
Fig. 1


Fig. 2

Canal anatomy: The ultimate directive in instrument design and utilisation

Author_ Dr Barry L. Musikant, USA

Fig. 1_Mandibular first molar (mesiodistal).
Fig. 2_Mandibular first molar (buccolingual).

_It may sound so basic that one would not even think to ask the question, but what constitutes an endodontic education? After teaching thousands of dentists over many years, I believe that the mechanical aspect of endodontic education is a rote exercise. The students are presented with a set of instruments and told how to use them. In the case of K-files, they may be told that the instrument must first engage dentine by rotating the instrument clockwise for the flutes to engage the dentine followed by a pull stroke that cleaves off the engaged dentine, or they may be taught to use these instruments with a watch-winding motion combined with an up-and-down stroke that randomly engages and cleaves small amounts of dentine away. That the K-file also impacts debris and distorts curved canals to the outside wall are considered side-effects that will not occur once the dentist learns how to use these instruments properly. Under any circumstances, any negative side-effects are not considered to be due to deficiency of design so much as the dentist's lack of skill. This mindset solidifies the continued use of K-files, even as the introduction of rotary NiTi has taken increasing hold.

The course of endodontic instrument development might take a different turn if the choice of instrument design and implementation were based on critical analysis. As it is, the increased adoption of rotary NiTi is confirmation that the pre-existing use of K-files as the sole instruments to shape and cleanse canals is inadequate. What is ironic is that while the adoption of rotary NiTi has been most dramatic, drastically reducing the usage of K-files, this clearly discernible trend has not led to a re-examination of why K-files, now used a good deal less, are still being used at all. The irony is doubly compounded by the fact that as the vulnerabilities, namely instrument separation, of rotary NiTi have become more pronounced, it has led to a rebound in the increased usage of K-files to further shape the glide path so the fracture-prone NiTi instruments are subject to less stress.

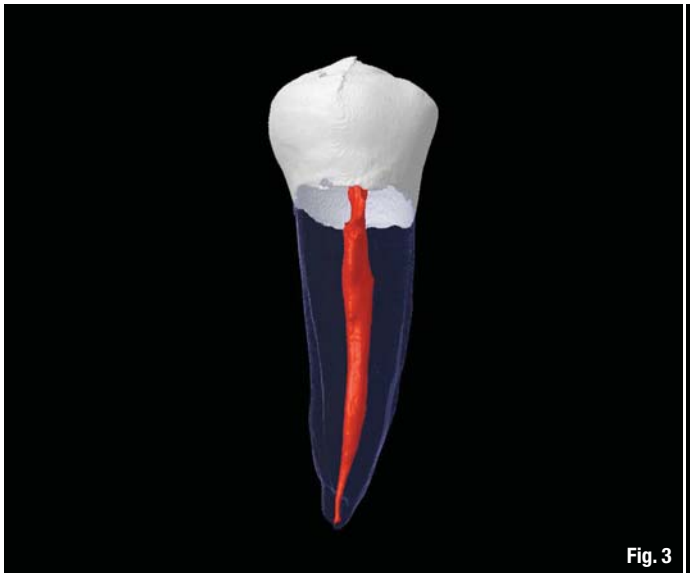
Fig. 3

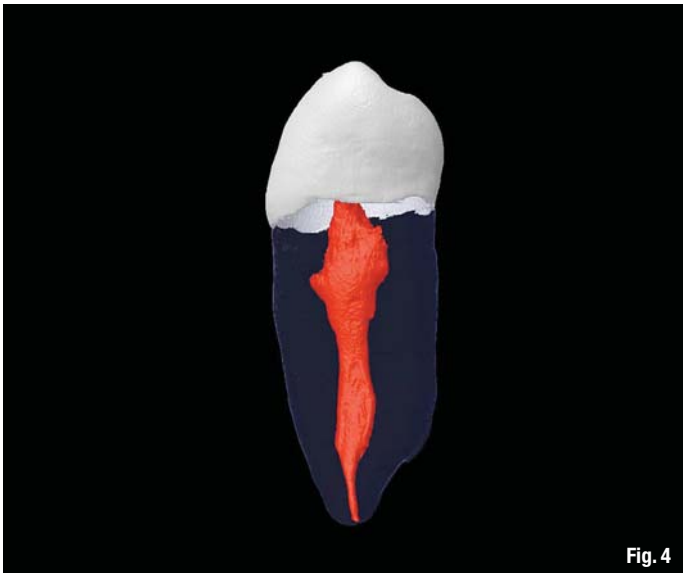
Fig. 4

Increasing the reliance on K-files, a system that demands a substitute in the form of rotary NiTi, represents a dichotomy in that neither system is workable by itself, with the weaknesses of both still present when combined. The result is a balancing act in which each tooth presents its own unique conditions for an ever-changing combination of these two shaping systems, a balancing act that is inherently unstable and leads to a reduced rate of successful outcomes. The most obvious shortcomings of K-files include the impaction of debris and the distortion of curved canals to the outer wall—something already attributed to the lack of operator skill. Rotary NiTi's greatest shortcoming is unpredictable separation, a problem intimately associated with the torsional stress[1] and cyclic fatigue[2] generated by this form of motion and compounded in canals of increasing curvature. The solution to this weakness is the use of these instruments in reciprocation rather than rotation. The form of reciprocation chosen for these instruments is a hybrid one that still produces 200 full rotations per minute, reducing but not eliminating cyclic fatigue,[3] while a 30-degree clockwise stroke compensates for a 150-degree counter-clockwise arc of motion, significantly reducing the torsional stress formerly generated by full rotation.

The introduction of a hybrid reciprocating system without question leads to less instrument separation. Yet, the manufacturer of this system also understood that marketing benefits would be derived if the system were less expensive with fewer instruments being the most direct way to reduce costs. They evidently determined that the increased costs for the one recommended instrument would be acceptable because the overall cost to the dentist for the procedure would be reduced. All that was necessary for this new system to be successful was to convince the dentist that the canal preparations done with one

Fig. 3_Mandibular second premolar (mesiodistal).
Fig. 4_Mandibular second premolar (buccolingual).

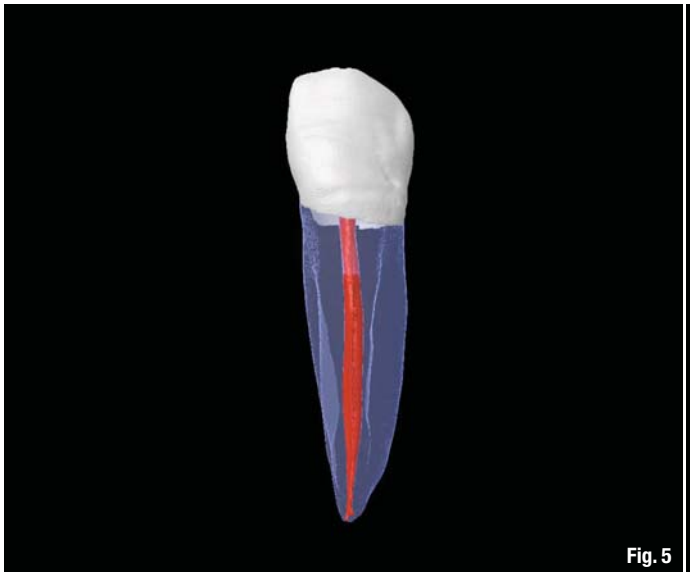
Fig. 5

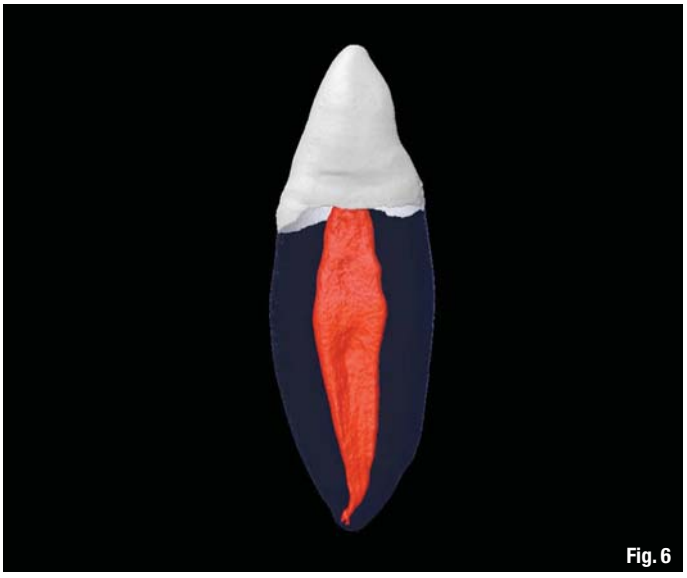
Fig. 6

Fig. 5_Mandibular incisor (mesiodistal).
Fig. 6_Mandibular incisor (buccolingual).

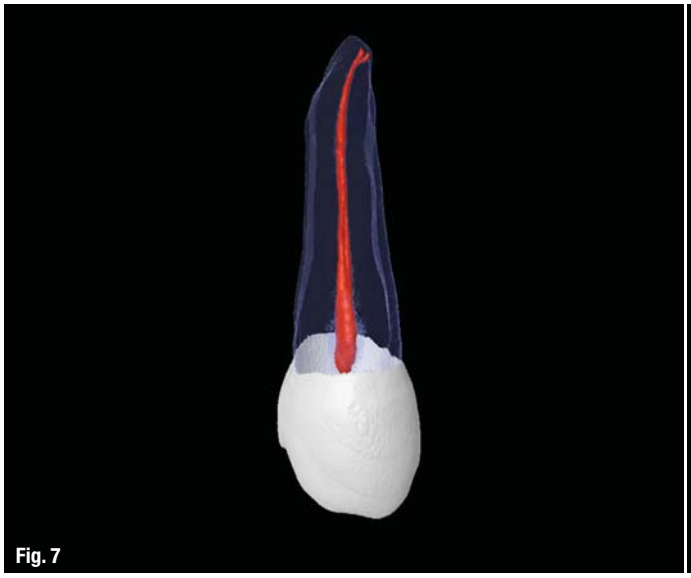
Fig. 7

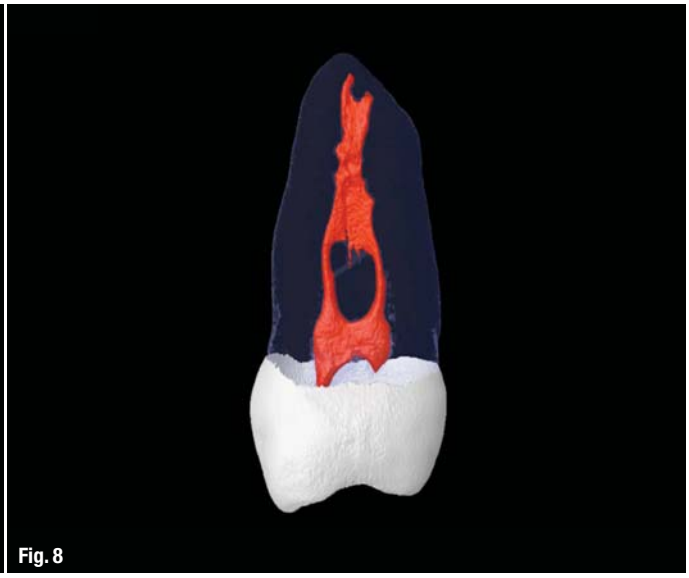
Fig. 8

Fig. 7_Maxillary second premolar (mesiodistal).
Fig. 8_Maxillary second premolar (buccolingual).

instrument produce results that are adequate for predictable success.

The greater our understanding of pulpal anatomy as it is, rather than an idealistic rendition that makes for a comfortable fit between results and perception, the better our judgement of what constitutes proper design and utilisation as it relates to the task at hand. The several micro-CT scans shown in this article, generated by Drs Versiani, Pecora and Neto, clearly demonstrate the typical anatomy of various teeth (Figs. 1–8). In addition to anastomoses, divergent branching and cul-de-sacs, the most common feature of pulp tissue is its asymmetric anatomy.[4] Far from displaying a uniform conical shape, it is most often far wider in the buccolingual plane than the mesiodistal. Thin sheaths of tissue rather than well-defined canals are often present. These anatomical variations present challenges to K-files, mostly because of their high level of canal engagement as they attempt to work themselves apically. They must be used with repetitive vertical strokes to cleanse the buccolingual extensions of these tissue sheaths, a motion that increases the chances of debris impaction blocking further access to the apex. Both hybrid reciprocating NiTi and full rotary NiTi systems tend to stay centred within the canal and, as many studies point out, the wider extensions of oval canals are not cleansed. If the canal is prepared to a maximum of 25.08, it may look adequate in the mesiodistal dimension, but be totally inadequate in the buccolingual plane, where the canal diameter is often five to six times greater. A canal may look very much like our ideal preconception in one plane and totally invalidate that perception when seen after 90 degrees of rotation.

If the cleansing of highly asymmetric canal anatomy is the goal that drives instrument design, then what we have at present is too often not up to the task. What we need are more rational designs based on a critical analysis of the interaction between design utilisation and results. Let's consider the use of relieved reamers designed with a flat (Fig. 9) along their entire working length used in a watch-winding motion that may be generated both manually and in a 30-degree reciprocating handpiece. All the instruments, including a thin 0.06 mm tipped reamer, have vertical flutes that when used with a horizontal watch-winding motion will immediately shave dentine away. The vertical pull stroke is simply employed for carrying the debris occupying the flutes in order

Fig. 9_A relieved reamer with a flat side. Note the decreased number of vertically oriented flutes.
Fig. 10_A K-file. Note the increased number of horizontal flutes.

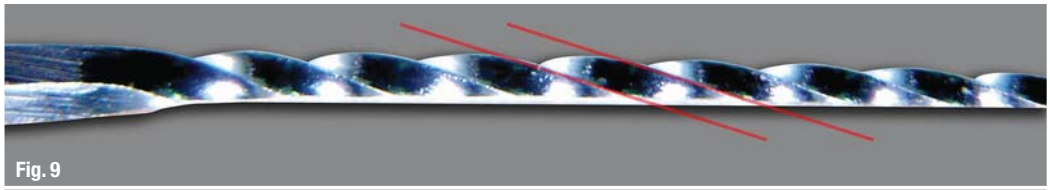
Fig. 9

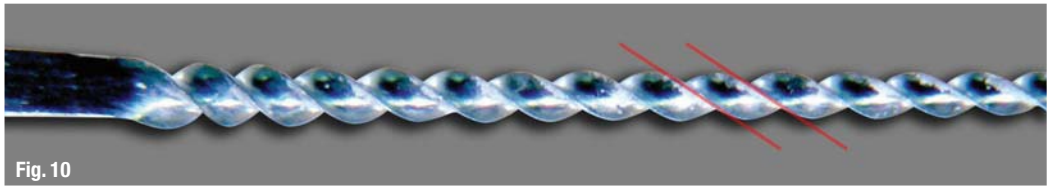
Fig. 10

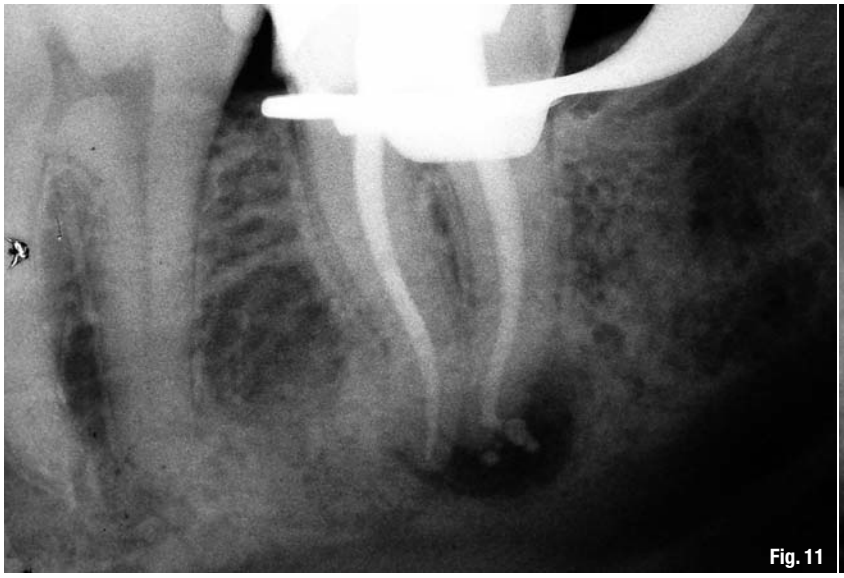
Fig. 11


Fig. 12

Figs. 11 &12_These radiographs show the ability of flat-sided reamers (SafeSiders) used in a reciprocating handpiece (Endo-Express) to shape, irrigate and clean irregular-shaped canals effectively. They were used without the fear of binding or breakage.

Figs. 1–12 (Courtesy of Dr Barry Musikant)

to be brought coronally and wiped away. The vertical orientation of the flutes tends to sweep through any debris that may be present in the canal when the reamers are directed apically, rather than impacting debris apically the way the horizontal flutes on a K-file (Fig. 10) tend to do.[5] With full depth far more easily attained with a relieved reamer than a K-file, leaning the vertically oriented blades against a broad sheath of tissue is more likely to remove that tissue than if the main function of the blades is to engage and disengage until the pull stroke is employed, an action that occurs with K-files.

Unbeknownst to most dentists, NiTi instruments are predominantly shaped like reamers even though they are still called files. They recognise the inherent advantages of an instrument that shaves dentine away rather than first embedding into it. Yet, NiTi instruments must stay centred, lest they encounter anatomy that may lock and bind anywhere along length.[6] Locking and binding is good for neither NiTi nor stainless steel, but where there is a large gap between deformation and fracture for stainless steel, NiTi has little room between the two, effectively allowing for safe usage within very narrow margins. These narrow safety margins empirically appreciated by dentists are major incentives for conservative NiTi canal preparation, which in light of the real anatomy that must be instrumented can lead to inadequate shaping and cleansing.

What I am attempting to show here are the possible consequences that occur simply because the instruments that have been traditionally employed are not designed to treat the canal anatomy as it is. It may provide pleasing results when viewed in the mesiodistal plane, but micro-CT scans clearly tell us there is far more to the story that must be addressed. Graduating dentists will be far more able to make sensible, rational decisions if they are taught instrument design as it relates to function, which in turn will produce results that are consistent with the stated goals. That is far better than using instruments that meet our ideal preconception of a canal anatomy that often exists nowhere but in our minds._

Editorial note: A complete list of references is available from the publisher.

Images by Prof. Marco A. Versiani, courtesy of The Root Canal Anatomy Project (original images can be found at rootcanalanatomy.blogspot.com)

_about the author

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Dr Barry Lee Musikant is a member of the American Dental Association, American Association of Endodontists, Academy of General Dentistry, Dental Society of New York, First District Dental Society, Academy of Oral Medicine, Alpha Omega International Dental Fraternity and the American Society for Dental Aesthetics. He is also a Fellow of the American College of Dentistry. His 35-plus years of practice experience as a partner in the largest endodontic practice in Manhattan has established him as one of the top authorities in endodontics.

To obtain more information about Dr Musikant, please visit www.essentialseminars.org, e-mail info@essentialseminars.org or call +1 888 542 6376.

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Dr Barry Lee Musikant
Essential Dental Systems, Inc.
89 Leuning Street
S. Hackensack, NJ 07606
USA

info@edsdental.com