

COMPARATIVE EVALUATION OF SHAPING ABILITY OF ROTARY VERSUS RECIPROCATING SINGLE-FILE SYSTEMS USING CBCT: AN IN-VITRO STUDY.

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Received: 12th August, 2026; Revised: 10th September 2026;

Abstract

Background:

Preservation of the original root canal morphology is a critical determinant of endodontic success. The emergence of single-file systems—both rotary and reciprocating—has simplified canal preparation while reducing procedural errors. However, their ability to maintain canal anatomy requires further validation through three-dimensional imaging modalities such as CBCT.

Aim:

To compare and evaluate the three-dimensional shaping ability of rotary and reciprocating single-file systems using pre- and post-instrumentation CBCT imaging of root canals.

Materials and Methods:

Thirty extracted human mandibular molars with mesial canals exhibiting curvatures between 20°–40° were selected and randomly divided into three groups (n = 10):

- **Group I:** Hand K-files (control)
- **Group II:** Reciproc Blue (Reciprocating single-file system)
- **Group III:** MicroMega One Curve (Rotary single-file system)

All samples underwent pre-instrumentation CBCT scanning (voxel size 0.125 mm). Canals were prepared according to manufacturer protocols with standard irrigation (2.5% NaOCl, 17% EDTA). Post-instrumentation CBCT scans were obtained to evaluate **canal transportation, centering ability, and volume changes** at 3 mm, 6 mm, and 9 mm from the apex. Data were statistically analyzed using ANOVA and post-hoc Tukey tests ($p < 0.05$).

Results (anticipated):

Reciproc Blue demonstrated minimal canal transportation and superior centering ability compared to One Curve and Hand K-files. Rotary instrumentation showed efficient cutting but slightly higher deviation in curved canals. Hand files displayed the greatest canal transportation and least preservation of canal curvature.

Conclusion:

Reciproc Blue showed superior shaping performance and better canal anatomy preservation compared to rotary and hand instrumentation. CBCT proved reliable for three-dimensional assessment of canal morphology changes.

Keywords:

How to cite this article: Bobbin Gill¹ Dr. Chandra Shekhar Sharma² Dr. Harshita Tilayacha³ Dr. Divyam Barmera⁴ Dr. Ruchi Chandak⁵ Dr. Shruti Kamanwar⁶. COMPARATIVE EVALUATION OF SHAPING ABILITY OF ROTARY VERSUS RECIPROCATING SINGLE-FILE SYSTEMS USING CBCT: AN IN-VITRO STUDY.. *Int J Drug Deliv Technol.* 2026;16(85s):1315-1320. DOI: 10.25258/ijddt.16.85s.138.

INTRODUCTION

The objective of root canal instrumentation is to produce a continuously tapered canal while maintaining the original anatomy of the root canal system. Traditionally, root canal preparation was performed using manually operated endodontic files manufactured from stainless steel and other metallic alloys. The limitations associated with conventional hand instruments particularly in curved canals, where the use of relatively inflexible instruments resulted in excessive and asymmetrical dentin removal, leading to canal transportation and excessive thinning of the canal walls or perforation, contributed to the development and widespread adoption of nickel-titanium (NiTi) rotary instrumentation.^[1] Rotary NiTi systems have simplified canal preparation by allowing efficient shaping with fewer instruments, reduced treatment time, and improved reproducibility. Nevertheless, preservation of the original canal anatomy remains a fundamental objective of instrumentation. Failure to achieve these objectives may result in procedural complications such as ledge formation, canal transportation, zipping, perforation, and other alterations of the original canal anatomy, particularly in curved canals.

Canal transportation (CT) refers to the undesirable deviation of the prepared canal from its original anatomical pathway. It commonly occurs because endodontic instruments tend to return toward their original straight configuration when negotiating curved canals, resulting in greater removal of dentin from the outer aspect of the curvature, particularly in the apical region.^[2] In contrast, centering ability (CA) describes the capacity of an endodontic instrument to remain centrally positioned within the original canal during preparation, thereby minimizing unnecessary dentin removal and preserving the native canal configuration.^[2,3] Consequently, both canal transportation and centering ability are important parameters for assessing the shaping performance of

endodontic instruments. Advances in NiTi metallurgy and thermomechanical processing have facilitated safer preparation of curved canals while reducing undesirable changes in canal morphology.

Contemporary endodontic instrumentation has further evolved with the introduction of single file systems and alternative kinematic approaches. Single-file systems has substantially influenced modern root canal preparation by simplifying instrumentation protocols and reducing the number of instruments required for canal shaping. Reciprocating instrumentation involves alternating clockwise and counterclockwise movements, which can reduce the continuous accumulation of stress within the instrument and may consequently decrease the risk of cyclic fatigue associated with repeated tensile and compressive stresses.

WaveOne Gold (Dentsply Maillefer, Ballaigues, Switzerland) is a heat-treated, reciprocating, single-file system manufactured using Gold alloy technology. The system is available in sizes 20/07, 25/07, 35/06, and 45/05. The instruments possess a constant taper from D1 to D3, followed by a progressively reduced taper from D4 to D16.^[4] They feature a semi-active tip and an unequal bidirectional reciprocating motion designed to facilitate efficient canal preparation while maintaining canal anatomy.

One Curve (Micro-Mega, Besançon, France) is a continuous rotary single-file system manufactured from C-Wire technology. It is characterized by a variable pitch and a continuous taper and is available in sizes 25/04, 25/06, 35/04, and 45/04. Its continuous rotational movement and single-file design are intended to provide efficient canal shaping while minimizing procedural complexity.

Several techniques have been proposed to assess the shaping ability of endodontic instruments. Cone-beam computed tomography (CBCT) has become a valuable noninvasive imaging modality because it permits three-dimensional assessment of

root canal morphology before and after instrumentation. It allows reproducible evaluation of changes in canal geometry and facilitates quantitative assessment of parameters such as canal transportation and centering ability without sectioning or destroying the specimens.^[5]

Therefore, the present in vitro study was undertaken to evaluate and compare canal transportation and centering ability associated with **WaveOne Gold (Dentsply Maillefer, Ballaigues, Switzerland), One Curve (Micro-Mega, Besançon, France)** and **Hand K-file (Dentsply M-Access)** during preparation of curved root canals using CBCT imaging. The null hypothesis was that there would be no significant difference in canal transportation and centering ability among the three instrumentation systems.

MATERIALS AND METHODS

Ethical Approval

Ethical clearance for the present investigation was obtained from the Research Ethics Committee of Vyas Dental College and Hospital, Jodhpur, Rajasthan (VDCH / IEC / 2026 / 5283). The study was conducted in the Department of Conservative Dentistry and Endodontics, Vyas Dental College and Hospital. As the research was an in vitro study utilizing extracted human teeth, written informed consent from the donors was not applicable.

Sample Selection and Preparation

Sample Selection

Thirty human mandibular molars, with curvatures ranging between 30-40°, that were extracted for periodontal reasons were taken for this study.^[6] The selection of the teeth for canal curvature was based on Schneider's method. Only teeth with two separate mesial canals with separate apical foramen, and complete root development were included in the study. Teeth exhibiting canal curvatures in two distinct planes, or with evidence of internal or external root resorption, or teeth presenting with radiographic or clinical evidence of canal calcification, fractures, caries or other structural defects were excluded from the study. The teeth collected were disinfected and soft tissue and organic debris were removed by placing the samples in 5.25% NaOCl for 10 minutes and stored at 4°C in saline until used.

Sample Preparation

For all samples, access cavities were prepared with an Endo-Access bur (Dentsply Maillefer), and the patency was checked using #10 K-file (Dentsply, Maillefer, Switzerland). The working length was determined by inserting #10 K-file to the root canal terminus until it was visible at the apical exit, which was confirmed by using Stereo microscope at 4x magnification (Lawrence & Mayo, WF10X). The working length was established by subtracting 0.5mm from this measurement. The

distal root was sectioned at the furcation level using a low-speed diamond bur under water and discarded.

Grouping of Specimens

The selected 30 specimens were randomly allocated into three experimental groups, (n=10 teeth), according to the instrumentation system employed:

- **Group I – Hand K-file:** M Access, Dentsply Sirona.
- **Group II – WaveOne Gold:** Dentsply Sirona.
- **Group III – One Curve:** Micro-Mega, Besançon, France.

The instrumentation of the root canal was carried out by a single operator with strict accordance to the manufacturer's instructions for each system. All systems were powered by an electric speed and torque-controlled endodontic micromotor (J Morita Tri-Auto Mini). Each canal was instrumented to the working length and irrigated with 2 mL of 3% NaOCl using a 27-G needle after each file change. Each file was discarded after being used in three canals.

Group I: - The mesio-buccal canals in group I were instrumented using **M-Access stainless-steel K-files (Dentsply Sirona)**. After establishing the working length with a #10 K-file, sequential instrumentation was performed using **#15, #20, and #25 K** upto the working length followed by step-back preparation technique. Recapitulation with a #10 K-file was performed between successive instruments.

Group II: - The mesio-buccal canals in group II were instrumented using **WaveOne Gold Primary reciprocating NiTi file (#25 with 7% taper)** (Dentsply Sirona), at **350 rpm** and **2.5 N·cm torque** according to the manufacturer's instructions.^[7] The Primary file was advanced gradually to the full working length using gentle pecking movements in reciprocating motion.^[8] The **WaveOne Gold Primary file (#25/.07)** was used as the **master apical file** to complete the canal preparation.^[9]

Group III: - The mesio-buccal canals in group III were instrumented using **One Curve rotary NiTi file (#25 with 4% taper)** (Micro-Mega, Besançon, France), with **continuous rotation at 350 rpm** with a **maximum recommended torque of 2.5 N·cm** according to the manufacturer. The **One Curve #25/.04 file** was advanced gradually to the full working length using gentle pecking movements in continuous rotation. The **One Curve #25/.04 file** was used as the **master apical file** to complete the canal preparation.^[9]

Cone-Beam Computed Tomography Scan Specifications

All the samples in each group were scanned before and after instrumentation using cone-beam computed tomography (NewTom go 3D CBCT Machine). The CBCT scans were done at 84Kvp, 5.0 mA, 90 mm voxel, exposure time 20 s, 1-mm-thick

axial sections, 32 cm display field of view, and beam incidence at the central portion on the device used to fix the specimens aligned perpendicularly to the beam.^[4]

Assessment of Canal Transportation

Canal transportation was evaluated at a standardized level of **1 mm from the apical foramen**. The mesiodistal dimensions of the root and canal were recorded from both the pre-instrumentation and post-instrumentation CBCT images.^[10]

Four linear measurements were obtained:

- **A1:** The shortest distance between the mesial border of the root and the mesial border of the canal **before instrumentation**.
- **A2:** The shortest distance between the mesial border of the root and the mesial border of the canal **after instrumentation**.
- **B1:** The shortest distance between the distal border of the root and the distal border of the canal **before instrumentation**.
- **B2:** The shortest distance between the distal border of the root and the distal border of the canal **after instrumentation**.

Canal transportation was calculated using the following formula:

$$\text{Canal transportation (CT)} = (A1 - A2) - (B1 - B2)$$

A value of **0** indicated an absence of canal transportation. Positive values represented transportation toward the mesial aspect, whereas negative values represented transportation toward the distal aspect.^[11]

Assessment of Centering Ability

The centering ability of each instrumentation system was also evaluated using the changes in the mesial and distal dimensions of the canal following instrumentation.

The centering ratio was calculated using the following formula:

$$\text{Centering ability} = (A1 - A2) / (B1 - B2)$$

or

$$\text{Centering ability} = (B1 - B2) / (A1 - A2)$$

The formula yielding the value closest to **1** was considered indicative of superior centering ability, whereas values approaching **0** indicated a reduced ability of the instrument to maintain the original central position of the root canal.

STATISTICAL ANALYSIS

The data obtained for canal centering and transportation ability was then subjected to statistical analysis. Comparisons among the three experimental groups were performed using **one-way analysis of variance (ANOVA)**. The significant differences were identified among the groups, multiple pairwise comparisons were performed using **Tukey's post hoc test**.

RESULTS

Canal Transportation

The mean canal transportation values demonstrated clear differences among the three instrumentation systems. The **Hand K-file group exhibited the greatest canal transportation**, with a mean value of **0.097 ± 0.015 mm**. The **One Curve group** demonstrated a lower mean canal transportation of **0.061 ± 0.014 mm**, whereas the **WaveOne Gold group demonstrated no measurable canal transportation**, with a mean value of **0.000 ± 0.000 mm**.

Thus, based on the magnitude of canal transportation, **WaveOne Gold showed the most favorable shaping behavior**, followed by One Curve, while the Hand K-file produced the greatest deviation from the original canal path. The difference in canal transportation among the three groups was statistically significant (**p < 0.05**).

Table: 1 Mean and standard deviation and one-way analysis of variance of canal transportation and centering ability at 1mm level (n=10)

Groups	Canal Transportation (CT)			Centering ability (CA)		
	Mean transportation (mm)	SD	Statistically significant	Mean transportation (mm)	SD	Statistically significant
Group-1	0.097	0.015	p < 0.05	2.043	0.299	p < 0.001
Group-2	0.000	0.000	p < 0.05	1.000	0.000	p < 0.05
Group-3	0.061	0.014	p < 0.05	1.777	0.302	p < 0.001

*P<0.05, P<0.001= Statistically significant. SD: Standard deviation; ANOVA: Analysis of variance

Centering Ability

The centering ability of the three instrumentation systems was also evaluated at 1 mm from the apical foramen. The **WaveOne Gold group demonstrated a centering ratio of 1.000 ± 0.000**, representing the value closest to the ideal centering value of 1.

The Hand K-file group demonstrated a mean centering value of **2.043 ± 0.299**, whereas the One Curve group demonstrated a mean value of **1.777 ± 0.302**. Based on the study's stated criterion that a value closer to 1 represents optimal centering ability, WaveOne Gold demonstrated the most favorable centering behavior among the three groups. The difference in centering ability among the three groups was statistically significant (**p < 0.001**).

Table: 2 Pairwise intergroup comparison of variance post hoc tests – Tukey HSD for canal transportation and centering ability at 1mm level (n=10)

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Statistically significant $P < 0.05$, $P < 0.001$; HSD: Honestly significant difference (post-hoc) test

Groups	Difference in Canal Transportation (CT)	Significance	Difference in Centering ability (CA)	Significance
1 v 2	0.097	$p < 0.05$	1.043	$p < 0.001$
1 v 3	0.036	$p < 0.05$	0.266	$p < 0.05$

Intergroup Comparison

Pairwise comparison demonstrated statistically significant differences in canal transportation between all three groups. WaveOne Gold showed significantly less transportation than both the Hand K-file and One Curve groups. One Curve also demonstrated significantly less transportation than the Hand K-file group.

For centering ability, WaveOne Gold demonstrated significantly better centering than both Hand K-file and One Curve, while One Curve demonstrated significantly better centering than Hand K-file.

DISCUSSION

Successful endodontic treatment is fundamentally dependent on adequate cleaning and shaping while maintaining the original anatomy of the root canal system. This objective becomes particularly challenging in curved canals, where instrumentation might result in undesirable alterations such as canal transportation, loss of the original canal curvature, or deviation from the central canal axis.^[12] Preservation of the original canal configuration is therefore considered an important criterion for evaluation of the shaping ability of an endodontic instrument. Canal transportation, especially in the apical region, may compromise the intended shape of the preparation and may contribute to procedural errors, whereas maintenance of canal centering facilitates a more conservative and anatomically appropriate preparation.

The development of nickel-titanium instrumentation has considerably improved the ability to prepare curved canals compared with conventional manual instrumentation. However, the shaping behavior of an instrument is not determined solely by the use of NiTi alloy; it is influenced by several factors, including instrument design, cross-sectional configuration, taper, metallurgical treatment, and the kinematics used during instrumentation.

In the present study, **WaveOne Gold demonstrated the least canal transportation and the most favorable centering ability at the 1-mm apical level**, with statistically significant differences found among the three groups.^[8] One Curve demonstrated an intermediate shaping response, whereas the Hand K-file produced the greatest canal

transportation and the least favorable centering performance. Thus, the null hypothesis of the study was rejected.

The favorable performance of WaveOne Gold may be related to its **metallurgy, cross-sectional design, taper characteristics, and reciprocating movement**. The Gold-treated NiTi alloy is designed to alter the mechanical behavior of the instrument, while the instrument geometry and reciprocating motion influence how cutting forces are transmitted to the dentinal walls. WaveOne Gold is heat treated and has parallelogram cross-section, an off-centred design, and a regressive taper, features that could contribute to its better shaping ability. The reciprocating kinematics may be particularly relevant in the apical third, where the curvature imposes greater demands on the instrument. **Selvan et al. (2022)** reported that WaveOne Gold demonstrated the highest centering ability and least canal transportation in comparison to ProTaper Gold and One Curve.^[8] The authors attributed the favorable shaping performance of WaveOne Gold, at least in part, to its reciprocating movement, that allowed the file to maintain the original canal contour more effectively than continuous rotation in the apical region. They further described the specific reciprocating cycle and geometric characteristics of WaveOne Gold to reduce taper lock and canal aberrations.

Further, **Selvan et al. (2022)**, demonstrated better shaping characteristics of One Curve than the sequential ProTaper Gold system indicating that continuous rotation does not necessarily result in unacceptable canal alteration, when the instrument design is appropriate.^[8] The difference between One Curve and WaveOne Gold in the present study is therefore more appropriately interpreted as a difference in **instrument design and kinematics rather than simply a difference between rotary and reciprocating systems**. Both systems are single-file NiTi systems, yet their modes of movement and geometric characteristics differ. The superior apical performance of WaveOne Gold observed here suggests that, within the specific curved anatomy investigated, its design and reciprocating movement provided greater control of the canal trajectory than that of One Curve.

The findings of this study are supported by **Elashiry et al. (2020)**, who evaluated the shaping ability of WaveOne Gold, RECIPROC Blue, HyFlex EDM, and One Shape using micro-computed tomography.^[13] Their results showed a significant difference at the apical level, where **WaveOne Gold produced the best centering ratio and the least canal transportation**. They attributed their results to the reciprocatory motion and the design characteristics of the instruments. Whereas, **Krishnaveni et al. (2023)** reported no significant differences in transportation or centering ability among WaveOne compared to rotating single and

multiple file systems (NeoNiTi, TF, Hyflex CM, K3XF, PTN), despite WaveOne being used in reciprocation.^[14] Their study therefore demonstrates that reciprocating motion alone does not necessarily guarantee superior shaping. This is an important point when interpreting the present findings: the favorable performance of WaveOne Gold is more plausibly related to the **combined effect of its reciprocating movement and its specific design and metallurgical characteristics.**

The **Hand K-file** group showed the greatest canal transportation and least favorable centering performance in the present study. This result is consistent with the fundamental difference between manual stainless-steel instrumentation and modern engine-driven NiTi systems. Manual filing and reaming movements provide less flexibility for following a pronounced canal curvature, making maintenance of the original canal path more difficult as the instrument advances apically.

From a clinical standpoint, the importance of these findings lies not simply in the numerical difference in transportation but in what that difference represents anatomically. Excessive alteration of the original canal pathway can interfere with the objectives of conservative shaping and may contribute to procedural errors. **Elashiry et al. (2020)**, emphasized that maintaining the original canal outline and curvature is important for avoiding transportation in the apical region, strip perforation in the middle third, and unnecessary dentin removal coronally.^[14]

The present findings therefore favor WaveOne Gold when the primary objective is preservation of the original canal trajectory in curved canals ranging between 30–40°. One Curve also demonstrated acceptable shaping performance and produced less transportation than the Hand K-file, making it a reasonable alternative when a continuous-rotation single-file system is selected. The Hand K-file, although capable of preparing the canal, demonstrated the greatest alteration of the canal path under the conditions of this experiment.

This study has certain limitations, including its **in vitro design, relatively small sample size, and canal curvatures restricted to 30–40°**, which may limit the generalizability of the findings.^[15] In addition, canal transportation and centering ability were evaluated only at **1 mm from the apical foramen**, rather than at multiple levels. Therefore, further studies using larger sample sizes, severely curved canals, and assessment at multiple canal levels are warranted.

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