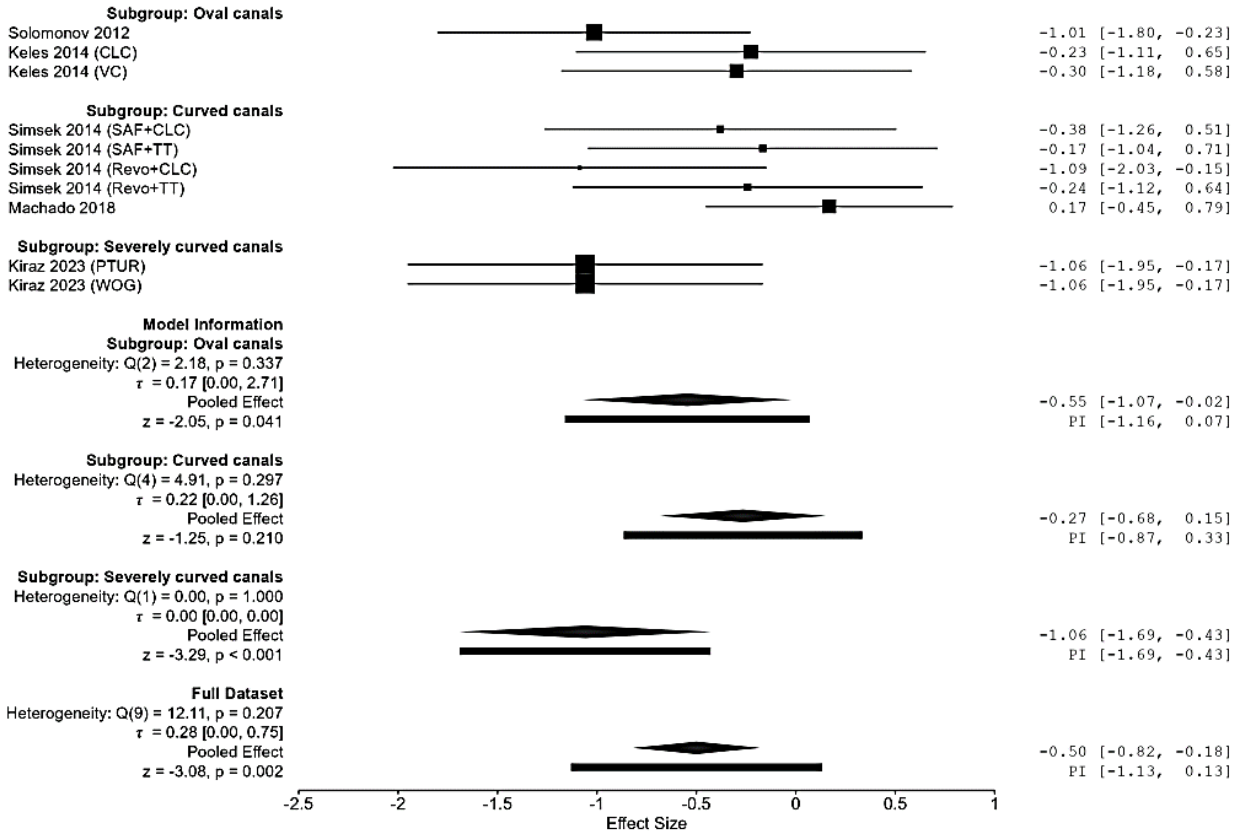

Figure 2. Forest plot of pooled effects by subgroup according to canal curvature (oval, curved, and severely curved canals)

Discussion

The removal of root canal obturation material represents a critical phase in orthograde endodontic retreatment, as it directly determines the potential for effective cleaning and disinfection. Although numerous techniques have been described for this purpose, there is a consensus in the literature that achieving complete freedom from residual material remains challenging, if not impossible [2].

Consequently, hybrid techniques are frequently investigated to identify effective and reproducible methods for root canal filling removal [16].

The rationale for this review was informed by a prior systematic review [25], which evaluated the efficacy of the XP-endo Finisher system as a final step in retreatment and served as a methodological reference for the present work. The findings of that review underscore the need to explore alternative supplementary cleaning methods, such as the Self-adjusting File (SAF) system.

The SAF system, by virtue of its unique design enabling adaptation to the canal cross-section, inherent abrasiveness, and integrated continuous irrigation, has been proposed as an effective means of cleaning canal walls following filling material removal [17]. Accordingly, this systematic review was conducted to evaluate the evidence supporting the use of the SAF system as a supplementary final step in orthograde endodontic retreatment.

The retreatment protocols and the main findings of the included studies are summarized in Table 3. Among the 16 studies included in this systematic review, eight concluded that the adjunctive use of the SAF system significantly improved the removal of root canal filling material and enhanced canal cleanliness [10-12, 14, 15, 18, 21, 24].

Considerable methodological heterogeneity was observed across the included studies. Disparities were noted with respect to sample characteristics, initial shaping and obturation techniques, and the methods employed for filling material removal. The use of a solvent, for instance, was inconsistent across studies; some authors employed one, while others deliberately avoided it, citing its potential as a confounding factor [14]. Given that each variable may directly influence outcomes, future research would benefit from the adoption of standardized protocols to enable more accurate and meaningful comparisons across studies.

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Table 2. Characteristics of included studies evaluating SAF in root canal retreatment

Study	Sample characteristics	Initial canal preparation technique	Irrigants	Master apical file	Obturation technique & materials	Storage conditions	Root canal filling removal technique
Abramovitz *et al.* [10]	25 mandibular molars (mesial roots only), curved canals (24°±10.6°)	ProTaper® rotary to F2+balanced force technique (#30–#45 NiTi K-files)	3% NaOCl	Size 45	Lateral compaction with size 45 cone+AH-26 sealer	7 days, 37°C, 100% humidity	Stage 1: ProTaper Universal Retreatment (D1–D3); Stage 2: SAF
Solomonov *et al.* [11]	40 mandibular molars	ProTaper® rotary system	NaOCl+17% EDTA	F2 (size 25)	ProTaper gutta-percha cone+AH-Plus sealer	30 days, 37°C, 100% humidity	G1: PTUR (D1–D3)+F1/F2 files; G2: Profile files (25/.06)+SAF
Voet *et al.* [12]	33 extracted maxillary first molars	ProTaper® rotary system	2% NaOCl+ EDTA+PUI	F3 (size 30)	Lateral compaction with 30/0.06 cone+AH-26 sealer	1 week, 37°C, 100% humidity	PTUR (D1–D3)+Hedström file (#30); Stage 2: SAF
Alves [13]	60 teeth (maxillary incisors and canines)	Alternating rotation movement technique	2.5% NaOCl+ EDTA	Size 50–60	Lateral compaction+AH-26 sealer	37°C, 100% humidity	D-RaCe retreatment files; additional groups: K-file, SAF, H-file techniques
Keleş *et al.* [5]	48 maxillary premolars with oval canals	Revo-S+K-file+SAF	5% NaOCl+15% EDTA	Size 45	Warm vertical condensation+AH-Plus sealer	3 weeks, 37°C, 100% humidity	R-Endo (Re-R3 #25)+SAF
Keleş *et al.* [14]	28 maxillary premolars with oval canals	Revo-S+K-file	5% NaOCl+saline	Size 45	Lateral compaction or warm vertical condensation+AH-Plus sealer	3 weeks, 37°C, 100% humidity	R-Endo (Re-R3)+SAF
Simsek *et al.* [15]	20 mandibular molars with curved mesial roots	MV canals: SAF; ML canals: Revo-S	2.5% NaOCl+17% EDTA	Size 25	Cold lateral compaction or thermoplasticized technique+AH-Plus	7 days, 37°C, 100% humidity	Gates Glidden+D-RaCe; reinstrumentation; SAF
Yürüker *et al.* [16]	48 mandibular premolars	ProTaper® rotary system	2.5% NaOCl+17% EDTA	F4 (size 40)	Lateral compaction with F4 cone+AH-26	2 weeks, 37°C, 100% humidity	PTUR alone; PTUR+SAF; PTUR+Reciproc; PTUR+H-file
Aslan *et al.* [17]	60 maxillary central incisors	Step-back technique	1% NaOCl+17% EDTA+saline	Size 35	Lateral compaction+AH-Plus	1 month, 37°C, 100% humidity	H-file; Mtwo; Revo-S; SAF
Pawar *et al.* [18]	40 maxillary canines	WaveOne Primary files	3% NaOCl+17% EDTA + distilled water	Size 25	Warm lateral compaction+AH-Plus	30 days, 37°C, 100% humidity	PTUR+WaveOne; PTUR+SAF
Keleş *et al.* [19]	90 mandibular canines	Revo-S crown-down technique	5% NaOCl+17% EDTA+distilled water	Size 25	Warm vertical compaction+AH Plus	1 week, 37°C, 100% humidity	R-Endo+K-file; SAF, PUI, Er:YAG, PIPS
Machado *et al.* [20]	60 mesial canals of mandibular molars (Vertucci type IV)	BioRaCe	2.5% NaOCl+17% EDTA+distilled water	Size 25	Single cone and warm vertical compaction+AH-26	7 days, 37°C, 100% humidity	D-RaCe retreatment+SAF/TRUShape/XP-endo Shaper+XP-endo Finisher R
Kumar *et al.* [21]	20 mandibular first premolars	ProTaper®	Not reported	Not reported	Warm vertical compaction	Not reported	Mtwo Retreatment+H-file or SAF
Silva *et al.* [22]	20 mandibular second molars with C-shaped canals	Reciproc	1% NaOCl+17% EDTA+PUI+saline	Size 25	Tagger hybrid technique (R25 gutta-percha+AH-26)	1 month, 37°C, 100% humidity	Reciproc+Mtwo; SAF or H-file
Kiraz *et al.* [23]	66 mandibular first molars with severely curved MV canals	ProTaper®	2.5% NaOCl+17% EDTA+saline	Size 25	Single cone ProTaper F2+AH-Plus	14 days, 37°C, 100% humidity	PTUR/WaveOne Gold followed by XP-endo Finisher, SAF, or Er,Cr:YSGG laser
Zhekov *et al.* [24]	50 single-rooted teeth with straight canals (<5°)	ProTaper Gold system	2.5% NaOCl+17% EDTA+saline	Size 25	Monocone technique (BioRoot RCS+F2 gutta-percha)	4 weeks, 37°C, 100% humidity	PTUR+F3; PTUR+PUI; PTUR+SAF; SAF+chloroform; SAF+citric acid

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Table 3. Summary of SAF-assisted root canal retreatment protocols and outcomes of included studies

Study	Solvent use	Irrigation during retreatment	SAF protocol during retreatment	Main findings
Abramovitz *et al.* [10]	Chloroform	3% NaOCl	SAF (#1.5 mm) activated with RDT3 at 5000 rpm for 4 min with continuous irrigation (4 mL/min). Chloroform (50 µL) was used after initial irrigation.	No technique achieved complete removal of filling material. SAF significantly reduced residual material; the clean apical region increased from 28% after initial retreatment to 84% after SAF.
Solomonov *et al.* [11]	Chloroform	Group 1: 5.25% NaOCl+17% EDTA; Group 2: 4% NaOCl	SAF (#2.0 mm) was activated under irrigation, followed by chloroform cycles and EDTA activation.	Complete removal was not achieved. Profile #25 combined with SAF showed greater reduction of residual debris and shorter operating time than ProTaper alone.
Voet *et al.* [12]	Not used	2% NaOCl	SAF was used under continuous internal irrigation (5 mL/min).	Supplementary SAF significantly reduced gutta-percha remnants compared with ProTaper instrumentation alone.
Alves *et al.* [13]	Eucalyptol	2.5% NaOCl	SAF was used under continuous internal irrigation (1 mL/min).	No significant difference was observed among techniques. SAF or H-file supplementation did not improve cleaning compared with manual instrumentation with larger apical enlargement.
Keleş *et al.* [5]	Not used	17% EDTA and 5% NaOCl	SAF (#2.0 mm) activated for 2 min with continuous irrigation (17% EDTA for 1 min followed by 5% NaOCl for 1 min; 5 mL/min).	No technique achieved complete removal. R-Endo + SAF improved debris removal in the coronal and middle thirds, but apical debris remained.
Keleş *et al.* [14]	Not used	17% EDTA and 5% NaOCl	SAF (#2.0 mm) was activated for 2 min under continuous irrigation (5 mL/min).	Complete removal was not achieved; SAF supplementation substantially reduced residual sealing material.
Simsek *et al.* [15]	Chloroform	2.5% NaOCl+17% EDTA	SAF (#2.0 mm) was activated for 2 min with continuous irrigation (5 mL/min), followed by EDTA and NaOCl rinse.	SAF was significantly more effective than D-RaCe alone. No technique achieved complete removal.
Yürüker *et al.* [16]	Not used	2.5% NaOCl+17% EDTA+distilled water	SAF (#2.0 mm) was used as supplementary instrumentation.	SAF improved removal after PTUR, but not significantly. Reciproc and H-file supplementation showed significantly greater removal.
Aslan *et al.* [17]	Guttasolv	1% NaOCl+17% EDTA+saline	SAF (#2.0 mm) under continuous irrigation (5 mL/min for 4 min).	No significant difference among the four retreatment approaches.
Pawar *et al.* [18]	Endosolv R	3% NaOCl	SAF was used with irrigation and Endosolv R activation cycles.	SAF after ProTaper retreatment improved canal cleanliness compared with ProTaper + WaveOne.
Keleş *et al.* [19]	Not used	5% NaOCl+17% EDTA+distilled water	SAF (#2.0 mm) for 2 min (EDTA 1 min + NaOCl 1 min) at 5 mL/min.	No technique achieved complete debris removal. Agitation methods improved debris removal.
Machado *et al.* [20]	Chloroform	2.5% NaOCl+17% EDTA	SAF (#1.5 mm) at 5000 vibrations/min with NaOCl irrigation followed by EDTA and NaOCl activation.	XP-endo Shaper and XP-endo Finisher R showed better cleaning than SAF; XP-endo Finisher R achieved complete cleaning.
Kumar *et al.* [21]	Not reported	Not reported	SAF was used as a supplementary final step.	SAF was more effective than H-files as a supplementary step after filling removal.
Silva *et al.* [22]	Not used	1% NaOCl+saline	SAF (#2.0 mm) under continuous irrigation for 3 min (5 mL/min).	C-shaped canals remained challenging. H-file supplementation removed more debris than SAF.
Kiraz *et al.* [23]	Orange oil	2.5% NaOCl	SAF (#2.0 mm) was activated for 2 min with continuous irrigation (5 mL/min).	SAF, XP-endo Finisher, and Er,Cr:YSGG laser significantly reduced residual debris with no difference among methods.
Zhekov *et al.* [24]	Chloroform	2.5% NaOCl+saline	SAF was used for 2 min with NaOCl irrigation (4 mL/min); additional groups used chloroform or citric acid.	All specimens had residual filling material. SAF or passive ultrasonic activation improved removal of bioceramic remnants; solvents did not enhance the removal.

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Nonetheless, not all studies supported these findings. Keleş *et al.* [5] reported that the SAF system achieved significantly greater debris removal than R-Endo (P<0.05); however, this effect was confined to the coronal two-thirds of the root canal. Conducted on maxillary premolars with oval canals, the study attributed the SAF's limited efficacy in the apical third to the challenging canal anatomy and a size mismatch between the master apical file (#25) and the SAF instrument diameter (#2.00), an outcome the authors considered predictable.

In contrast, a study employing a comparable methodology [14] reported that the SAF system significantly reduced endodontic debris, even in oval canals. This effect was more pronounced in teeth obturated with warm vertical compaction than in those filled with lateral condensation. The authors attributed this difference to the higher adhesive strength of AH-Plus sealer to dentin in the lateral condensation group, which likely complicated the removal process.

This finding is further supported by recent evidence demonstrating that supplementary cleaning techniques significantly enhance filling material removal in oval root canals [26].

In the study by Aslan *et al.* [17], conducted on maxillary incisors with wide canals, the SAF system proved less effective than the H-file. The authors reasoned that the SAF's abrasive action requires intimate contact with the canal walls, which is difficult to achieve in wide canal anatomies. This finding is consistent with those reported by Alves *et al.* [13] and further corroborated by Yürüker *et al.* [16], who attributed the superior efficacy of the H-file to its rigidity, aggressiveness, and the mechanical action of its circumferential filing and retraction movement.

In contrast, Zhekov and Keleş [19, 24] reported that the SAF instrument was effective for debris removal in straight, wide canals. This discrepancy may be explained by the nature of the comparisons employed; in these studies, the SAF was evaluated against intracanal agitation techniques such as sonic or ultrasonic activation, which share a similarly limited cutting efficiency compared to a rigid H-file.

In a study comparing hybrid retreatment techniques in mandibular molars with C-shaped canals, Silva *et al.* [22] found the SAF system to be less effective than the H-file. The authors suggested that the compression-induced contraction of the SAF file may prevent adequate navigation of the narrow isthmus characteristic of C-shaped canal anatomies.

The divergent results among the included studies preclude a definitive conclusion regarding the adjunctive use of the SAF system following filling material removal. This inconsistency is likely attributable to variations in sample characteristics, particularly canal anatomy, as well as differences in shaping and retreatment protocols across studies.

The cited authors primarily criticized the SAF file's performance in wide canals [13, 17]. The instrument's cleaning action relies on compression. In a narrow canal, the compressed file exerts lateral pressure against the walls, enhancing its abrasive effect. However, in wide, round canals, the file's high flexibility prevents this necessary compression and wall contact, reducing its cleaning effectiveness [10].

On the other hand, the SAF file has proven effective for debris removal in curved [10, 12, 15, 23] and narrow canals [14, 21]. While other methods, such as using larger instruments or hybrid techniques, can achieve high percentages of filling removal in simple anatomies, they carry a risk of causing apical transportation and straightening in curved canals [10]. The use of the SAF file could be advantageous in this specific situation due to its flexibility.

That is consistent with the results of the present meta-analysis, which demonstrate that the benefit of the SAF as a supplementary retreatment step is closely related to root canal morphology. The greatest advantage was observed in severely curved canals and oval-shaped canals, where conventional rotary instruments fail to contact the entire canal wall. This finding is consistent with the adaptive design of the SAF, which allows the instrument to conform to irregular cross-sections and reach areas inaccessible to circumferential rotary files. Overall, these results suggest that the SAF provides the greatest clinical benefit when used in canals with a non-circular cross-section, which represents precisely the anatomical context in which its supplementary use is most justified.

The findings of the present meta-analysis are broadly consistent with those of a recent systematic review, which similarly concluded that supplementary instrumentation improves root canal cleanliness following conventional retreatment procedures [25]. However, unlike the XP-Endo Finisher R, the benefit of the SAF observed in the present review was not uniform across clinical situations. The SAF demonstrated a significant advantage in oval-shaped and severely curved canals. These findings suggest that the SAF should not be regarded as a universally effective supplementary retreatment instrument, but rather as one whose clinical benefit is strongly dependent on root canal morphology. A direct comparison between the SAF and the XP-Endo Finisher R cannot be established from the available evidence, as no study has directly evaluated both instruments under identical experimental conditions. Future research directly comparing available supplementary systems across morphologically

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defined canal populations is therefore warranted to guide evidence-based clinical decision-making.

Approximately half of the included studies, comprising two with a low risk of bias [5, 24] and seven with a moderate risk [10-12, 14, 15, 18, 21] concluded that the SAF system significantly reduced canal debris. However, a nearly equal proportion of three studies with a low risk [13, 19, 23] and four with a moderate risk of bias [16, 17, 20, 22] reported inconsistent findings or limited efficacy. Given this equipoise and the considerable methodological heterogeneity across studies, the evidence supporting the routine adjunctive use of the SAF system remains inconclusive.

This divergence in both reported outcomes and methodological quality underscores the need for further research employing standardized protocols to yield more consistent and reliable results.

Furthermore, the vast majority of included studies failed to describe or implement blinding procedures. The absence of blinding during outcome assessment introduces a substantial risk of bias, particularly given the subjective nature of the primary endpoints. Evaluators' expectations may have influenced the interpretation of results, potentially compromising the objectivity of the data and the robustness of the conclusions drawn.

A notable methodological limitation of the present systematic review is the heterogeneity of outcome assessment methods. Residual root canal filling material was evaluated using fundamentally different techniques, including micro-computed tomography, cone-beam computed tomography, and stereomicroscopy, which differ substantially in resolution, dimensionality, and sensitivity to residual material. This inconsistency limits the direct comparability of results and should be considered when interpreting the findings of the present review. Standardization of outcome assessment methods, preferably using micro-CT with clearly defined resolution parameters, is therefore essential in future investigations to reduce methodological heterogeneity in this field.

Conclusion

Current evidence indicates that no instrumentation system has achieved complete removal of root canal filling material, thereby rendering canals entirely free of residual debris [2]. Consequently, considerable research effort has been directed toward establishing a reproducible and effective method for this purpose. Among the strategies investigated is the adjunctive use of the Self-Adjusting File (SAF) system following the initial phase of filling material removal.

The collective evidence from this systematic review and meta-analysis suggests that complete obturation removal remains an unrealistic objective, even with the adjunctive use of the SAF system. While the SAF demonstrates potential efficacy in anatomically challenging canals such as narrow, oval-shaped, or curved configurations, its clinical value in these specific contexts warrants careful consideration.

A key consideration is that residual debris from the previous obturation has not been established as a direct cause of retreatment failure [16], unless it creates a physical barrier that compromises adequate disinfection of the root canal system.

Mirroring the principles of initial endodontic therapy, the primary goal of retreatment is to establish and maintain canal patency to facilitate effective disinfection. In this context, minor residual debris should not be regarded as a primary cause of failure, particularly given that a threshold of 0.5% residual material has been proposed as an indicator of effective cleaning [11].

In conclusion, the present systematic review and meta-analysis find that the evidence supporting the adjunctive use of the SAF system for filling material removal is contingent upon root canal morphology, and its routine clinical application cannot be universally recommended.

From a clinical standpoint, conventional approaches such as hybrid techniques combining manual and mechanical instrumentation, or the use of larger-diameter instruments [2] appear effective for root canal filling removal in most cases. Other adaptive systems, such as the GentleFile, have also demonstrated promising cleaning ability as alternative instrumentation strategies [27]. Clinicians are advised to employ techniques with which they are proficient and that are readily available in their clinical setting.

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