# Effect of Canal Length and Curvature on Working Length Alteration with WaveOne Reciprocating Files

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*Elio Berutti, MD, DDS,* Giorgio Chiandussi, MS, PhD,† Davide Salvatore Paolino, MS, PhD,† Nicola Scotti, DDS,* Giuseppe Cantatore, MD,‡ Arnaldo Castellucci, MD, DDS,§ and Damiano Pasqualini, DDS**

## Abstract

**Introduction:** This study evaluated the working length (WL) modification after instrumentation with WaveOne Primary (Dentsply Maillefer, Ballaigues, Switzerland) reciprocating files and the incidence of overinstrumentation in relation to the initial WL. **Methods:** Thirty-two root canals of permanent teeth were used. The angles of curvature of the canals were calculated on digital radiographs. The initial WL with K-files was transferred to the matched WaveOne Primary reciprocating files. After glide paths were established with PathFile (Dentsply Maillefer, Ballaigues, Switzerland), canals were shaped with WaveOne Primary referring to the initial WL. The difference between the postinstrumentation canal length and the initial canal length was analyzed by using a fiberoptic inspection microscope. Data were analyzed with a balanced 2-way factorial analysis of variance ($P < .05$). **Results:** Referring to the initial WL, 24 of 32 WaveOne Primary files projected beyond the experimental apical foramen (minimum–maximum, 0.14–0.76 mm). A significant decrease in the canal length after instrumentation (95% confidence interval ranging from −0.34 mm to −0.26 mm) was detected. The canal curvature significantly influenced the WL variation ($F_1 = 30.65$, $P < .001$). The interaction between the initial canal length and the canal curvature was statistically significant ($F_2 = 4.38$, $P = .014$). **Conclusions:** Checking the WL before preparation of the apical third of the root canal is recommended when using the new WaveOne NiTi single-file system. *(J Endod 2011;37:1687–1690)*

## Key Words

Nickel-titanium, reciprocating motion, WaveOne, working length

From the *Department of Endodontics, University of Turin Dental School, Turin; †Department of Mechanics, Polytechincal School of Turin, Turin; ‡Department of Endodontics, School of Dentistry, University of Verona, Verona; and §Department of Endodontics, School of Dentistry, University of Florence, Italy.

Address requests for reprints to Dr Damiano Pasqualini, University of Turin Dental School, Department of Endodontics, via Barrili, 9–10134 Turin, Italy. E-mail address: damianox@mac.com

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Nickel titanium (NiTi) rotary instruments were introduced to improve root canal preparation (1). In clinical practice, these instruments are commonly associated with a risk of fracture. Fracture may be caused by normal cyclic stresses caused by bending (fatigue failure) and to shear stresses exceeding the elastic limit of the alloy caused by torque (ductile failure) (2–4). Both the clinician and the instrumentation technique used play a significant role in preventing large shear stresses caused by torque. These stresses dramatically increase when an excessive pressure is applied on the handpiece (5), when the contact area between the canal walls and the cutting edge of the instrument widens (6, 7), or when the canal cross-section is smaller than the nonactive or noncutting tip of the instrument (6, 7). The latter case can cause what has been described as taper lock, a phenomenon usually occurring with regularly tapered instruments (8). This risk may be reduced by performing coronal enlargement (9, 10) and by creating a manual (11, 12) and/or mechanical (13) glide path before using NiTi rotary instrumentation. However, canal curvature is considered the predominant risk factor for the instrument fatigue failure because of cyclic normal stresses caused by bending (1). In this case, little can be done by the clinician to reduce this type of stresses and, consequently, the risk of the instrument fatigue failure.

A reciprocating motion may decrease the impact of cyclic fatigue on NiTi rotary instrument life compared with rotational motion (14, 15). The new WaveOne NiTi single-file system (Fig. 1) has been recently introduced by Dentsply Maillefer (Ballaigues, Switzerland). This system is designed to be used with a dedicated reciprocating motion motor. It consists of 3 single-use files: small (ISO 21 tip and 6% taper) for small canals, primary (ISO 25 tip and 8% taper) for the majority of canals, and large (ISO 40 and 8% taper) for large canals. The files are manufactured with M-Wire (Dentsply Tulsa Dental, Tulsa, OK) NiTi alloy (16).

It has been shown that root canal instrumentation leads to changes in working length (WL) by straightening of the canal during the course of the treatment (17, 18). Although NiTi rotary instrumentation may lead to a smaller WL change during shaping procedures (19) compared with stainless-steel instrumentation, the appropriate determination of WL throughout the entire treatment is still a key factor for successful endodontic therapy. Davies et al (18) suggested that verifying the WL after early coronal flaring and late coronal flaring before definitive instrumentation of the apical segment of the root is the most appropriate action. The new WaveOne single-file reciprocating system is designed to reach complete shaping with only 1 instrument used to the full WL. No data are available on the modifications of WL with this new instrument. Thus, the aim of the study was to analyze the WL variation when the WaveOne single-file reciprocating system is used and to assess the influence of overinstrumentation.

## Materials and Methods

Thirty-two root canals of extracted permanent teeth with a fully formed apex (first and second upper molar buccal canals and first and second lower molar mesial canals) and a set of 8 controls (upper central incisors with relatively straight root canals) were used. The specimens had not undergone prior endodontic treatment. After debriding the root surface, specimens were immersed in a 5% solution of NaOCl (Niclor 5; OGNA, Muggiò, Italy) for 1 hour and then stored in saline solution until preparation.

**Figure 1.** WaveOne instruments. Small (*yellow*), primary (*red*), and large (*black*) files.

Preoperative radiographs were taken (Planmeca Intra, Helsinki, Finland) by using phosphor sensor imaging plates, processed, and archived by dedicated scanner and software interface (OpTime, Soredex, Finland). After access cavity preparation, the appropriate reference cusp and root end were flattened by using a grinding/polishing wheel to provide reproducible and accurate measurements as previously described (18). The root ends were flattened slightly coronal to the apical foramen. A flat glass surface was placed in contact with each flattened root end, and the WL was established by a previously calibrated examiner under microscopic vision (OPMI Pro Ergo; Carl Zeiss, Oberkochen, Germany) at 10× magnification when the tip of a #10 K-file was visible at the root tip in contact with the glass surface. Afterwards, the silicone stop position was fixed with cyanoacrylate (Loctite, Henkel, Italy). The WL obtained with K-files was transferred to WaveOne single files by matching corresponding files. Digital images of K-files and corresponding WaveOne Primary (Dentsply Maillefer) were acquired by a digital reflex camera (Canon EOS 350D, 8 Mpx resolution, ISO 100, f/18, 1/60 seconds; Canon, Tokyo, Japan). For each instrument, 2 measurements were taken by 2 different examiners (32 × 2 × 2 × 2) for a total of 256 measures using software Rhino (version 4.0; McNeel, Seattle, WA).

Glide path was achieved with PathFile 1, 2, and 3 (Dentsply Maillefer) at the full WL as previously determined by using Glyde (Dentsply Maillefer) as a lubricating agent. The specimens were positioned and blocked onto ProTrain (Dentsply Maillefer), which is a patented support device for the *in vivo* simulation of the endodontic therapy on extracted teeth. The system allows blocking every type of tooth thanks to the 3 interchangeable grabs with different diameters; the tooth is blocked in the grab, and the root is dipped in a conductor gel that simulates the periodontium.

Canals were shaped with WaveOne Primary reciprocating files with the silicone stop position fixed with cyanoacrylate. Instrumentation was performed by a different operator previously trained on the new technique who was blind to the specimens' root tips. The shaping procedure was performed with a pecking motion, until reaching the full WL, referring to the appropriate reference cusp. The WaveOne dedicated reciprocating motor was used with the manufacturer configuration setup. Irrigation was performed as follows with a 30-G needle syringe: 10 mL of 5% sodium hypochlorite at 50°C (Niclor 5) alternating with 10 mL of 10% EDTA (Tubuliclean, OGNA). The WaveOne Primary files were then left in the root canal with the rubber stop in contact with the reference cusp and fixed with cyanoacrylate. Specimens were then analyzed by a fiberoptic inspection microscope (FORT GLV 154; FORT, Bergamo, Italy) with 50× magnification (Fig. 2). The portion of the instrument visible externally was measured. For each specimen, 2 measurements were made using software Rhino (version 4.0) for a total of 48 measurements. To calculate the difference between the postinstrumentation canal length ($CL_{final}$) and the initial canal length ($CL_{initial}$), described as the delta canal length (DCL), for each specimen, the following measured quantities were considered: $WL_{kf}$ (working Length *kf*): K-file length, $WL_{w1}$ (working length *w1*): WaveOne length, and projecting length (PL): length beyond the apex; the following formula was applied as reported in Figure 3: $DCL = CL_{final} - CL_{initial} = (WL_{w1} - PL) - WL_{kf} = (WL_{w1} - WL_{kf}) - PL$. For each canal, 8 independent DCL values were calculated, and 192 (24 × 8) DCL values were finally obtained.

The angles of curvature of the canals were calculated as previously described (20) and classified as moderate (10°-25°) or severe (>25°). On the basis of mean $WL_{kf}$ values distribution, canals were also classified as short (<18 mm), medium (18-19.5 mm), or long (>19.5 mm). A balanced 2-way factorial analysis of variance with 32 DCL replications for each treatment combination was performed to evaluate significance of the canal curvature (CC) factor at 2 levels (moderate and severe) and the canal length (CL) factor at 3 levels (ie, short, medium, and long) and assess the significance of the interaction between the 2 factors. The significance level was set to 5% ($P < .05$). All statistical analyses were performed by using the Minitab 15 software package (Minitab Inc, State College, PA).

## Results

In the control group, only 3 of the 8 WaveOne Primary files projected beyond the experimental apical foramen with a mean DCL variation of 0.1 mm (± 0.02 mm). Twenty-four of 32 WaveOne Primary files projected beyond the experimental apical foramen (minimum–maximum PL range, 0.14–0.76 mm). This large incidence (75%) of overinstrumentation may be related to the experimental conditions and the fact that instrumentation was accomplished according to the initial $WL_{kf}$.

Statistical inference on DCL values showed a statistically significant decrease of the canal length after instrumentation (95% confidence interval ranging from −0.34 mm to −0.26 mm). Factor CC significantly influenced the DCL values ($F_1 = 30.65$, $P < .001$) as confirmed by the interval plot (Fig. 4). According to the analysis of variance table, the initial canal length (factor CL) did not significantly influence the DCL values ($F_2 = 0.79$, $P = .456$). However, the interaction between the initial canal length (factor CL) and the canal curvature (factor CC) was statistically significant for the DCL values ($F_2 = 4.38$, $P = .014$) as shown in Figure 5.

## Discussion

The present study evidenced that a significant decrease in the WL may occur after instrumentation with the new reciprocating single file

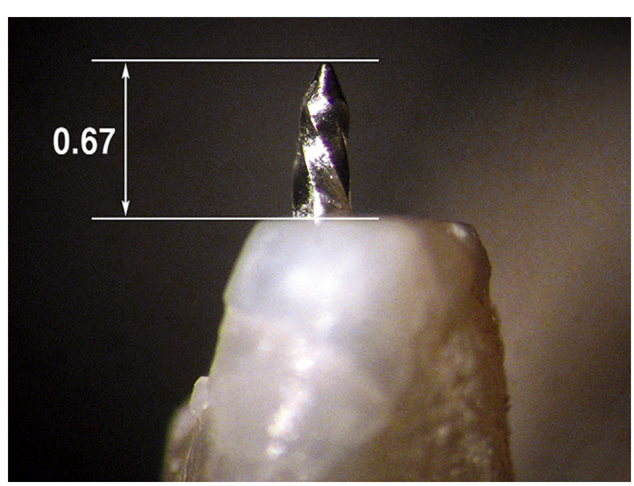


**Figure 2.** A microscopic image (50×) of specimen #14 with severe canal curvature where the file projected beyond the experimental apical foramen (in millimeters).

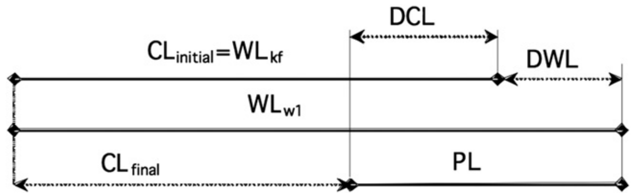


**Figure 3.** Evaluation of the DCL differences. The continuous line indicates the length values measured, whereas the dotted line indicates the length values calculated indirectly. C, canal; D, delta (difference); L, length; P, projecting; W, working.

WaveOne Primary, mainly because of the straightening of the root canal curves. These results are in agreement with the findings of other investigations on WL reduction after root canal shaping with stainless-steel hand files (21), stainless-steel hand files plus Gates Glidden burs (18), and NiTi rotary instruments (18, 22). However, it has been shown that NiTi rotary instrumentation may lead to a considerable, yet smaller, amount of curve straightening and to a WL decrease (18, 22). This is probably caused by the superior ability of NiTi instrumentation to remain centered into the root canal compared with stainless steel instrumentation (1, 18, 23). Modifications of the WL during instrumentation are influenced by several important factors. The original canal anatomy (ie, the canal curvature [17]) and the coronal flaring of root canals (24) were found to be the primary determining factors. In this study, the canal length and the canal curvature were correlated to the WL decrease. As expected, the interaction of both factors as well as the canal curvature by itself significantly influenced WL reduction; a severe curvature is more likely to lead to a higher decrease in the WL. On the contrary, straight canals, such as the ones used in the control group, did not undergo significant WL modifications after instrumentation. In case of severe curvature, flaring the coronal portion of the root canal should be the procedure of choice in order to facilitate the placement of files into the apical segment (24) and prevent excessive flexural stress to the Ni-Ti instruments (25, 26). It has been shown that, in case of severe curvature, the coronal flaring always leads to a WL decrease independently from the root canal preparation technique (27). However, WL reduction is higher after immediate coronal flaring compared with late coronal flaring before apical preparation (18). NiTi rotary files showed a mean WL decrease of −0.22 mm after canal preparation, but a less pronounced WL reduction (−0.14 mm) was evident after late canal flaring. Therefore, it is highly recommended to check the WL at least twice during root canal

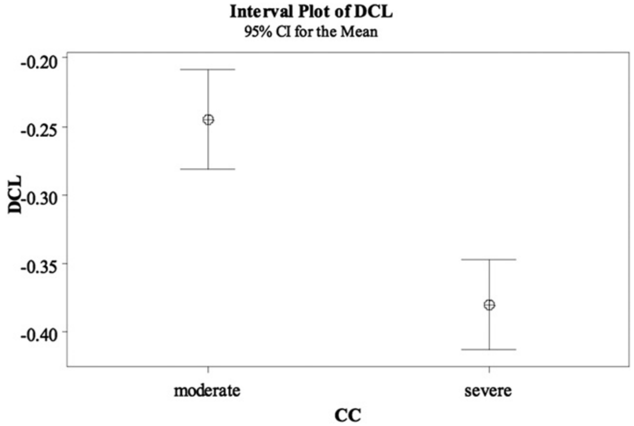


**Figure 4.** A 95% interval plot estimate of the effect of the CC on DCL; the considerable difference between the confidence intervals highlights the significance of the CC factor.

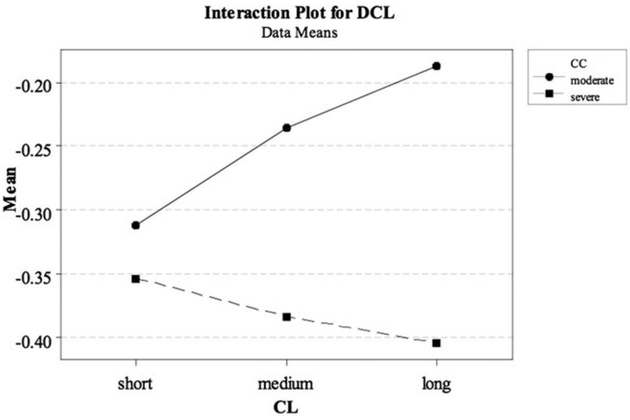


**Figure 5.** An interaction plot for DCL; the gradient variation between the dotted and continuous lines highlights the significance of the interaction.

shaping; an initial check is suggested during canal scouting. Canal scouting is usually performed with #10 K-file when the patency of the root canal is explored. Afterwards, a glide path is created, either manual or mechanical (11–13), to prevent NiTi rotary file tip blockage. A second check of the WL is suggested after canal flaring, before preparation of the apical portion of the root canal, because the WL is expected to undergo significant changes. This recommendation is particularly important when using the new WaveOne single-file reciprocating system, which is designed to reach complete shaping with only 1 instrument used to the full WL. In this study, the decrease of the canal length after instrumentation ranged from −0.34 mm to −0.26 mm (95% confidence interval). Furthermore, 24 of 32 WaveOne Primary files projected beyond the experimental apical foramen. The large incidence (75%) of overinstrumentation was simply caused by the fact that instrumentation was accomplished only according to the initial WL. Overinstrumentation with NiTi rotary files of augmented taper beyond the apical foramen may lead to apical transportation (28) and overfilling (29) with defective apical seal control, especially in severely curved canals. This type of intraoperative complication is a significant predictor of outcome of the initial endodontic treatment, especially in teeth with preoperative radiolucency (30). Furthermore, overinstrumentation may also cause complications such as a greater incidence of postoperative pain (31). The findings of this study confirm the importance of checking the WL when canal preparation has reached the limit between medium and apical third of the root canal before instrumentation of the apical third. Radiographic estimates have been shown to be inaccurate in determining the correct WL in many clinical situations, probably because of anatomic variability, and to be associated with the tendency to underestimation (32). Electronic apex locators showed to be precise and reliable in more than 90% of cases (33) and are superior in reducing overestimation of the root canal length (34). Their accuracy is improved by the flaring of the canal before WL determination (35). In conclusion, within the limits of this study, checking the WL before preparation of the apical third of the root canal is a highly recommended strategy when the new WaveOne NiTi single-file system is used.

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