# Comparative Study of Four Endodontic File Systems to Assess Changes in Working Length during Root Canal Instrumentation and the Effect of Canal Curvature on Working Length Change

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## SIGNIFICANCE

TF Adaptive files had the least reduction in working length and the smallest increase in canal enlargement. ProTaper Next files were comparable but the increased curvature increased the length reduction. Hedström files had less length reduction and canal enlargement than K files.


## ABSTRACT

**Introduction:** The aim of this study was to compare a reduction in working length and area of canal enlargement resulting from instrumentation with Hedström (Kerr Dental, Orange, CA), K (Kerr Dental), ProTaper Next (Dentsply Sirona, York, PA), and TF Adaptive (Kerr Dental) files. The effect of the canal curvature on the working length and area of canal enlargement was also assessed. **Methods:** A total of 80 plastic canal models were used, 40 with a canal curvature of 10° and another 40 with a canal curvature of 30°. Instrumentation of 10 models with a 10° canal curvature and 10 models with a 30° canal curvature was performed using each of the file systems up to size 25. Working length measurements were taken before and after instrumentation with each file type and size. Twenty composite images were made from superimposition of pre- and postpreparation photographs, and the difference in area was calculated using ImageJ software (National Institutes of Health, Bethesda, MD). **Results:** ProTaper Next rotary files and TF Adaptive files produced the smallest reduction in the working length and the least canal enlargement followed by Hedström files and K files, respectively. The degree of canal curvature increased the working length reduction by a significant amount when K files and ProTaper Next rotary files were used, and the degree of curvature increased canal enlargement by a significant amount when K files were used. **Conclusions:** Nickel-titanium rotary files produced more favorable results than stainless steel hand files in terms of maintaining a consistent working length and producing minimal canal enlargement. Hedström files performed significantly better than K files in terms of working length reduction and canal enlargement. *(J Endod 2020;46:110–115.)*



## KEY WORDS

Canal curvature; hand files; root canal preparation; rotary instruments; working length reduction


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Root canal instrumentation shapes the root canals, preparing them for the root canal filling. The ideal shape is a continuously tapering, conical canal where the widest part is at the canal orifice and the narrowest part is at the apical foramen, maintained at its original size and position[1]. In order to achieve this, an accurate measure of the root canal working length, which is the distance from a coronal reference point to the apical constriction, is essential. The working length is used throughout a course of endodontic treatment to guide the clinician during instrumentation and for filling the canal to the desired apical location.

The apical position of the root filling with respect to the radiographic apex is a significant variable in determining the outcome after root canal treatment[2,3]. A favorable outcome for teeth affected with apical periodontitis is most predictably achieved when the root canal filling is placed within 2 mm of the radiographic apex (94%) compared with root canal fillings placed more than 2 mm short of the radiographic apex (68%) and those extruded beyond the radiographic apex (76%)[2].

Despite efforts to maintain a consistent working length, numerous studies have shown that a reduction in the working length commonly occurs during root canal instrumentation[4–16]. Changes to the working length result in an unpredictable depth of canal preparation during treatment. When the working length is reduced, overinstrumentation and overfilling are likely to occur, which may manifest in clinical symptoms of delayed periapical healing or a foreign body reaction. The reduction in the working length is most pronounced in curved canals[6–12] and has been attributed to the tendency of files to straighten in the canal and thus remove excessive amounts of dentin from the inner wall in the midroot area and from the outer wall in the apical part of the canal[17,18]. Although the degree of canal curvature is a factor outside the clinician's control, another significant variable affecting working length reduction is the type of endodontic file system used during instrumentation, and this is directly controlled by the clinician.

The majority of research on working length reduction has compared the magnitude of reduction produced using various file systems[6–16,19–22]. There are 3 major groups of endodontic files:

1. stainless steel (SS) hand files, traditionally used for instrumentation;
2. nickel-titanium (NiTi) rotary files, which are motor powered and exhibit 2 to 3 times the flexibility of SS files; and
3. NiTi reciprocating files, which switch between rotating in the cutting direction and the opposite direction every cycle.

The NiTi rotary file systems used in many of the previous studies are no longer available on the market. Additionally, SS hand files have received considerably less scrutiny in the literature than NiTi files, despite surveys indicating that 68% of United States and 78% of Australian general dental practitioners routinely use SS hand files[23,24]. Notably, no studies have examined working length changes produced by instrumentation with Hedström files, despite a survey indicating they are the most used SS hand file by United States dentists[23]. Given the discontinuation of a number of rotary file brands and the continued popularity of SS hand files among general dentists, a comparison of working length reduction produced by commonly used contemporary

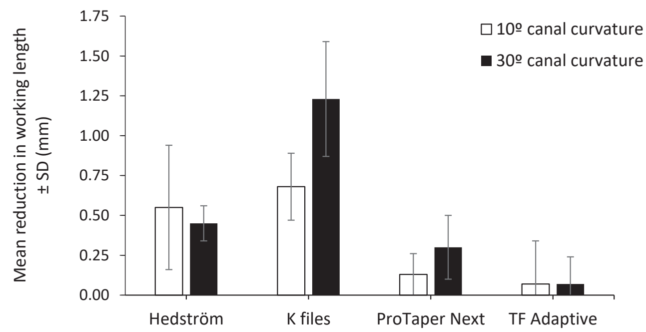


**FIGURE 1 –** The mean reduction in working length (mm) ± standard deviation (SD) produced by instrumentation with 4 different endodontic file systems in canals of 10° and 30° curvatures.

endodontic file types would be clinically useful.

In this study, the primary aim was to quantify and compare the reduction in working length and area of canal enlargement produced by instrumentation using Hedström, K, ProTaper Next, and TF Adaptive files. The secondary aim of this study was to assess the effect of canal curvature on working length reduction and area of canal enlargement associated with each of the file systems listed previously.

## MATERIALS AND METHODS

Eighty plastic canal models (Nissin Trimunt S4 Series; Nissin Dental Products, Kyoto, Japan) were used to simulate the root canals of human teeth. Forty models had a mean canal curvature of 10° (S4-U1-10°), and 40 had a mean canal curvature of 30° (S4-U1-30°). Each group of 40 was subsequently divided into 4 groups of 10 for instrumentation with Hedström (Kerr Dental, Orange, CA), K (Kerr Dental), ProTaper Next (Dentsply Sirona, York, PA), and TF Adaptive files (Kerr Dental), respectively.

The canal working length was determined using a size 15 Hedström file and a metal ruler to measure the distance from the superior border of the canal to the apical constriction of the resin blocks. All canals were prepared to this initial working length up to a size 25 file, or its equivalent, according to a sequence specific to the endodontic file system.

Instrumentation with Hedström files involved sequential filing with a size 15, 20, and 25 Hedström file. A one-eighth clockwise turn was used to engage the resin walls followed by circumferential filing in push-pull strokes to remove resin on the pull stroke. Filing was continued until the file easily reached a pre-determined apical stop within the resin canal and sat loosely within the canal. Instrumentation with K files followed the step-back technique, with apical preparation up to size 25 and coronal tapering up to size 40. Instrumentation with ProTaper Next and TF Adaptive files was performed according to the manufacturer's instructions. A glide path was established with a size 15 Hedström file. ProTaper Next files of size 017/04 and 025/06 were attached to the Tri Auto ZX2 cordless handpiece (Morita, Tokyo, Japan) on the M4 default setting (300 r/min, 180°) powered by an electric motor. TF Adaptive files of size SM1 (small canals) #20/0.04 and SM2 #25/0.06 were attached to the

**TABLE 1 -** The Mean Reduction in Working Length (mm) ± Standard Deviation (SD) and the Mean Percentage of Canal Enlargement (%) ± SD Produced by Instrumentation with 4 Different Endodontic File Systems in Canals of 10° and 30° Curvatures

| | Mean reduction in working length (mm ± SD) | | | |
|---|---|---|---|---|
| Canal curvature | Hedström | K file | ProTaper Next | TF Adaptive |
| 10° canals | 0.55 ± 0.39 | 0.68 ± 0.21 | 0.13 ± 0.13 | 0.07 ± 0.27 |
| 30° canals | 0.45 ± 0.11 | 1.23 ± 0.36 | 0.30 ± 0.20 | 0.07 ± 0.17 |

| | Mean percentage canal enlargement (% ± SD) | | | |
|---|---|---|---|---|
| | Hedström | K file | ProTaper Next | TF Adaptive |
| 10° canals | 16.30 ± 6.40 | 41.20 ± 11.70 | 8.70 ± 5.10 | 8.60 ± 4.00 |
| 30° canals | 21.10 ± 9.50 | 27.70 ± 6.50 | 9.00 ± 3.70 | 3.30 ± 4.00 |

Elements motor (SybronEndo/Kerr, Orange, CA) on the TF Adaptive setting (reciprocation mode with clockwise and counterclockwise angles varying from 600/0° to 370°/50°).

One operator prepared all samples of a file type. Irrigation with water was performed repeatedly after every instrument was used, and the files were cleaned regularly on a sponge to remove resin debris. After instrumentation with each file, the canal was dried, and working length measurements were recorded using a size 15 Hedström file and metal ruler to the nearest 0.25 mm. The canals were then reirrigated and filled with water before the next file was used so that all instrumentation was performed with water in the canals as a lubricant.

Images of resin canals before and after instrumentation were taken using a Canon (Tokyo, Japan) camera with a Canon EF 100mm f/2.8L IS USM Macro Lens. Red dye was added to the canals after instrumentation to improve visibility. The same position was maintained for each photograph. The canal area before and after instrumentation was calculated using ImageJ software (National Institutes of Health, Bethesda, MD) and the percentage change in canal area calculated. Twenty composite images were created from superimposed preinstrumentation and postinstrumentation images.

Data were recorded directly and stored in a cloud-based electronic system. Statistical analysis was performed using STATA version 15 (StataCorp LLC, College Station, TX). The mean ± standard deviation of changes in the working length and change in canal area were calculated for each file type (Hedström, K, ProTaper Adaptive, or TF Adaptive files) and canal curvature (10° or 30°). The significance of the file type on change in the working length and canal area was assessed using the Kruskal-Wallis test, and the Dunn post hoc test was conducted for comparison between file systems. The significance of the canal curvature on change in the working length and the canal area was assessed using paired *t* tests and confidence limits at 95% probability.

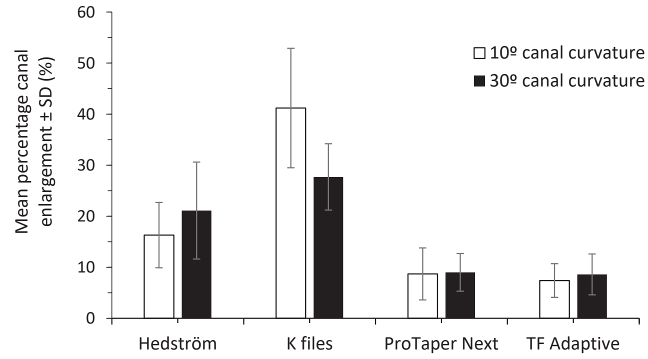


**FIGURE 2 –** The mean percentage of canal enlargement (%) ± standard deviation (SD) produced by instrumentation with 4 different endodontic file systems in canals of 10° and 30° curvatures.

## RESULTS

### Effect of File Type on Change in Working Length

Instrumentation with each file system produced a reduction in the mean working lengths (Fig. 1, Table 1). The Kruskal-Wallis H test found that there was a statistically significant difference in the mean working length change between the 4 file groups ($\chi^2_2$ = 47.72, $P$ = .0001). The Dunn post hoc test showed that there was a statistically significant difference in the mean working length reduction among all file groups ($P < .05$), except when comparing ProTaper with TF Adaptive files ($P > .05$) (ie, ProTaper Next and TF Adaptive files produced the smallest mean reduction in working length followed by Hedström and K files, respectively).

### Effect of File Type on Change in Canal Area

Instrumentation with each file system resulted in canal enlargement (Fig. 2, Table 2). The Kruskal-Wallis H test found that there was a statistically significant difference in the mean percentage of canal enlargement between the 4 file groups ($\chi^2_2$ = 51.421, $P$ = .0001). The Dunn post hoc test showed that there was a statistically significant difference in the mean percentage of canal enlargement among all file groups ($P < .05$), except when comparing ProTaper with TF Adaptive files ($P > .05$) (ie, ProTaper Next and TF Adaptive files produced the smallest mean area of canal enlargement followed by Hedström and K files, respectively) (Fig. 2).

### Effect of Canal Curvature on Change in Working Length

The degree of canal curvature appeared to produce an increase in working length reduction for some file systems. A paired *t* test was run on each sample of 20 resin canal blocks instrumented by a single file type to determine whether there was a statistically significant mean difference between the working length reduction for filed resin blocks at 10° compared with 30° canal curvature (Table 3). Resin blocks instrumented with K and ProTaper Next files exhibited a greater working length reduction at a 30° canal curvature (1.23 ± 0.36 mm and 0.30 ± 0.20 mm, respectively) when compared with a 10° canal curvature (0.68 ± 0.21 mm and 0.13 ± 0.13 mm, respectively). In 30° canals, a statistically significant increase in working length reduction was produced ($P < .05$).

**TABLE 2 -** The Dunn Post Hoc Test for the Significance of Working Length Reduction and Canal Enlargement Produced by 4 Different Endodontic File Systems

| | Working length reduction | | |
|---|---|---|---|
| **File type** | **Hedström** | **K file** | **ProTaper** |
| K file | $P$ = .0049 | — | — |
| ProTaper | $P$ = .0053 | $P$ = .0000 | — |
| TF Adaptive | $P$ = .0000 | $P$ = .0000 | $P$ = .0782* |
| | **Canal enlargement** | | |
| | **Hedström** | **K file** | **ProTaper** |
| K file | $P$ = .0043 | — | — |
| ProTaper | $P$ = .0007 | $P$ = .0000 | — |
| TF Adaptive | $P$ = .0002 | $P$ = .0000 | $P$ = .3341* |

*Not statistically significant ($P > .05$).

**TABLE 3 -** The Paired *t* Test for the Significance of the Canal Curvature (10° or 30°) on the Mean Reduction in Working Length and the Mean Percentage of Canal Enlargement Using 4 Different Endodontic File Systems

| File type | Mean working length reduction (mm) | *P* value (working length) | Mean canal enlargement (%) | *P* value (canal enlargement) |
|---|---|---|---|---|
| Hedström | −0.10 | .440 | −4.74 | .207 |
| K file | 0.55 | .001* | 13.46 | .0052* |
| ProTaper | 0.18 | .031* | −0.35 | .863 |
| TF Adaptive | 0 | 1.000 | −1.20 | .477 |

*Statistically significant ($P < .05$).

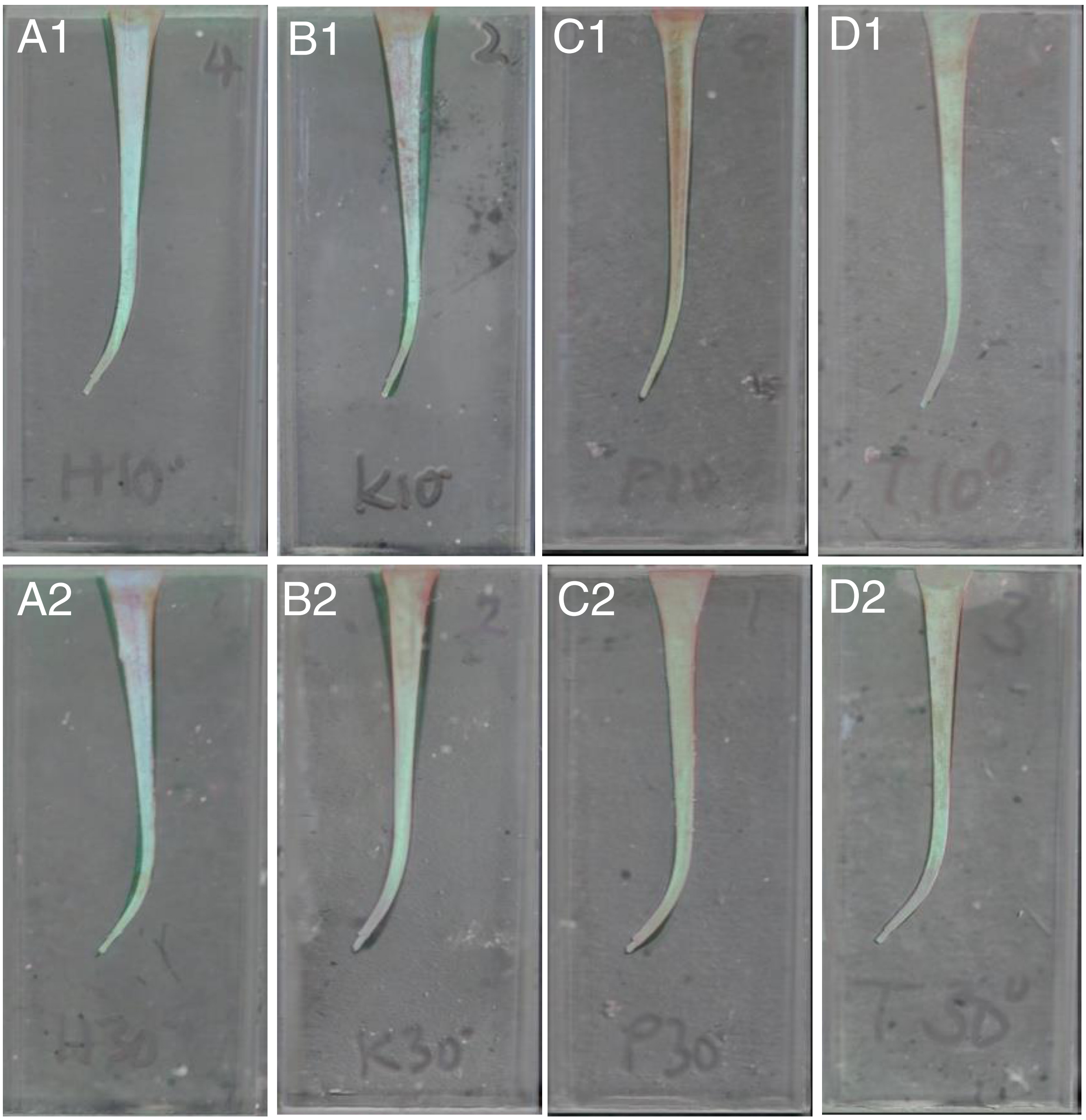


**FIGURE 3 –** The shape of canal enlargement produced by instrumentation with (*A1* and *A2*) Hedström files, (*B1* and *B2*) K files, (*C1* and *C2*) ProTaper Next files, and (*D1* and *D2*) TF Adaptive files in (*A1*, *B1*, *C1*, and *D1*) 10° and (*A2*, *B2*, *C2*, and *D2*) 30° canals.

### Effect of Canal Curvature on Change in Canal Area

The degree of canal curvature did not appear to have a significant effect on canal size after canal preparation, except for K files where a greater mean percentage canal enlargement was produced in 10° canals (41.20% ± 11.70%) as opposed to 30° canals (27.70% ± 6.50%). For K files, a mean percentage canal enlargement of 13.46% in 10° canals was statistically significant (95% confidence interval, 4.56%–22.36%; $t_{18} = 3.18$; $P = .0052$) (Fig. 3*A1–D2*).

## DISCUSSION

The results of this study indicate that a reduction in working length consistently occurs during instrumentation of curved canals. Four different endodontic file systems produced statistically significant differences in mean working length reduction, except when comparing ProTaper Next and TF Adaptive files (Fig. 1, Table 1). This indicates that the type of endodontic file system is a significant factor in determining the working length reduction produced during instrumentation. K files produced the greatest reduction in the mean working length followed by Hedström, ProTaper Next, and TF Adaptive files (Fig. 1, Table 1). These findings are consistent with a number of other studies[13,20] that indicate that NiTi rotary files produce a smaller reduction in the working length when compared with SS hand files. This may be attributed to the superior flexibility, superelastic nature (allowing the file to undergo extensive deformation followed by reverse transformation after unloading), and shape memory exhibited by NiTi files when compared with SS files[25]. These properties have been theorized to allow NiTi files to remain centered within the canal during instrumentation, thus minimizing straightening of the canal and reductions in the working length.

The amount and pattern of canal enlargement produced during instrumentation are also dependent on the endodontic file system used. ProTaper Next and TF Adaptive files produced the smallest mean area of canal enlargement followed by Hedström and K files, respectively (Fig. 2, Table 2). This may also be attributed to the material properties of NiTi rotary files. This theory is supported by comparisons of the shape of canal enlargement produced by the 4 file types. Although the SS hand files produce noticeable straightening of the curved canals, NiTi rotary files appear to remove resin uniformly from the inner walls of the canal, thus evenly enlarging the canal (Fig. 3).

The degree of canal curvature significantly influenced the mean working length reduction in some file systems. Resin blocks instrumented with K and ProTaper Next files exhibited significantly greater working length reduction in 30° canals than 10° canals. It is well recognized that the reduction in working length is more pronounced in curved canals[6–12] because of the tendency of files to straighten in the canal. The increased canal curvature did not result in a significant reduction in working length for Hedström and TF Adaptive file systems. This may be attributed to the size of preparation or the degree of canal curvature being insufficient to show a significant change in the working length.

The degree of canal curvature had a significant effect on the canal size for K files only in which a greater mean percentage canal enlargement was produced in 10° canals when compared with 30° canals. During canal preparation using the step-back technique, coronal tapering up to a size 40 file removed a significant amount of resin from the lateral walls of the canal coronally. Preparation of 10° canals appeared to have more extensive resin removal coronally when compared with 30° canals and thus a greater mean percentage canal enlargement. The size of the preparation or degree of canal curvature in this study was likely insufficient to demonstrate a significant change in canal enlargement with increasing canal curvature.

In conclusion, this study indicates that TF Adaptive files produced the least mean reduction in working length and the smallest percentage increase in canal size. An increase in the canal curvature had no significant effect on the mean working length reduction or canal enlargement with TF Adaptive files. Instrumentation with TF Adaptive files also appears to produce uniform enlargement of canals. Instrumentation with ProTaper Next files produced a comparable reduction in the working length and canal enlargement; however, an increase in the canal curvature significantly increased the working length reduction. Hedström files performed significantly better than K files in terms of working length reduction and canal enlargement.

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*The authors deny any conflicts of interest related to this study.*

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