# From Files to SAF: 3D Endodontic Treatment is Possible at Last

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**Abstract**

**3D cleaning, shaping and obturation of root canals has always been the desired goal of endodontic treatment which in many cases is difficult to attain. The introduction of NiTi rotary files made a major change in endodontic practice, making treatment easier, safer and faster. Nevertheless, after 16 years of intensive development, most of these instruments still share several drawbacks, the major one being the inability to three-dimensionally clean and shape oval root canals. The Self-Adjusting File (SAF) System was designed to overcome many of the current drawbacks of rotary file systems. It is based on a hollow, highly compressible file that adapts itself three-dimensionally to the shape of a given root canal, including its cross section. The file is operated with vibratory in-and-out motion, with continuous irrigation delivered by a peristaltic pump through the hollow file. A uniform layer of dentin is removed from the whole circumference of the root canal, thus achieving the main goals of root canal treatment while preserving the remaining root dentin. The 3D scrubbing effect of the file, combined with the always fresh irrigant, result in unprecedentedly clean canals which facilitate in turn better obturation. More effective disinfection of flat-oval root canals is another goal which is simultaneously attained. The safety of the root-canal treatment is also greatly enhanced by the high mechanical stability of the SAF and by using a new concept of no-pressure irrigation. The SAF System gets the operator much closer to the long-desired goal of 3D root-canal treatment.**

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## NiTi Rotary Files: A Paradigm Shift

The introduction of nickel titanium rotary files represented a paradigm shift in cleaning and shaping of root canals. This new technology revolutionized the process of endodontic treatment to the extent that a new era in endodontics, the NiTi era, was initiated. Over the years, there have been substantial developments in the design of rotary NiTi files, which can be divided into three generations. In the first generation, all instruments had a uniform taper and a uniform helical and flute design. ProFile, Quantec, GT, Hero 624 and FlexMaster are just a few of the instruments in this group. The second generation of instruments abandoned the uniform design, and they instead were designed with tapers that vary along the working part of the instruments and/or with a non-uniform flute design. Instruments such as ProTaper, Race, K3, Hero Shaper and Revo-S are included in this group. Currently, a third generation of rotary NiTi files is being developed based on new metallurgical concepts, including the Twisted File, on the one hand, and instruments made of the new M wire, such as GTX or WaveOne, on the other hand.

When considering the progress over the last 18 years, it is evident that a substantial improvement has occurred in everyday endodontic practices. Curved root canals may be treated efficiently and safely using a mechanized process and the efficiency of cleaning and shaping has been greatly enhanced. Nevertheless, there are still certain limitations and drawbacks.

### Complicated File Systems

Most file systems have too many instruments and recommend complicated sequences. A few manufacturers have recently recognized this drawback and have reduced the number of instruments in their systems. Some manufacturers have made modifications to the extent that they have created a "single file" concept in their instruments.

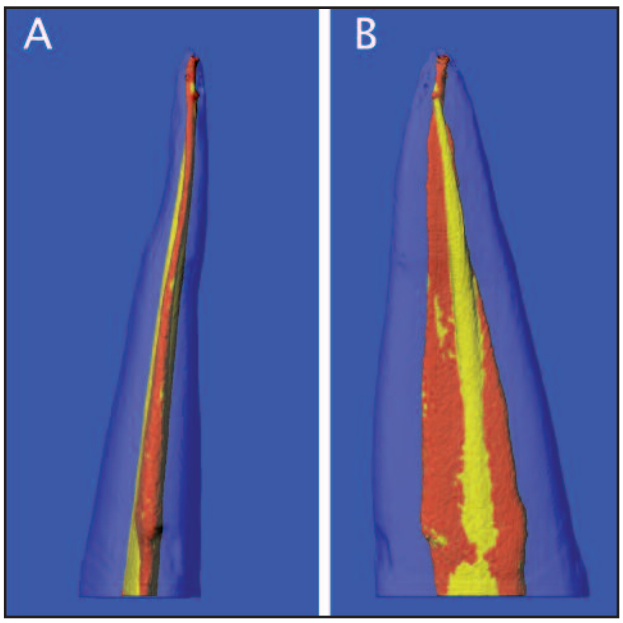


**Fig. 1** Flat-oval canal prepared with a rotary file. Buccal **(A)** and proximal **(B)** views of a micro-CT reconstruction of flat-oval canal prepared with a rotary file. Yellow: area affected by the procedure. Red: area unaffected by the procedure. Note that once obturated, the RCF is likely to look great on a 2D periapical radiograph, although the 3D micro-CT indicates that this preparation leaves much to be desired.

### Tedious Irrigation

Repeated and tedious irrigation is required when using the currently available instruments, and syringes and needles are frequently used during procedures. In recognition of the limitations and risks of using syringes and needles as irrigation tools, new irrigation technologies have recently begun to emerge based on negative pressure, but these new techniques make irrigation an even more complicated and time-consuming process.

### Canal Transportation

While the thinner rotary NiTi files are extremely flexible, the thicker files have a tendency to straighten a curved canal and cause apical transportation of the canal to the outer side of the curvature. Straightening canals with a double curvature is another aspect of the same issue, and it is not uncommon to find that an S-shaped canal is turned into one which resembles the $ sign, as presented by Peters et al.[1]

### Unexpected File Separation

File separation is a major drawback of many NiTi rotary file systems. This separation may occur with no warning signs, and the separated portion of the file is usually firmly screwed into the canal and is difficult to remove. With all of the advancements that have been made to date, file separation continues to be a major issue when using NiTi rotary files, both for novice and experienced operators.

### Ignoring the 3D Shape of the Root Canal

All rotary NiTi files are similar in that they ignore the 3D shape of the root canal. All of these files have a rotating blade and flutes to carry the cut dentin chips and debris coronally. In fact, NiTi files are not really "files" but may rather be considered to be circular machining devices. The use of the name "file" was extended from hand files, which were used with a filing motion. A circulating blade can only produce a circular bore, and indeed such a bore is imposed on every root canal, regardless of whether the cross-section is round or flat-oval. Attempts to overcome this issue with a "brushing" motion are of a limited value as they only affect the coronal third of the canal. The extent of this problem has recently been demonstrated in a study by Paqué et al, which was carried out in flat-oval canals of the distal roots of lower molars.[2]

### Oval Canals

Oval canals are found in 50%-70% of root canals.[3] In addition, canals with a tear-shaped cross section are common whenever a single root contains two canals (e.g., mesial roots of lower molars). Nevertheless, these aspects of root-canal anatomy are not seen or recognized in conventional 2D radiographs, as the long axis of their flat cross section is usually directed bucco-lingually, parallel to the direction of the x-ray beam. With the increased use of CBCT, these shapes are likely to be more and more often seen and recognized not only by endodontists but also in the clinical environment of general practice.

When rotary NiTi files are used in canals with flat-oval or tear-shaped cross sections, a circular bore is created, while the buccal and/or lingual recesses remain un-instrumented[4] (Fig. 1). It takes (a) the awareness that a given canal is flat and (b) expertise in creative use of hand instruments to try to overcome this problem.

Tissue or biofilm remnants along such un-instrumented recesses may lead to failure due both to inadequate disinfection and to the inability to properly obdurate the root-canal space[5,6] (Fig. 2).

It is commonly assumed that cleaning and disinfecting of such un-instrumented recesses is taken care of by the sodium hypochlorite irrigant. Nevertheless, recent studies indicate that the notion that "The file shapes; the irrigant cleans" in many cases represents wishful thinking rather than experimentally proved reality.[7]

Furthermore, recent studies by Paqué et al have demonstrated that not only does the isthmus area in mesial roots of lower molars fail to be cleaned by rotary files, but the rotating files *actively pack these recesses with dentin chips* that cannot be fully dislodged even with passive ultrasonic irrigation.[8,9]

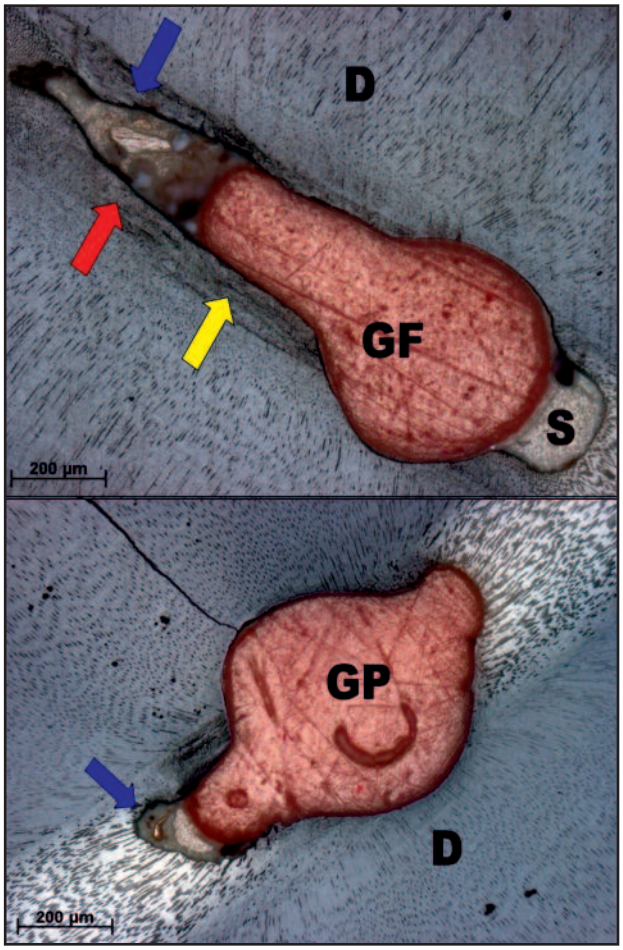


**Fig. 2** Flat-oval canals prepared with rotary files and obturated with warm gutta-percha. Buccal and/or lingual recesses full of debris (blue arrows) cannot be filled with either sealer (S) or gutta-percha (GP). *(Courtesy of Prof. Gustavo De-deus, Rio de Janero, Brazil).*

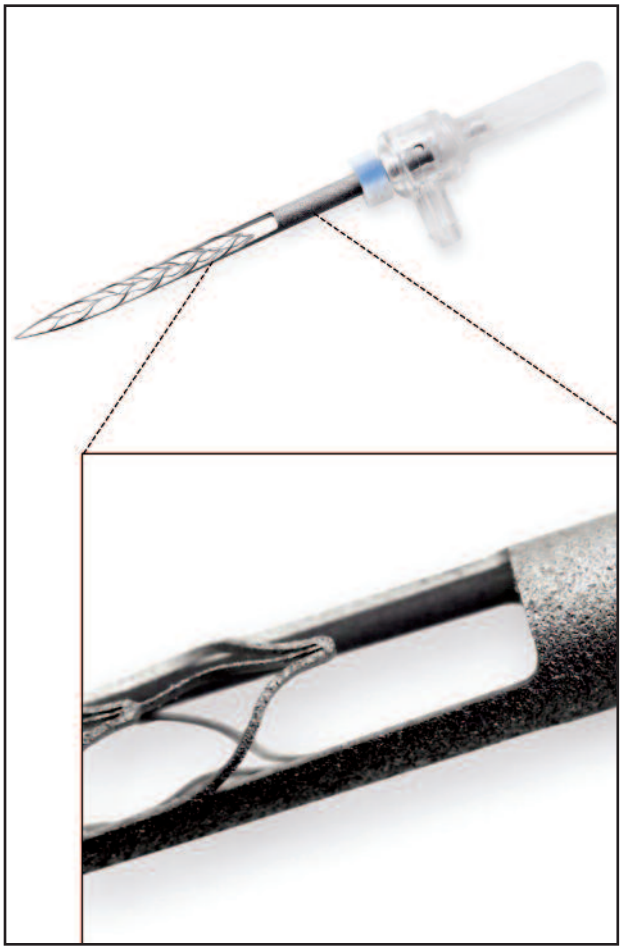

**Fig. 3** The Self-Adjusting File (SAF). The Self-Adjusting File (upper) and partial magnification of the file. Note the longitudinal beams, the structure of the arches, connected by strats, and the rough surface of the file's elements.

The clinical operator is usually happy with the radiographic results of root canal treatment performed with rotary NiTi files. Unbelievable curvatures negotiated with these files are presented in endodontic meetings and seminars. Nevertheless, one should always raise the question: *is the target of root canal treatment to produce beautiful x-ray images, or is it a 3D cleaning, shaping, disinfection and obturation of the root canal?* When looking at a periapical radiograph, one should always keep in mind that it is a mere bucco-lingual projection of the treatment outcome, potentially failing to reveal its 3D shape. Nevertheless, it is the 3D quality of our work that will actually make all the difference.

Looking at the great efforts and ingenuity that went into the development of NiTi files over the last 16 years and confronting the still remaining limitations and drawbacks of this great innovation, one cannot avoid the conclusion that solving these remaining problems and meeting these yet unmet challenges calls for out-of-the-box thinking. The newly introduced Self-Adjusting File (SAF) System represents just such a way of thinking.

## The SAF-System

The SAF-System is built around a hollow self-adjusting file, operated with a vibrating in-and-out motion while a continuous flow of fresh irrigant is simultaneously delivered into the canal through the hollow file.[10]

### The Self-Adjusting File (SAF)

The SAF is built as a hollow cylinder made of a thin NiTi lattice, with an asymmetrical tapered tip (Fig. 3). The file is extremely compressible: it can be compressed from its original 1.5 mm diameter to dimensions resembling those of a #20 K file[11] (Fig. 4). When inserted into a canal with

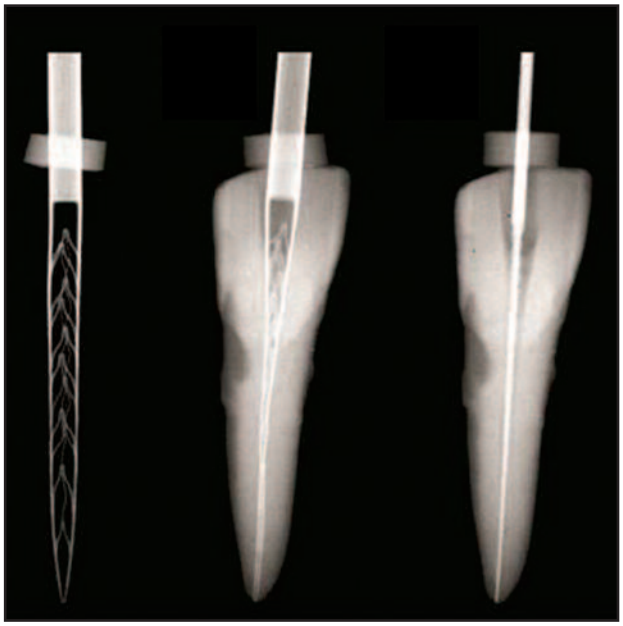

**Fig. 4** Compressibility of the Self-Adjusting File. Left: SAF in its relaxed form. Right: #20 K file inserted into the root canal. Center: The same SAF file inserted into the same root canal. Note the extreme compressibility from a 1.5 mm diameter to dimensions similar to those of #20 K file.

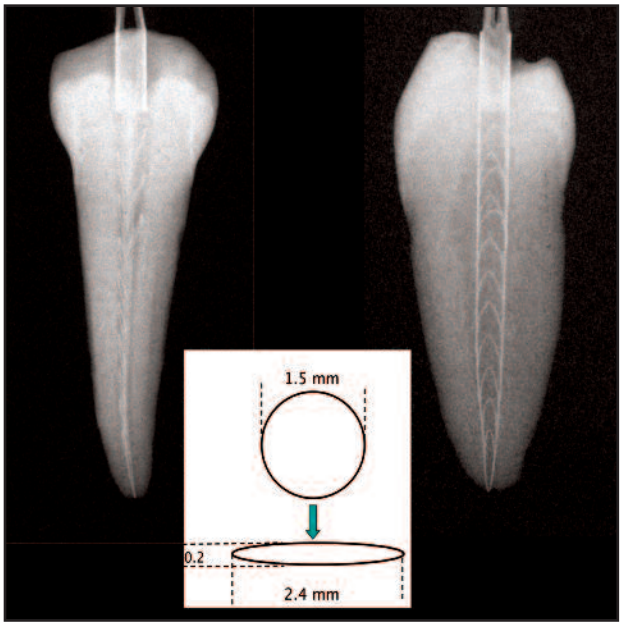


**Fig. 5** SAF adaptation into a flat-oval canal. SAF file inserted into a flat-oval root canal. Left: bucco-lingual view. Right: the same root from a mesio-distal projection. When a SAF is fully compressed mesio-distally in a flat oval canal, it will spread bucco-lingually as far as 2.4 mm. This occurs with no attention nor any action of the operator, thus the name "Self-Adjusting File."

a round cross section, it will be symmetrically, circularly compressed, but when inserted into a flat-oval canal, it will spread buccally and lingually and assume the cross section of that canal[10] (Fig. 5). This adaptation occurs without any special action or awareness on the side of the operator, hence the name Self-Adjusting File. The wall thickness of the lattice making the file is ~100 µm, and thus when fully compressed mesio-distally, the file may spread bucco-lingually as far as 2.4 mm.[7]

The asymmetrical tip of the SAF bends more easily to the peripheral direction than to any of the other directions (Fig. 3), a feature that is used to negotiate curvatures in the canal, as will be explained below.

### The RDT3 Handpiece Head

The SAF is operated with a special handpiece head, RDT3 (ReDent-Nova, Raanana, Israel) that is designed to be used with a variety of available handpieces such as KaVo GENTLEpower or similar (Fig. 6).

The RDT3 head turns the rotation of the motor into an in-and-out vibrating motion of the SAF file. It is operated at 5000 rpm and generates 5000 vibrations per min with amplitude of 0.4 mm.[10] The RDT3 also contains a special clutch element that allows it to slowly rotate when not engaged in the canal and to stop the rotation immediately when the file is inserted into the canal and engages its walls. Thus, the file never rotates when in contact with the canal walls, but rotates slowly during every outbound motion of the operator. This way, the SAF works as a file with only the vibratory mode, but enters the canal in a different circular position in every inbound motion of the operator. It was designed this way so that (a) the canal preparation will be uniform and even all around the canal and (b) the asymmetrical tip of the file will be able to find and negotiate curvatures without any special action on the side of the operator. This further justifies the name Self-Adjusting File.

### The VATEA Pump

The hollow design of the SAF is used to provide a continuous flow of fresh sodium hypochlorite throughout the file operation.[10,11] The SAF file is equipped with a rotating hub, to which a silicone tube is attached. The other end of the tube is attached to the special VATEA peristaltic pump (ReDent-Nova, Raanana, Israel) (Fig. 7). The pump is operated by a rechargeable battery and has a container that holds 500 mL of irrigant. A control panel allows the operator to set the flow rate between 1 and 10 mL/min and provides indications of the time elapsed. The pump is activated by a foot pedal with an on/off

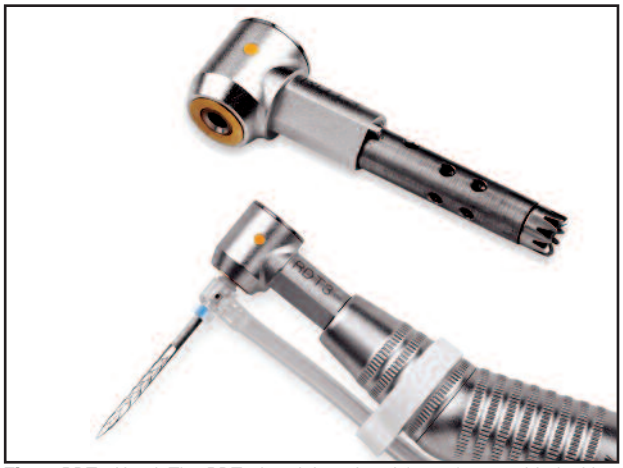

**Fig. 6** RDT3 Head. The RDT3 handpiece-head (upper) assembled with a KaVo handpiece (lower).

**Fig. 7** VATEA peristaltic pump. The VATEA peristaltic pump, attached to the SAF via a silicone tube. The control panel is set at 5 mL/min.

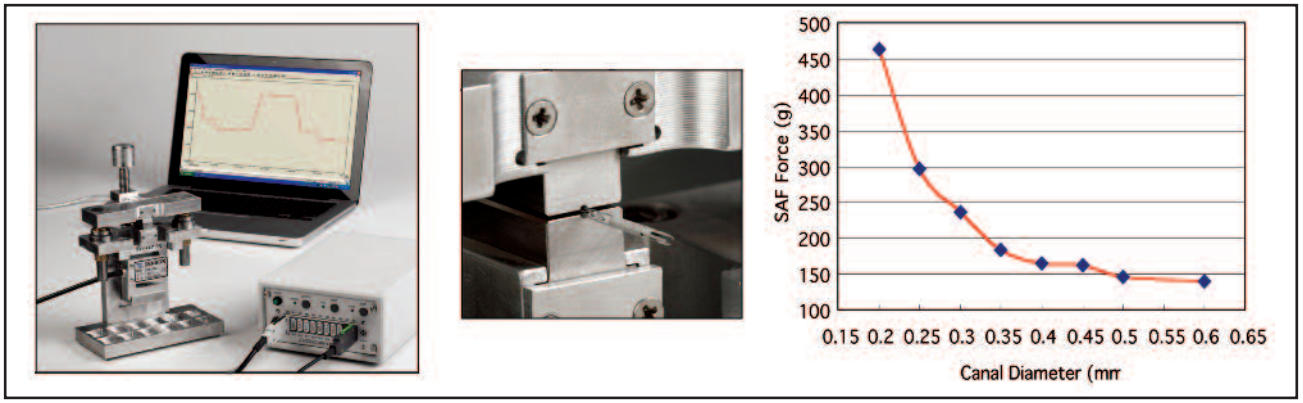


**Fig. 8** Force applied by a compressed SAF. SAF files were inserted into the artificial canal (center) of a measuring setup (left) and the force applied by the compressed file measured as function of the "canal" size (right).

action. The pump and all its connectors are compatible with any irrigating solution, including full-strength sodium hypochlorite.

**Mode of Action**

The SAF removes dentin with a filing motion in a manner similar to using sandpaper. When using sandpaper, a rough surface is applied with light pressure and with repeated motion back and forth, which allows the even removal of material. The surface of the SAF is delicately rough with 3 µm peak-to-bottom dimensions[11] (Fig. 3). This rough surface is present on every thin element of the NiTi lattice. The compression of the file generates circumferential pressure on the canal walls (Fig. 8). With the vibrating motion of the file, dentin is gradually and uniformly removed, resulting in a smooth surface that looks as if it were sandblasted.[11]

The pressure is greatest when the file is inserted into the root canal and declines with the gradual enlargement of the canal.[11] This change in pressure in turn affects the amount of dentin removed, which declines in a similar manner (Fig. 9).

The SAF file preserves the original shape of the canal and removes a uniform dentin layer from the entire circumference of the root canal.[10,11] A round canal will be enlarged as a round canal, while a flat-oval canal will be enlarged as a flat-oval canal (Figs. 10, 11, 12). This kind of preparation is substantially different from that of rotary NiTi files, which tend to create a "bore" with a circular cross section. Their results may be adequate if the canal originally had a round cross section but leaves much to be desired when a flat-oval root canal is concerned. Un-instrumented buccal and/or lingual fins are commonly encountered in such canals[4-7,10] (Figs. 11, 13).

**The Irrigation**

The VATEA peristaltic pump delivers a continuous flow of irrigant, which enters the canal through the hollow file

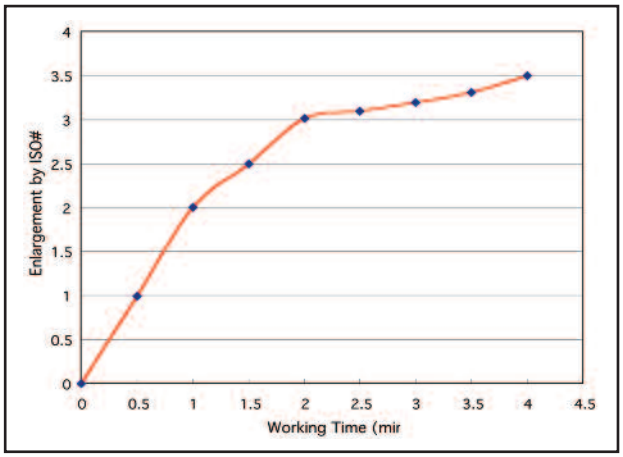


**Fig. 9** Dentin removal by the SAF. Dentin removal by the SAF over operation time. Note that most of the enlargement is done during the first 2 min of operation. Dentin removal was equivalent to 3 ISO sizes.

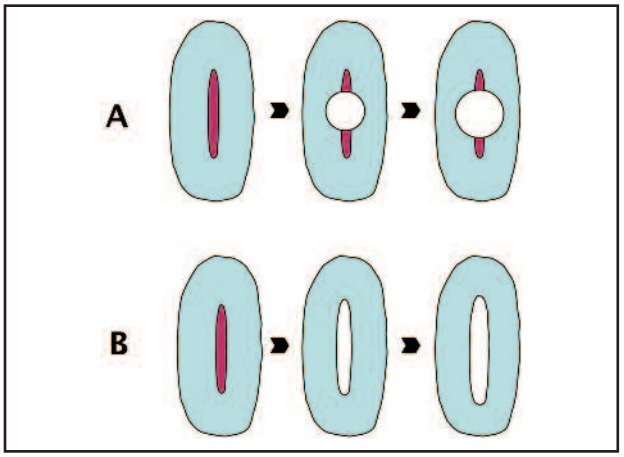


**Fig. 10** Preparing a flat-oval canal with rotary file vs. SAF. Schematic presentation of preparation of a flat-oval canal with a rotary file (upper) or the SAF (lower). The rotary file enlarges the center of the canal to accommodate a master cone, leaving the buccal and lingual recesses unaffected. The SAF enlarges the flat canal to a flat canal of larger dimensions. Note that the upper-center form is likely to result in an acceptable 2D radiograph. Also note the uneven remaining wall thickness of the canal treated with a rotary file, vs. the even wall thickness remaining after SAF preparation.

(Fig. 7). Because the file is built like a mesh, no pressure builds up in the canal. The motion of the file agitates the irrigant to such an extent that it effectively reaches the apical part of the canal with sonic activation. Throughout the procedure, the metal mesh is intimately adapted to the canal walls, resulting in a scrubbing motion. In an era of disputes between positive and negative irrigation systems, the SAF system may be defined as a *no-pressure irrigation system with sonic activation and a scrubbing effect*.

This filing and irrigation method results in a clean canal surface, even in the cul-de-sac apical part of the canal, which is commonly considered the most difficult part of the canal to clean.[12] Scanning Electron Microscopy (SEM) shows an unprecedentedly clean surface even in the apical part of the canal.

A recent study by Paqué et al has indicated that the packing of dentin chips into the isthmus, which occurs with rotary files, does not occur when the SAF System is applied in similar canals (personal communication). This strength of the SAF System is most probably due to the removal of dentin as a delicate powder suspended in a continuously replaced irrigant, as well as to the lack of rotation that would tend to pack the material into the isthmus.[8,9]

### Canal Disinfection

The continuous flow of fresh sodium hypochlorite is very effective in disinfecting the root canal. A recent study by Siqueira et al, conducted in challenging flat-oval canals, has shown that rotary files used with copious sodium hypochlorite irrigation had a limited antibacterial effect.[13] In 55% of the canals, bacterial growth could still be detected at the end of the cleaning and shaping procedure. When the SAF System was used in similar canals, the presence of bacterial growth could be detected in only 20% of the canals.[13]

### Obturation of Flat-Oval Canals

Studies by De-Deus et al[5,6] and others have shown that oval canals treated with conventional rotary files often cannot be properly obturated. When untreated buccal and/or lingual recesses contained tissue remnants or debris, neither the sealer nor the most flowable warm gutta-percha could flow into these recesses, resulting in compromised obturation (Fig. 2). Similar results were presented in a recent obturation study that examined the 3D adaptation of root-canal filling material to the canal walls using a micro-CT analysis.[14] Flat oval canals treated with rotary NiTi files and irrigated with syringe and needle presented with both a high percentage of the canal wall unaffected by the procedure and a high percentage of the canal wall untouched by the root-canal filling (Fig. 13). Similar SAF-treated canals were found to have lower values for both parameters, indicating better obturation that was attributed to better preparation of these challenging root canals[14] (Fig. 14).

### Resistance to File Separation

The SAF file is subjected to vigorous mechanical abuse during its operation. The file is repeatedly compressed and released with 5000 vibrations per min. Nevertheless, file separation is practically absent. When operated for as long

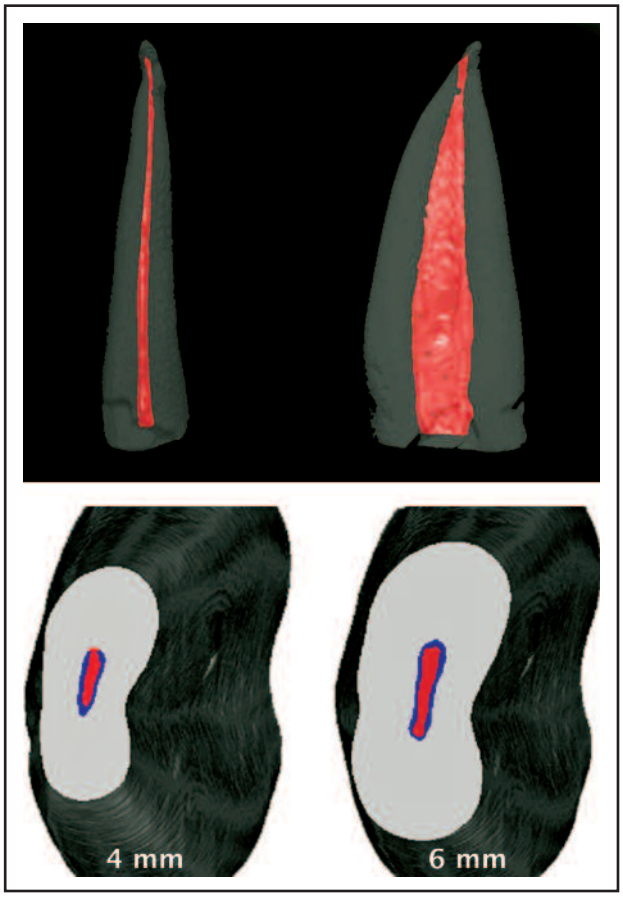


**Fig. 11** Flat-oval canal prepared with SAF. A micro-CT reconstruction of a flat-oval canal treated with a SAF. Upper: proximal and buccal views of the root canal before preparation. Lower: cross sections after preparation. Red: the canal before preparation; blue: the canal after preparation. Note the uniform removal of dentin at the whole circumference of the root canal.

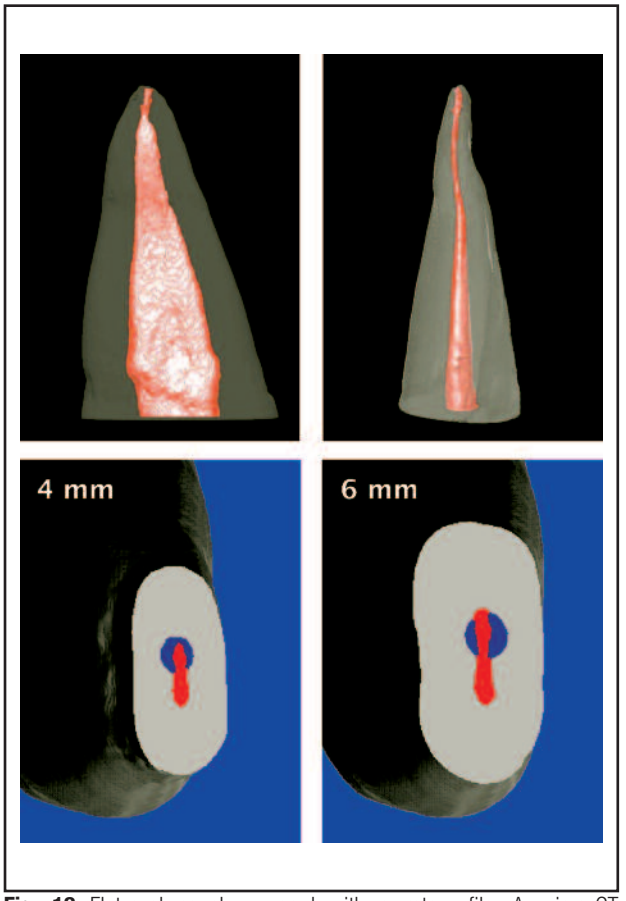


**Fig. 12** Flat-oval canal prepared with a rotary file. A micro-CT reconstruction of a flat-oval canal treated with a rotary file. Upper: proximal and buccal views of the root canal before preparation. Lower: cross sections after preparation. Red: the canal before preparation; blue: the canal after preparation. Note the untreated buccal recess.

as 30 min in simulated canals (Fig. 15A), the file retained its mechanical integrity.[11] Even when mechanical damage did occur after such prolonged use, it was limited to detachment of an arch and not to file separation (Fig. 15B). This mechanical resistance to file separation constitutes a new standard in mechanized NiTi files.

**Quality of Treatment**

Although long-term follow-up studies are not yet available, current experimental results indicate that the new SAF-System provides several benefits compared to rotary NiTi files. It has advantages in several aspects which are commonly accepted as desired goals in endodontic treatment: (a) 3D preparation resulting in a higher percentage of the canal wall affected by the procedure in both curved canals and oval-shaped ones; (b) better cleaning of root canals, including their apical part; (c) better disinfection in flat-oval canals; (d) enabling better 3D obturation, even of flat-oval root canals. Altogether, it is reasonable to conclude that the new SAF System constitutes a major step toward the desired goal of improved 3D preparation, cleaning, disinfection and obturation of root canals.

It is important to understand that the new system is not a magical panacea. As with any new system, it has a learning curve.[15] The system's mode of action is so different from any other traditional NiTi system that the novice operator, even if an experienced endodontist, should not begin by using it in the most challenging cases. Rather, one should first familiarize oneself with the system in a hands-on training setup, then use it on few simple, straightforward cases, and only then apply it in cases with gradually increasing challenge.

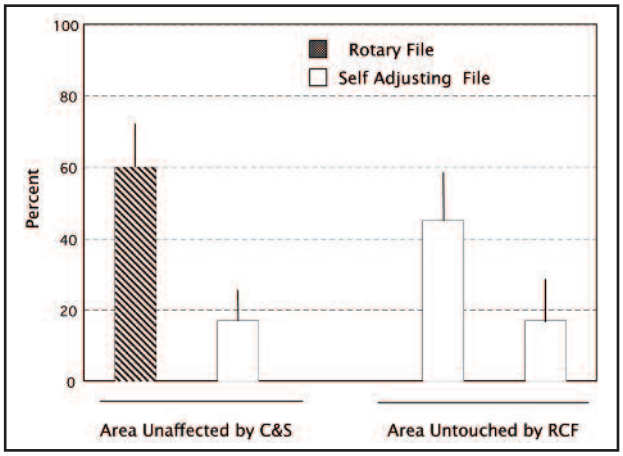


**Fig. 13** Area unaffected by the procedure and untouched by the root-canal filling: SAF vs. rotary file. Root canals were treated with either rotary files or the SAF, and the percent of wall area unaffected by the procedure was determined using micro-CT. The canals were obturated with lateral compaction and sealer, and percent of the root canal wall area (after preparation) that was un-touched by the root-canal filling was determined 3-dimensionally using a new micro-CT based method. SAF-treated canals presented lower values of both parameters, compared to those treated with rotary files.

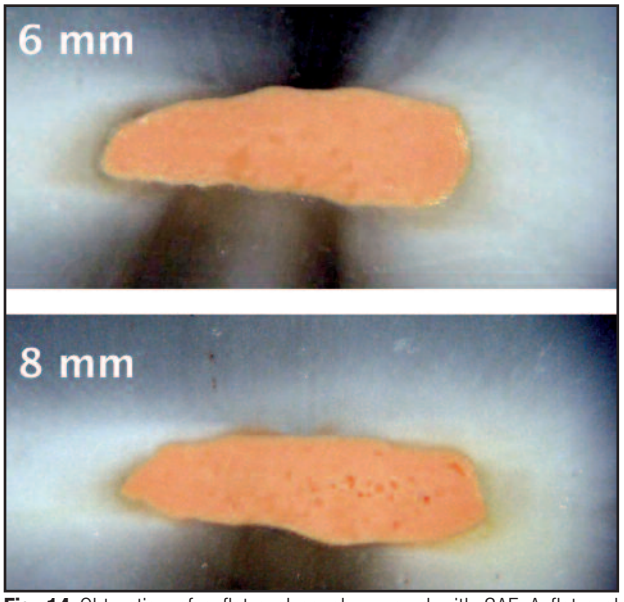


**Fig. 14** Obturation of a flat-oval canal prepared with SAF. A flat-oval root canal was treated with the SAF and then obturated with warm gutta-percha and sealer. Note the perfect adaptation to the clean root canal walls, and compare to Figure 2.

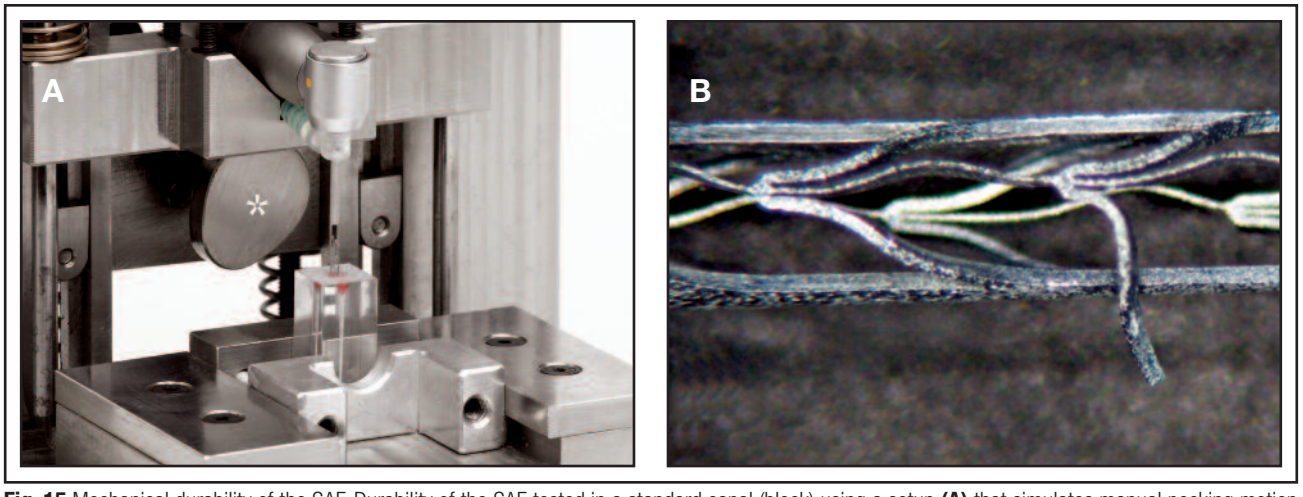


**Fig. 15** Mechanical durability of the SAF. Durability of the SAF tested in a standard canal (block) using a setup **(A)** that simulates manual pecking motion by the movement of the asymmetric cam (*). The file was inspected at 1 min intervals for 29 min before any mechanical damage occurred. When such damage did occur, it was in the form of arch detachment **(B)**. No file separation was encountered.

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The radiographic results of cases treated with the SAF-System are not much different from cases treated using other methods. The only radiographic pattern is a relatively high frequency of accessory and lateral canals that were filled, most probably due to the effective cleaning of tissue remnants from their orifices by the SAF system.[15]

The unique features of the system cannot be readily seen in a simple 2D radiograph. It is the *scientifically substantiated knowledge*[7,10-18] that one can at last get closer to the long-desired goal of 3D root-canal treatment that will provide the drive to test and master this new concept and technique in endodontic practice. ❑

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## About the Author


**Prof. Zvi Metzger** graduated from the Hebrew University School of Dental Medicine in Jerusalem in 1970. Since 1973 he has been on the faculty at the Tel Aviv University School of Dental Medicine, where he served as Dean in the years 1987-1991. Prof. Metzger is specialist in Endodontics and was the Chairman of the National Board of Endodontics in Israel. He is an Associate Professor in Oral Biology and Endodontology at Tel Aviv University.

Prof. Metzger was a Visiting Fellow at the National Institute of Dental Research, NIH, Maryland (1978-1981) and a Visiting Professor at the University of North Carolina at Chapel Hill (1995-1996). He currently serves as Chairman of the Department of Endodontology and until recently served also as Director of Research Laboratories at the Tel Aviv University School of Dental Medicine. He retains a private endodontic specialist practice in Tel Aviv.

Prof. Metzger has published and lectured extensively in the fields of Oral Biology and Endodontics. He served on the Editorial Board of Endodontics and Dental Traumatology and of ENDO- Endodontic Practice Today and serves currently on the Scientific Advisory Panel of Journal of Endodontics and as a referee for International Endodontic Journal and Oral Surgery Oral Medicine Oral Pathology Oral Radiology and Endodontics. He was the President of the Israeli Division of the International Association for Dental Research (1987), Chairman of the Israeli Endodontic Society (2000-2002) and is a recipient of the Honorary Achievement Award of the Israel Dental Association (2003) for his contributions in dental research and education. Prof. Metzger is a member of Alpha Omega International Dental Fraternity.