Comparative Analysis of Endodontic Pathfinders

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Abstract

Because no scientific literature exists regarding endodontic pathfinders, the aim of this study was to compare such instruments. Ten different pathfinder-type files were analyzed with respect to dimensional characteristics, pitch, and rigidity; efficiency, wear, and distortion were assessed by using an in vitro simulation exercise. SEM cross-sections and tip images were obtained and analyzed. To assess efficacy and distortion, 10 operators attempted to achieve patency with the files in small, S-shaped canals in acrylic blocks. Trends in canal negotiation efficiency and file distortion were recorded. Results showed that the Hi-5 (Miltex, York, PA) and C+ files (Dentsply/Maillefer, Johnson City, TN) were the least flexible, whereas the Pathfinder CS (SybronEndo, Glendora, CA) and Pathfinder SS (SybronEndo) files were the most. Pathfinder SS, S finder (JSDental/Sendoline, Ridgefield, CT), and D finder (Mani, Tochigi-ken, Japan) were the most efficient during the simulation exercise. Within the parameters of this study, pitch, taper, cross-section, heat tempering, metal type, tip geometry, and operator skills all influenced pathfinder efficiency. *(J Endod 2007;33:723–726)*

Key Words

Endodontic instruments, files, pathfinding

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Negotiation of small canals is challenging (1–10). Dodds et al. (11) outlined helpful hints in finding and instrumenting such canals. They emphasized the use of multiple quality radiographs as well as making sufficient access openings for proper visualization (11). Others have provided systematic approaches for canal negotiation of constricted canals, including coronal preflaring in conjunction with copious irrigation and ample lubrication (2–4, 8–11). Typically, small files are required for initial pathfinding; however, these files lack the rigidity required to traverse constricted spaces and can often buckle when vertical watch-winding forces are apically directed. Larger or more tapered files would have the rigidity but are too bulky to slide through a constricted space. To overcome this problem, Kobayashi ground size #10 K files at the tip with a diamond disc so as to maintain the rigidity of the larger file while decreasing tip size (12). Several manufacturers have also attempted to manage the problem by altering tip geometry, by heat tempering stainless steel to increase stiffness, or by using carbon steel to enhance sharpness (13). Variations in shape, design, pitch, and taper have also been considered to maximize the necessary balance between small size, increased rigidity, and minimal deformation (14–19).

To our knowledge, there is currently no study comparing the various endodontic pathfinder-type files that are available in the marketplace. The objectives of this study were to compare and contrast the dimensions, physical properties, and rigidity of various pathfinder-type hand instruments and to evaluate the efficiency, wear, and distortion of these files via an in vitro simulation exercise.

Materials and Methods

Files included in this study were the Antaeos Stiff "C" file (Schwed, Kew Gardens, NY), C file (Dentsply/Tulsa, Tulsa, OK), C file (Roydent, Hoboken, NJ), C+ file (Dentsply/Maillefer, Johnson City, TN), D finder (Mani, Tochigi-ken, Japan), Hi-5 file (Miltex, York, PA), Pathfinder CS (SybronEndo, Glendora, CA), Pathfinder SS (SybronEndo), S finder (JSDental/Sendoline, Ridgefield, CT), Stiff K file (Brasseler, Savannah, GA), and Flexofile (Dentsply/Maillefer) as a positive control.

Geometric Analysis

The pitch of an instrument is the distance between a point on the leading edge and the corresponding point on the adjacent leading edge (i.e., distance between flutes) (20). A digital image of each file type was obtained via a microscope, and the pitch was determined by dividing the length of instrument fluting (16-18 mm) by the number of flutes (spirals) on the file image.

Each file type was bonded together with cyanoacrylate at the handles so that the files were parallel to each other in one group of five and one group of six. The file groups were then placed parallel inside metallic rings and embedded in acrylic; the resin blocks were cut 9 mm from the handles by using a low-speed saw. The block surfaces were processed, sputter coated with gold, and viewed under a scanning electron microscope (SEM) (JSM-6300, JEOL, Tokyo, Japan) at 270 to 330× magnification. An image of each file cross-section was obtained, and similarities and differences in geometry were recorded.

For the SEM tip analysis, one file from each manufacturer was sheared with wire cutters at $\sim D_5$; cut portions were longitudinally placed on carbon tape and viewed under the SEM at 90 to 110×.

Deflection Analysis

File stiffness was assessed by using a digital caliper (Absolute; Mitutoyo Corp, Aurora, IL), a digital apparatus that measures the distance (micrometers) a connected

TABLE 1. Pitch of Each File Type

File Type	Mm of Cutting Shank/Flutes	Pitch
Hi-5 file	17/65	.26
PFCS file	18/44	.41
PFSS file	18/44	.41
Stiff K file	17/35	.49
C file (Dentsply/Tulsa)	17/35	.49
C file (Roydent)	17/35	.49
Flexofile	16/32	.50
Stiff C file	17/34	.50
C+file	17/27	.63
S finder	16/16	1.0
D finder	16/8	2.0

stylus vertically moves. Twelve 21.0-mm files of each file type were tested. A secured chuck held each file perpendicular to the stylus and parallel to the ground so that the stylus directed 8 g of force perpendicular to the file at D_3. File deflection was recorded in micrometers. Each file was tested 5 consecutive times; an average was calculated for 12 files, 5 readings per file, for a total of 60 readings per file type. Each file type tested was a size #10 except for the Pathfinder CS and the Pathfinder SS, which are K2, a size between #8 and #10 according to the manufacturer. The deflections were analyzed by using a Kruskal-Wallis 1-way analysis of variance ($p \leq 0.05$), followed by Dunn's method, a pairwise multiple comparison.

Simulation Analysis

Seven senior endodontic residents and three faculty were each provided seven standardized acrylic blocks (Endo-Training-Bloc-S; Dentsply/Maillefer, Ballaigues, Switzerland) containing a constricted S-shaped canal along with a sponge with a series of seven randomly placed pathfinders. Testing one file per block at a time and using water as an irrigant, operators were instructed to watch wind the file into the canal until it bound. If the file did not reach the end of the canal (i.e., to the simulated foramen), the clinician was to measure the remaining distance from the file tip to the foramen and retrieve the file in a direct pull out motion. Operators used 2.5 to 4.0× loupes to detect and record any deformations. This exercise was repeated for each file type, and results and specific feedback were recorded on a short questionnaire.

Results

Geometric Analysis

The pitch varied from 0.26 to 2.0 mm among the different file types (Table 1).

The most common cross-sectional design was that of the square and included most of the files. The D finder exhibited a cross-sectional design of an incomplete circle with one straight edge (D shaped). The S finder exhibited an incomplete circle with two parallel straight edges, whereas the Hi-5 file resembled a pentagon in cross-section (Fig. 1).

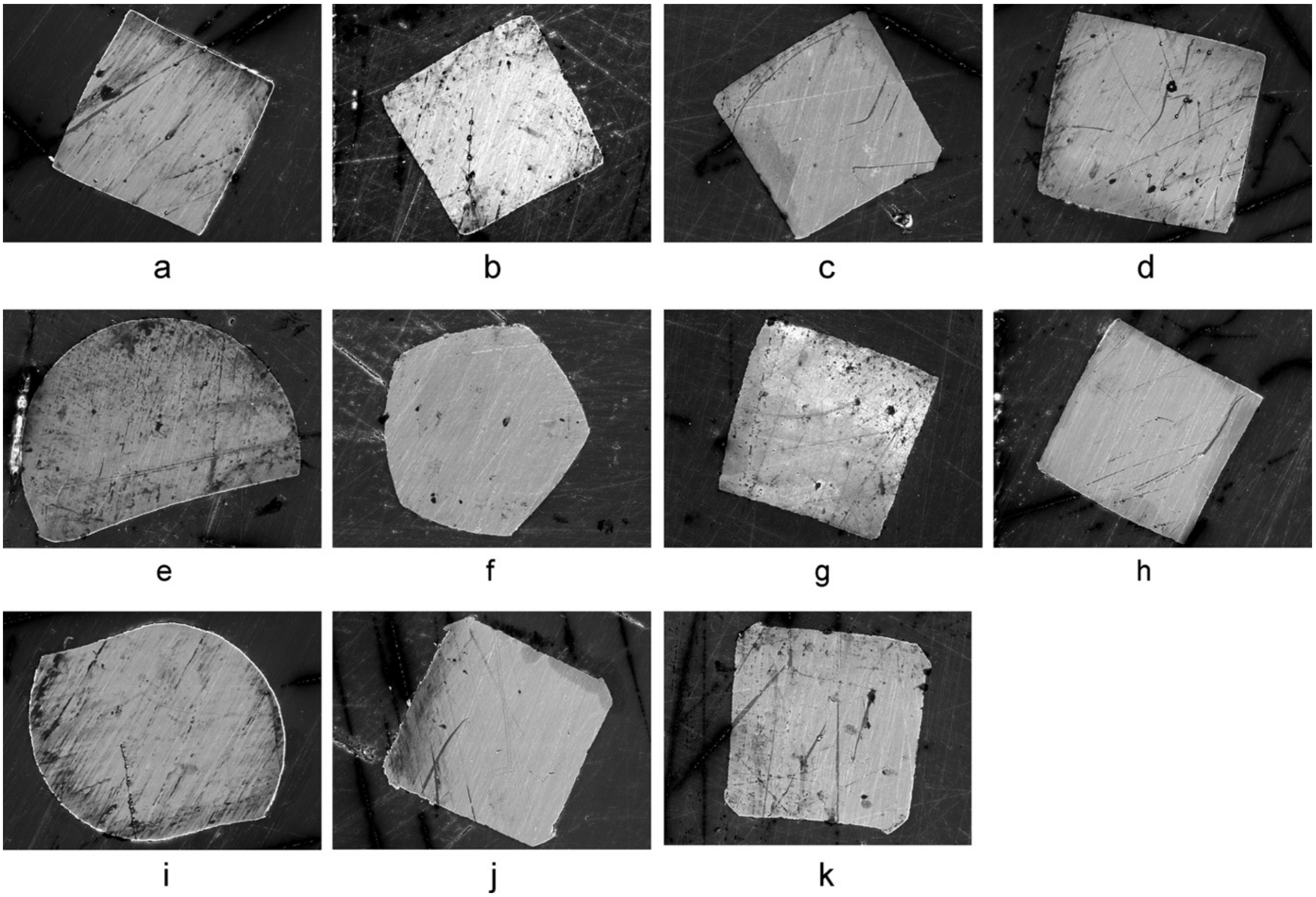

Figure 1. SEM cross-sections of each file type at 270 to 330×. (a) Stiff K file, (b) C+ file, (c) C file (Dentsply/Tulsa), (d) Flexofile, (e) D finder, (f) Hi-5 file, (g) Pathfinder SS, (h) Pathfinder CS, (i) S finder, (j) C file (Roydent), and (k) Stiff C file.

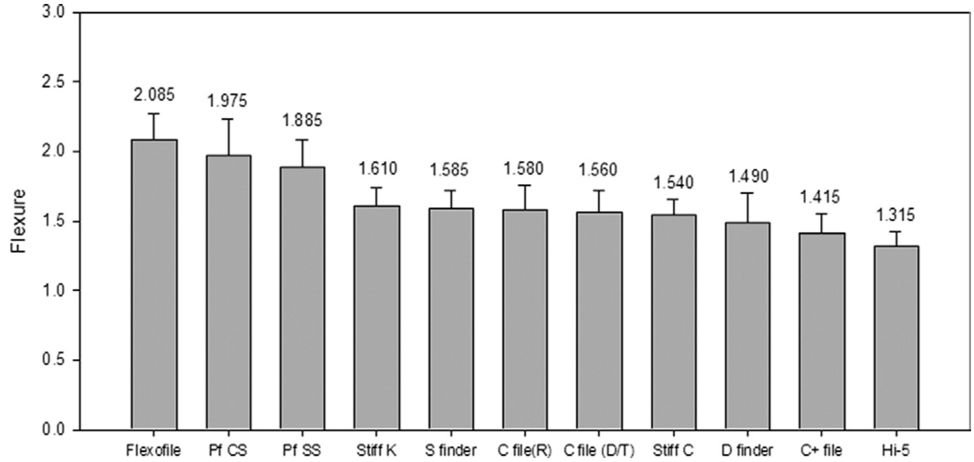

Figure 2. Flexure (millimeters) of each file type using Kruskal-Wallis one-way analysis of variance on ranks ($p \leq 0.05$).

The file tips appeared to be conical but mostly pyramidal in shape in the SEM tip analysis.

Deflection Analysis

The median distances of file flexure are recorded in Figure 2. Using all pair-wise multiple comparison procedures (Dunn's method, $p \leq 0.05$), the following statistically homologous subsets were noted: Hi-5 file and C+file; C+ file and D finder; D finder, Stiff C file, C file (Dentsply/Tulsa), C file (Roydent), S finder and Stiff K file; Pathfinder CS, Pathfinder SS, and Flexofile.

Simulation Analysis

No files separated and there were minimal degrees of distortion. Pathfinder SS, S finder, and D finder were the most efficient files, each achieving patency or near patency (i.e., within 2 mm of the foramen) by all operators. None of the operators achieved patency with the C+ file.

Discussion

Instrument design is inherently a complex subject because there are multiple variables that can influence the efficiency of a pathfinding instrument. Minimal rigidity, high flexibility, and variability in cutting, all inherent in small file design, can contribute to problems associated with pathfinding in small, curved canals. Without such a comparison of pathfinding instruments, the clinician is at the mercy of manufacturer claims of superiority or branding.

Most of the files evaluated in this study approximated a pitch of .5. The Hi-5 file exhibited the lowest pitch and the S finder and D finder had the highest pitch. The pitch of an instrument may be significant for several reasons, some of which could impact efficiency in pathfinding. The more flutes an instrument has, the less flexible it becomes, and the more points of contact it uses in contributing to tactile sensation. A lesser pitched instrument will be inherently more effective in filing, less effective in reaming. The pitch of an instrument should be considered in a path-finding file because it influences flexibility, tactile sense (more surface contact points), and cutting efficiency.

The cross-sectional design of the instrument provides information on potential rigidity, strength, and cutting ability. Most of the files in cross-section exhibited a nearly congruent square shank. The Hi-5 file exhibited pentagonal geometry, suggesting greater shank bulk than square shanked instruments of similar size and taper. The C+ file has greater taper and would be expected to be more rigid, perhaps binding earlier in a constricted canal but resisting deformation because of its robust quadrangular design.

How efficiently an instrument traverses a canal is also influenced by the tip and the proximity of the initial fluting to the tip. Each of the instruments showed either a conical or pyramidal tip. The pyramidal tip may better negotiate constricted canals because of increased cutting ability. File geometry, cross-sectional thickness, and the properties of the metal from which a file is constructed should dictate the degree of rigidity. Most of the files in this study were twisted from heat-tempered stainless steel blanks; heat tempering is a method of work hardening the alloy, potentially enhancing rigidity (13). Pathfinder CS is composed of carbon steel, which is initially sharper than stainless steel but quicker to corrode in the presence of sodium hypochlorite and sterilization procedures (13).

With respect to degree of flexure, the Stiff K file, both C files, and the Antaeos Stiff C file were similar. In addition, the S finder and D finder were not statistically different from the aforementioned instruments. The Flexofile, as expected, had the greatest degree of flexure because it is constructed from a non–heat-tempered alloy. With a relatively smaller file size (between 08 and 10), the Pathfinder files expectedly had a greater degree of flexure. With greater taper and slightly more pitch, the C+ file flexed less than all other files except for the Hi-5 file.

The final portion of the study evaluated file efficiency and deformation during canal negotiation in simulated canals. Because of visible and obvious differences in some of the file designs, including handle color and pitch, blind testing of the files was not possible; however, random ordering of the files in the sponge helped minimize effects the order of file analysis may have had on operator feedback. The Endo-Training-Bloc-S (.02 taper) presented a challenge for negotiation because of its small canal size and S-shaped design. Questions on the survey were designed to assess file efficiency even though results may have been influenced by variations in operator skills. Three file types were excluded because of similar morphology and deflection testing between four files. These four groups were represented by the C file (Roydent), which was randomly selected out of a container. In this exercise, the two Pathfinders had a potentially decisive advantage in achieving patency because their respective size was slightly smaller than the other files.

None of the files separated. Recordable distortions included buckling, tip flattening, and tip bending involving several different files. All of the file distortions were observed by only 3 of the 10 clinicians involved in the simulation exercise, suggesting that file distortion may be as much a function of the clinician as of the instrument.

Trends in operator feedback were noted. Recurring phrases and comments regarding the C file was that it was "familiar, stiff, and sturdy." Comments of the C+ file included that it was "harder, slower, and generally not liked as well in this exercise." The S finder was reported as feeling "smooth" and that it had an "unfamiliar design." The D finder was said to "reach patency easily, had an unfamiliar design, and had inefficient cutting." The Hi-5 file was claimed to "engage more aggressively" and "require more force, especially in removal." The Pathfinder CS was said to be "smooth, easy, and quick" but "offers more resistance upon insertion." The Pathfinder SS files were said to be "smaller, easy, and smooth."

Summary and Conclusions

This is the first study to compare and contrast endodontic pathfinders. Most files evaluated had quadrangular cross-sections, thus enhancing rigidity with a degree of flexure less than the Flexofile control. The High-5 file was the most spiraled file, whereas the S finder and D finder were the least spiraled. Tip geometry ranged from conical (more pathfinding) to pyramidal (more cutting).

There are multiple factors that can influence pathfinder efficiency including tip design, degree of spiraling, taper, cross-sectional design, heat tempering, metal type, operator skills, and clinical conditions. Future research should include evaluation of negotiation and cutting efficiency of pathfinders in selected extracted teeth as well as determination of their respective rake and helical angles.

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