Published online: 2019-09-04

Shaping ability of reciprocating single-file and full-sequence rotary instrumentation systems in simulated curved canals

Demet Altunbas[1], Betul Kutuk[2], Alper Kustarci[3]

[1]Department of Endodontics, Cumhuriyet University, Sivas, Turkiye,
[2]Department of Endodontics, Oral and Dental Health Center, Republic of Turkey Ministry of Health, Mersin, Turkiye,
[3]Department of Endodontics, Akdeniz University, Antalya, Turkiye

Correspondence: Dr. Demet Altunbas
Email: dt_demmet@hotmail.com

ABSTRACT

Objective: The purpose of this study was to evaluate the shaping ability of three nickel-titanium systems in simulated curved canals. **Materials and Methods:** Sixty simulated canals were prepared to apical size 25 with Reciproc, S5, and twisted file (TF) instruments. Standardized pre and postoperative images were taken using a digital camera, were superimposed and aberrations were recorded. Material removal was measured at five points: The canal orifice, halfway to the orifice, beginning of the curve, the apex of the curve, and end-point. The data were analyzed using Kolmogorov–Smirnov, analysis of variance, and Tukey tests. **Results:** The mean total width of the prepared canals in the Reciproc group was greater than the TF and S5 groups at halfway to the orifice, the beginning of the curve, the apex of the curve, and the end-point ($P < 0.05$). Mean absolute transportation was always <0.16 mm; however, significant differences occurred between the three systems at the orifice, halfway to the orifice, and the beginning of the curve ($P < 0.05$). TF created minimal absolute transportation at halfway to the orifice and the beginning of the curve, and greater absolute transportation at the orifice compared with the Reciproc and S5 instruments. However, the difference between the S5 and TF groups was not statistically significant at halfway to the orifice ($P > 0.05$). **Conclusions:** Under the conditions of the study, Reciproc produced widest canal shapes. TF provided more centered apical preparation and maintained the original canal shape well.

Key words: Canal transportation, Reciproc, shaping, S5, twisted file

INTRODUCTION

Root canal instrumentation is one of the most important step in any root canal treatment.[1] The ideal preparation for the root canal is a tapered funnel shaped form with increasing diameters from the end-point to the canal orifice.[2] However, instrumentation of narrow and curved root canals is not easy and may cause canal transportation and undesirable aberrations such as elbows, zips, or ledges.[3,4] Various endodontic instruments, devices, and canal instrumentation techniques have been introduced to reduce these errors aiming to achieve optimum cleaning and shaping, especially in curved narrow canals. It is known that nickel-titanium (NiTi) alloy is resilient, tough, and has a low elastic modulus.[5] These properties make it the material of choice for root canal instruments. NiTi instruments are able to maintain the original canal shape, because of their superelasticity and shape memory property. Nevertheless, despite these advantages, manufacturers keep introducing different kinematics NiTi systems with new

How to cite this article: Altunbas D, Kutuk B, Kustarci A. Shaping ability of reciprocating single-file and full-sequence rotary instrumentation systems in simulated curved canals. Eur J Dent 2015;9:346-51.

DOI: 10.4103/1305-7456.163221

designs, manufacturing processes, and materials. Recently, a new instrument design: Reciproc (VDW, Munich, Germany) has been introduced that has a S-shape cross-section and a noncutting tip. Reciproc instruments are manufactured from M-wire alloy that is created with a proprietary thermomechanical processing procedure. The structure of the M-wire NiTi alloy (mixture of nearly equal amounts of R-phase and austenite) is different from conventional superelastic NiTi alloy (austenite).[6] The manufacturer has claimed that instruments made with this new alloy have enhanced flexibility and fatigue resistance compared with the conventional NiTi instruments. Furthermore, Reciproc is a single file system, and the instruments are available in three sizes: R25 (0.08/25 in the first millimeters), R40 (0.06/40 in the first millimeters), and R50 (0.05/50 in the first millimeters). These instruments have been designed for use in a reciprocating motion powered by an endodontic motor (Silver/Gold Reciproc; VDW) using specific presetting (10 reciprocating cycles per second, which is represent the equivalent of approximately 300 rpm). Reciprocation is an alternating movement in which the instrument rotates in a counterclockwise cutting direction, and after in a clockwise direction. The rotation in the cutting direction is larger than the reverse rotation.[7] This motion aims to minimize the risk of instruments fracture caused by torsional stress.

S5 (Sendoline, Täby, Sweden) is a new NiTi rotary system. The instruments are made of conventional NiTi alloy and have a unique S-shape profile and long progressive flutes. This design ensures enhanced debris transportation and reduces the risk of fractures. The series of S5 instruments comprises five instruments: S1 (0.08/30), S2 (0.06/30), S3 (0.04/30), S4 (0.04/25), and S5 (0.04/20). The instruments are intended to be used with the S5 Endo Motor and used at a rotational speed of 300 rpm and its own torque settings (4.0 Ncm, 3.0 Ncm, 2.3 Ncm, 1.2 Ncm, and 0.5 Ncm, respectively). The root canals are instrumented with these instruments using the crown-down technique in a rotary motion. To our knowledge, there are no published studies to evaluate the shaping ability of S5 instruments in root canals.

The Twisted file (TF; SybronEndo, Orange, CA, USA) is another NiTi rotary system, and three new design methods, such as R-phase heat treatment, twisting of the metal, and special surface conditioning are used during their manufacturing process.[8] This process significantly increases the instrument resistance to cyclic fatigue and flexibility.[9] TF is characterized by a triangular cross-section, variable pitch, and safe ended tip. The instruments are available in sizes from 25 to 50 with tapers of 0.04, 0.06, 0.08, 0.10, and 0.12. The recommended speed with torque setting is 500 rpm with 400 gcm for this system.

The purpose of this study was to assess the morphological characteristics of prepared simulated curved canals by the use of three NiTi systems with different design features and kinematics. The shaping effects were evaluated by analyzing the resin removed from the original canal wall, canal transportation, and incidence of procedural errors such as perforation, ledge, zip, and elbow.

MATERIALS AND METHODS

A total of 60 simulated canals with 40° curvature in clear resin blocks (plastic training blocks, Ref. V040245, VDW) were used to assess instrumentation. The length of the canals in the resin blocks was 19 mm, with straight coronal section 13 mm and curved apical section 6 mm.

The blocks with simulated canals were randomly divided into three groups (Reciproc, S5, and TF groups) and preinstrumentation photographs of the canals were taken in a standardized manner using a digital camera [Figure 1a]. The operator was shielded from seeing the canal during instrumentation by an aluminum leaf that covered the resin block. All canals were prepared by the same operator to a working length (WL) of 18.5 mm, and each instrument was used 4 times before being replaced. Copious irrigation

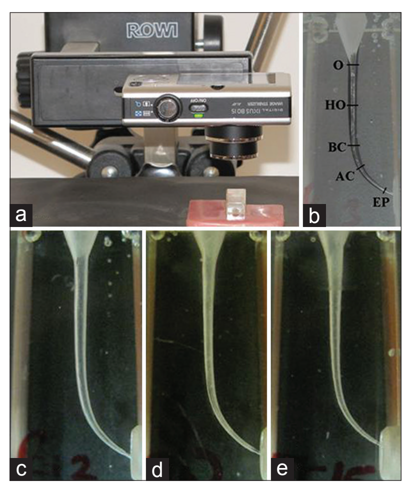

Figure 1: Imaging system with digital camera (a); superimposed image of a simulated canal with the five measuring points (b); representative images of the canals after instrumentation with Reciproc (c), S5 (d), and TF (e) systems

with distilled water was performed after the use of each instrument. The final apical preparation was set at to #25. Patency of the simulated canals was checked by a size 10 K-file to the WL. The instrumentation sequences were as follows:

Reciproc group (*n* = 20)
A Reciproc R25 (0.08/25) instrument was used with an endomotor (VDW Silver; VDW) in a reciprocating, slow, in-and-out pecking motion at the "Reciproc all" mode until reaching the WL according to the manufacturer's instructions. The flutes of the instrument were cleaned after three pecks.

Twisted file group (*n* = 20)
TF instruments were used with an endomotor (VDW Silver; VDW) according to manufacturer's instructions and root canal instrumentation commenced with coronal flaring using a size 0.08/25 file. A size 0.06/25 instrument was then inserted and used 2 mm short of the WL. Apical instrumentation to the WL was achieved using a size 0.04/25 instrument.

S5 group (*n* = 20)
S5 instruments were used with the S5 endomotor (Sendoline, Täby, Sweden) in a crown-down manner according to manufacturer's instructions using a gentle in-and-out motion. The simulated canals were instrumented according to the following sequence: Size 0.08/30 at coronal third of the WL; size 0.06/30 at two-thirds of the WL; size 0.04/25 at 2 mm short of the WL; size 0.04/20 at the WL; and size 0.04/25 at the WL.

Postinstrumentation photographs of the canals were taken after canal preparation. A composite image was produced from the pre and postinstrumentation images of each canal and superimposed using Adobe Photoshop CS3 (Adobe System, San Jose, CA, USA). Measurements were made on superimposed images using Image J 1.42q computer program (National Institutes of Health, Bethesda, MD, USA) with an accuracy level of 0.001 mm. The material removal was measured at five different points [Figure 1b] established on each canal, using a method described by Calberson *et al*.:[10] the canal orifice (Point O), halfway from the beginning of the curve to the orifice (Point HO), the beginning of the curve (Point BC), the apex of the curve of the original canal (Point AC), and end-point of the preparation (Point EP).

The total width of the prepared canals and the width of resin removed from the inner and outer aspects of the curve were measured at each of the five points. The amount of canal transportation was determined from the inner and outer width measurements.

Different types of canal aberrations such as zip, elbow, ledge, and perforation were assessed on the images of superimposed canals.[11]

Statistical analysis
All statistical analyses were performed using SPSS software (SPSS Inc, Chicago, IL, USA). The normality of the data was confirmed by the Kolmogorov–Smirnov test and the groups were statistically compared using analysis of variance complemented by Tukey's test with a level of significance of $P < 0.05$.

RESULTS

The mean total width of the prepared canals is shown in Table 1. The Reciproc group caused significantly greater widening of canals than the other two groups at halfway to the orifice, the beginning of the curve, the apex of the curve, and the end-point ($P < 0.05$; [Figure 1c-e]). At the beginning of the curve, the apex of the curve, and the end-point the narrowest total width measurements were noted in the TF group ($P < 0.05$). Mean total width measurement was less with S5 than with Reciproc and TF at the orifice ($P < 0.05$).

The resin removal from the inner aspect of the curve was greater with Reciproc than with S5 and TF instruments at all measuring points ($P < 0.05$). At the beginning of the curve, the apex of the curve, and the end-point, least resin removed from the inner aspect of the curve with TF instruments ($P < 0.05$) [Table 2].

Reciproc instruments removed more resin from the outer aspect of the curve compared with the S5 and TF at halfway to the orifice, the beginning of the curve, the apex of the curve, and the end-point ($P < 0.05$). At the orifice, more resin removed from the outer aspect of the curve with TF instruments ($P < 0.05$) [Table 2].

Table 1: Mean total width (mm) of the canals at the different measuring points

	Reciproc	S5	TF	*P*
Orifice	0.949^a	0.861^b	0.960^a	0.001
Halfway to orifice	0.802^a	0.653^b	0.674^b	0.001
Beginning of curve	0.657^a	0.568^b	0.489^c	0.001
Apex of curve	0.514^a	0.447^b	0.362^c	0.001
End-point	0.319^a	0.296^b	0.255^c	0.001

Different superscript letter indicates statistically significant difference between groups ($P<0.05$). TF: Twisted file

Table 2: Mean inner and outer width measurements (mm) of the canals at the different measuring points

	Orifice		Halfway to orifice		Beginning of curve		Apex of curve		End-point	
	Inner	Outer	Inner	Outer	Inner	Outer	Inner	Outer	Inner	Outer
Reciproc	0.219[a]	0.207[a]	0.195[a]	0.265[a]	0.262[a]	0.119[a]	0.135[a]	0.128[a]	0.057[a]	0.067[a]
S5	0.160[b]	0.189[a]	0.139[b]	0.188[b]	0.233[b]	0.077[b]	0.109[b]	0.094[b]	0.040[b]	0.050[b]
TF	0.183[b]	0.249[b]	0.158[b]	0.194[b]	0.147[c]	0.084[b]	0.050[c]	0.083[b]	0.028[c]	0.039[b]
P	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001

Different superscript letter indicates statistically significant difference between groups (P<0.05)

Table 3: Mean distance of absolute transportation (mm) at the different measuring points

	Reciproc	S5	TF	*P*
Orifice	0.029[a]	0.047[a]	0.096[b]	0.001
Halfway to orifice	0.070[a]	0.051[ac]	0.037[c]	0.008
Beginning of curve	0.142[a]	0.155[a]	0.063[b]	0.001
Apex of curve	0.025	0.027	0.033	0.609
End-point	0.013	0.016	0.012	0.610

Different superscript letter indicates statistically significant difference between groups (P<0.05)

The degree of absolute transportation irrespective of direction for the measurement positions is detailed in Table 3. The use of TF instruments resulted in significantly more transportation compared with the other two instruments at the orifice ($P < 0.05$). The absolute transportation with Reciproc was greater than TF at halfway to the orifice ($P < 0.05$). Reciproc and S5 instruments created the greater absolute transportation than the TF instruments at the beginning of the curve ($P < 0.05$). No significant differences were obtained between Reciproc, S5, and TF regarding canal transportation at the apex of the curve and the end-point ($P > 0.05$).

No aberrations of any kind such as zip, elbow, ledge, and perforation were found when canals were instrumented with all three instruments.

DISCUSSION

The present study assessed the shaping abilities of three instrumentation systems with different manufacturing processes, using simulated curved canals. Instrumentation of simulated canals in resin blocks may not reflect the behavior of the instruments in root canals of natural teeth because of differences in surface texture, hardness, and cross-section;[1] however, this allows standardizing conditions and direct comparison of the shaping ability of different instrument systems.[12]

The results of this study revealed that although the mean width was similar with TF and Reciproc instruments at the orifice, Reciproc provided the widest instrumentation from the orifice to the end-point and removed more resin from the inner and outer aspect of the curve. This is in agreement with previous studies that showed that Reciproc instruments removed more dentin along the canal.[13,14] A sharp double cutting edge S-shaped geometry, smaller cross-sectional area,[15] and the dissimilarities between tapers of the master apical instruments may explain the greater cutting ability of Reciproc instruments. In the present study, the final taper was 0.08 at the apical 3 mm for Reciproc, 0.04 for S5 and TF. Shaping ability of the root canal instruments that have different tapers has been compared each other in many studies.[14,16-20] The final taper might have influenced the material removal as it has been shown in recent studies.[14,20] In a recent study, the shaping ability of four single file systems have different tapers has been compared and the study reported that more tapered instruments removed more resin compared with less tapered instruments and that the taper of the instruments is the predetermining factor regarding the shaping ability of the tested instruments.[20] Another recent study showed that 0.06 taper OneShape and TF Adaptive instruments removed less dentin than R25 instrument, but 0.06 taper ProTaper Next instrument removed similar amounts of dentin compared with other instruments having a 0.08 apical taper.[14] Hence, differences between the resin removal of the instruments can be attributed to their common features such as the cross-section, working motion, manufacturing method, and taper.

The apical third of the root canal needs to be enlarged sufficiently to remove debris and to allow proper irrigation for successful treatment. Furthermore, larger instrumentation size may decrease remaining bacteria in the root canal system and especially in the apical third.[21] However, increased apical enlargement may cause in a poor hermetic seal during root canal obturation when the apical instrumentation size of the canal is greater from the gutta-percha point, which is a similar size with the master apical instrument.[22] The final apical preparation was set to size 25 to ensure comparability between the groups. At the end-point of the instrumentation, the mean width in the Reciproc and S5 group was greater than the nominal size of the master apical instruments; whereas, the mean width was 0.255 mm for TF system. This might be attributed to a combination of its cross-section and manufacturing method like twisting that produced less resin removal at the end-point.

In the present study, all three instruments produced minimal transportation (always <0.16 mm). Reciproc and S5 instruments showed similar transportation at all measuring points. Despite the Reciproc and S5 instruments having different features (alloy, kinematic, taper, and number of the files), their similar cross-section design may explain this result. This finding cannot be compared with existing data because so far no reports on the shaping ability of S5 instruments are available. The results of the present study suggested that TF instruments prepared the curved canals with less transportation than the other two file at halfway to the orifice and the beginning of the curve. However, the difference between the S5 and TF groups was not statistically significant at halfway to the orifice. The present finding is corroborated by recent studies reported that TF instruments caused less transportation than Reciproc and WaveOne instruments,[23] ProTaper instruments,[24] and K3 instruments.[25,26] Furthermore, a recent study noted that Reciproc and TF instruments do not differ significantly in terms of canal centering ability and transportation.[27] Concerning Reciproc system, previous studies have showed that these instruments produced more transportation than TF Adaptive and WaveOne systems.[13,28] Better shaping results of the TF instruments, which are manufactured by twisting, can be attributed to the fact that these instruments are more flexible than the other NiTi instruments, which are manufactured by grinding.[24] Furthermore, R-phase heat treatment and special surface conditioning of the alloy during manufacturing, which makes it more flexible and strength are minimizing canal transportation even in severely curved canals.

CONCLUSIONS

Within the limitations of this study, Reciproc, S5, and TF systems instrumented curved canals without creating zips, elbows, ledges, or perforations. Reciproc produced widest canal shapes and removed more resin from the inner and outer aspect of the curve. TF provided more centered apical preparation and maintained the original shape of the simulated curved canals well.

Financial support and sponsorship
Nil.

Conflicts of interest
There are no conflicts of interest.

REFERENCES

1. Peters OA. Current challenges and concepts in the preparation of root canal systems: A review. J Endod 2004;30:559-67.
2. Schilder H. Cleaning and shaping the root canal. Dent Clin North Am 1974;18:269-96.
3. Esposito PT, Cunningham CJ. A comparison of canal preparation with nickel-titanium and stainless steel instruments. J Endod 1995;21:173-6.
4. Perez F, Schoumacher M, Peli JF. Shaping ability of two rotary instruments in simulated canals: Stainless steel ENDOflash and nickel-titanium HERO shaper. Int Endod J 2005;38:637-44.
5. Thompson SA. An overview of nickel-titanium alloys used in dentistry. Int Endod J 2000;33:297-310.
6. Alapati SB, Brantley WA, Iijima M, Clark WA, Kovarik L, Buie C, *et al.* Metallurgical characterization of a new nickel-titanium wire for rotary endodontic instruments. J Endod 2009;35:1589-93.
7. Plotino G, Grande NM, Porciani PF. Deformation and fracture incidence of reciproc instruments: A clinical evaluation. Int Endod J 2015;48:199-205.
8. Larsen CM, Watanabe I, Glickman GN, He J. Cyclic fatigue analysis of a new generation of nickel titanium rotary instruments. J Endod 2009;35:401-3.
9. Huang HM, Chang WJ, Teng NC, Lin HL, Hsieh SC. Structural analysis of cyclic-loaded nickel-titanium rotary instruments by using resonance frequency as a parameter. J Endod 2011;37:993-6.
10. Calberson FL, Deroose CA, Hommez GM, Raes H, De Moor RJ. Shaping ability of GT™ Rotary Files in simulated resin root canals. Int Endod J 2002;35:607-14.
11. Thompson SA, Dummer PM. Shaping ability of hero 642 rotary nickel-titanium instruments in simulated root canals: Part 2. Int Endod J 2000;33:255-61.
12. Schäfer E, Tepel J, Hoppe W. Properties of endodontic hand instruments used in rotary motion. Part 2. Instrumentation of curved canals. J Endod 1995;21:493-7.
13. Gergi R, Osta N, Bourbouze G, Zgheib C, Arbab-Chirani R, Naaman A. Effects of three nickel titanium instrument systems on root canal geometry assessed by micro-computed tomography. Int Endod J 2015;48:162-70.
14. Capar ID, Ertas H, Ok E, Arslan H, Ertas ET. Comparative study of different novel nickel-titanium rotary systems for root canal preparation in severely curved root canals. J Endod 2014;40:852-6.
15. Giansiracusa Rubini A, Plotino G, Al-Sudani D, Grande NM, Sonnino G, Putorti E, *et al.* A new device to test cutting efficiency of mechanical endodontic instruments. Med Sci Monit 2014;20:374-8.
16. Schäfer E, Erler M, Dammaschke T. Comparative study on the shaping ability and cleaning efficiency of rotary Mtwo instruments. Part 1. Shaping ability in simulated curved canals. Int Endod J 2006;39:196-202.
17. Aydin C, Inan U, Yasar S, Bulucu B, Tunca YM. Comparison of shaping ability of RaCe and hero shaper instruments in simulated curved canals. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2008;105:e92-7.
18. Bürklein S, Benten S, Schäfer E. Shaping ability of different single-file systems in severely curved root canals of extracted teeth. Int Endod J 2013;46:590-7.
19. Bürklein S, Börjes L, Schäfer E. Comparison of preparation of curved root canals with Hyflex CM and Revo-S rotary nickel-titanium instruments. Int Endod J 2014;47:470-6.
20. Saleh AM, Vakili Gilani P, Tavanafar S, Schäfer E. Shaping ability of 4 different single-file systems in simulated S-shaped canals. J Endod 2015;41:548-52.
21. Baugh D, Wallace J. The role of apical instrumentation in root canal treatment: A review of the literature. J Endod 2005;31:333-40.
22. Jeon HJ, Paranjpe A, Ha JH, Kim E, Lee W, Kim HC. Apical enlargement according to different pecking times at working length

using reciprocating files. J Endod 2014;40:281-4.
23. Marceliano-Alves MF, Sousa-Neto MD, Fidel SR, Steier L, Robinson JP, Pécora JD, *et al.* Shaping ability of single-file reciprocating and heat-treated multifile rotary systems: A micro-CT study. Int Endod J doi: 10.1111/iej.12412. Epub ahead of print [Last accessed on 2014 Nov 14].
24. Gergi R, Rjeily JA, Sader J, Naaman A. Comparison of canal transportation and centering ability of twisted files, pathfile-ProTaper system, and stainless steel hand K-files by using computed tomography. J Endod 2010;36:904-7.
25. Zhao D, Shen Y, Peng B, Haapasalo M. Micro-computed tomography evaluation of the preparation of mesiobuccal root canals in maxillary first molars with hyflex CM, twisted files, and K3 instruments. J Endod 2013;39:385-8.
26. El Batouty KM, Elmallah WE. Comparison of canal transportation and changes in canal curvature of two nickel-titanium rotary instruments. J Endod 2011;37:1290-2.
27. Nazari Moghadam K, Shahab S, Rostami G. Canal transportation and centering ability of twisted file and reciproc: A cone-beam computed tomography assessment. Iran Endod J 2014;9:174-9.
28. Gergi R, Arbab-Chirani R, Osta N, Naaman A. Micro-computed tomographic evaluation of canal transportation instrumented by different kinematics rotary nickel-titanium instruments. J Endod 2014;40:1223-7.

Access this article online	
Quick Response Code:	**Website:** www.eurjdent.com