

# Laboratory Evaluation of Fracture Resistance and Deformation Analysis of One Curve™ and NeoNiTi™ Systems in Double-Curvature Canals

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## ABSTRACT

**Objectives:** The purpose of this *in vitro* experimental study was to evaluate the fracture resistance of One Curve™ (Micro-Mega) and NeoNiTi™ (Neolix) during the preparation of simulated canals with severe curvature.

**Material and Methods:** A total of 120 resin blocks with simulated double-curved canals were randomly divided into two groups and prepared using One Curve™ and NeoNiTi™ files, following manufacturer guidelines. Each set of files cleaned and shaped five canals, was sterilized after each use, and had deformation occurrences recorded. The files were used until fracture, and failure time was measured with a digital stopwatch to calculate the number of rotations before fracture. The lengths of broken file segments were recorded, and statistical analysis was performed using an independent t-test.

**Results:** Deformation occurred in 1 (8.33%) and 5 (20.83%) of One Curve™ and NeoNiTi™ A1 files, respectively ( $P < 0.05$ ). The average number of rotations until fracture for NeoNiTi™ A1 was significantly lower than that of One Curve™ files ( $P < 0.05$ ). No statistically significant difference was observed in fractured segment lengths between the two groups.

**Conclusions:** One Curve™ files demonstrated superior resistance to cyclic fatigue compared to NeoNiTi™ A1 files in double-curvature canals, suggesting their potential advantage in clinical applications requiring enhanced durability.

**Keywords:** fatigue; endodontics; tensile strength; nickel; titanium; root canal preparation.

Accepted for publication: 27 March 2026

### To cite this article:

Mobaraki B, Mobaraki-Omoumi ME.

Laboratory Evaluation of Fracture Resistance and Deformation Analysis of One Curve™ and NeoNiTi™ Systems in Double-Curvature Canals

J Oral Maxillofac Res 2026;17(1):e4

URL: <http://www.ejomr.org/JOMR/archives/2026/1/e4/v17n1e4.pdf>

doi: [10.5037/jomr.2026.17104](https://doi.org/10.5037/jomr.2026.17104)

## INTRODUCTION

One of the most important stages of root canal treatment is the preparation of the root canal, which ensures adequate debridement of the canal and provides a suitable space for the placement of the canal filling material [1].

The canal preparation can be performed manually or using rotary instruments. Manual methods are time-consuming and, especially in narrow and curved canals, the use of manual files may cause complications such as ledge formation or canal path deviation due to their low flexibility. In narrow and curved canals, files made from nickel-titanium alloy, with higher flexibility, are more effective in reducing errors during preparation [2].

The superelasticity property of nickel-titanium alloy allows these files to return to their original shape after initial deformation, unlike stainless steel instruments. In these files, deformations of up to 11% are completely reversed, whereas in conventional alloys, the maximum recovery is around 1%. Additionally, these files exhibit less wear and deformation compared to stainless steel ones and appear to have excellent corrosion resistance. These characteristics make nickel-titanium endodontic files more resilient, better adapted to canal curvature, and more resistant to fracture [3].

However, during the use of these files, there is a risk of fracture due to fatigue or shear stress [4-6]. The curvature of the canal is also a significant risk factor in the fracture of endodontic files, as it leads to bending stresses [7,8].

From an engineering perspective, the failure of endodontic rotary files can be explained by analyzing the combined effects of cyclic fatigue, shear stress, bending stress, and torque. As a file navigates the curvature of a canal, it undergoes cyclic bending, especially in the apical third, producing alternating tensile and compressive stresses that can lead to fatigue failure over repeated use. Additionally, as the file rotates under load, it is subjected to torsional or shear stress, particularly when the tip binds within the canal while the shank continues rotating.

The sudden fracture may occur if the applied torque surpasses the material's shear strength. The cross-sectional geometry, material treatment, and design of NiTi rotary systems directly affect their capacity to withstand these mechanical loads and cyclic fatigue [9,10].

Manufacturers of rotary files have focused their efforts on improving the mechanical properties of these instruments to reduce the occurrence of accidents

during use, particularly minimizing file fractures. However, the breakage of rotary files inside the root canal, especially in severely curved canals, remains a significant challenge [11].

NeoNiTi™ (Neolix SAS; Châtres-la-Forêt, France) files have recently been introduced to the market and feature full rotational movement. The NeoNiTi™ system is an efficient file for uniformly shaping the canal into a tapered form. The cross-section of this file is asymmetrically rectangular. These files are made using the wire-cut electrical discharge machining (WEDM) system (Neolix SAS; Châtres-la-Forêt, France), which creates a hardened surface and leads to faster canal preparation. Additionally, they can help prevent file fractures. The features of this file include sharp and cutting edges and a gothic-like tip. The Neolix file system consists of two files: NeoNiTi™ A1 and NeoNiTi™ C1. The NeoNiTi™ A1 file is used for shaping the canal up to the apex. This file shapes the middle section and the apical third. NeoNiTi™ files are used at a speed of 350 to 500 RPM and a torque of 1.5 Ncm [12-14].

The One Curve™ Classic (Micro-Mega SA; Besançon, Cedex, France) file system is a single-file system that operates with continuous rotational movement and is made from Ni-Ti alloy processed at high temperatures. It has high flexibility and fracture resistance. Thanks to the C-wire technology (Micro-Mega SA; Besançon, Cedex, France) used in its production, it allows for pre-bending and use even in canals with complex anatomy and difficult microbial elimination [15]. The file has a tip diameter of 0.25 mm and a taper of 6% along its cutting surface (#25.06). Its most important characteristic feature is its asymmetrical horizontal cross-sectional design. One Curve™ has three cutting edges and a triangular cross-section at the tip. Moving toward the handle, it transitions to two cutting edges in the middle section and features a modified S-shaped cross-section at the handle. One Curve™ files are used at 300 RPM and 2.5 Ncm torque, in accordance with the manufacturer's instructions [16].

Considering that the failure rate of the NeoNiTi™ and One Curve™ rotary systems during the preparation of severely curved canals has not been previously investigated. This *in vitro* experimental study was conducted to compare the failure rate of these two rotary systems. Since the location of the file fracture is important for treatment prognosis, as well as for bypassing or removing the fractured file, the distance of the broken fragment from the apical foramen and canal orifice was also determined.

## MATERIAL AND METHODS

### Study design and setting

This *in vitro* experimental study was conducted between January 2024 and March 2024 at the Department of Endodontics, Faculty of Dentistry, Istanbul Yeni Yüzyıl University, Istanbul, Turkey. Mechanical engineering support for deformation analysis was provided by the Department of Mechanical Engineering, University of Oklahoma, Norman, Oklahoma, USA.

### Sample size and power analysis

Sample size was calculated a priori using G\*Power 3.1 software [17]. Assuming an effect size of  $d = 0.8$ ,  $\alpha = 0.05$ , and power = 0.80, the minimum required sample size was determined to be  $n = 12$  per group. In the present study, 12 One Curve™ and 12 NeoNiTi™ A1 files were used, each tested in 5 resin blocks, resulting in a total of 120 blocks. This sample size exceeded the minimum requirement and ensured adequate statistical power.

### Determination of dentin hardness

To select resin blocks with hardness values close to natural dentin, root dentin hardness was measured directly from three freshly extracted human teeth. The teeth were sectioned at the cemento-enamel junction using a CNC micro-cutting machine (KERN Micro HD, KERN Microtechnik GmbH; Eschenlohe, Germany). The roots were divided into three sections, and the middle two-thirds were mounted in acrylic. Vickers microhardness testing (MVK-H1, Mitutoyo Co.; Kanagawa, Japan) was performed near the canal wall. The mean value of dentin hardness was measured at 30.76 HVN.

### Selection of resin blocks

Three types of pre-made resin blocks were tested: Acidental Endo Training Blocks (Acidental Inc.; Lenexa, KS, USA), VDW Endo Training Blocks (VDW GmbH; Munich, Germany), and iDENTical Endo Training Bloc (iDENTical Dental Products; PRC, China). Hardness was measured three times per block, and mean values were recorded: iDENTical 19.6 HVN, VDW 27.6 HVN, and Acidental 30.05 HVN. Since Acidental blocks most closely approximated natural dentin hardness, they were selected for the study.

### Rationale for block selection

Although natural teeth provide anatomical realism, they present considerable variability in canal morphology, dentin hardness, and curvature, which may confound fracture resistance outcomes. Therefore, standardized resin blocks were preferred to ensure reproducibility and control over experimental variables. Acidental blocks were specifically chosen because their hardness (30.05 HVN) was closest to that of natural dentin (30.76 HVN), as determined by Vickers microhardness testing. This selection aimed to simulate clinical conditions as closely as possible while maintaining methodological consistency.

### Standardization of canal morphology

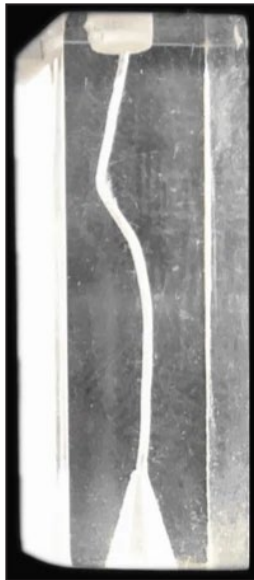
Resin blocks with standardized canal morphology, including shape, size, taper, and curvature, were used to evaluate the fracture resistance of the examined rotary files. This approach ensured consistency across samples and eliminated the anatomical variability inherent in natural teeth, such as differences in canal diameter and curvature angle. Importantly, the hardness of root dentin was not assumed from literature values alone but was directly measured using freshly extracted human teeth. The samples were sectioned using a CNC micro-cutting machine, and Vickers microhardness testing was performed on the middle two-thirds of the root dentin, close to the canal wall.

### Sample preparation

A total of 120 Acidental resin blocks with standardized double-curved canals were used. Each canal had a coronal curvature of 20° and an apical curvature of 40°, apical tip size 15 with a taper of 2%, and equal working length. Blocks were randomly divided into two groups of 60. All canal preparations were performed by an experienced endodontist (Figure 1).

### Assessment of files and instrumentation protocols

In the first group, root canal instrumentation was performed using One Curve™ rotary files. Initially, the working length up to the apical foramen was measured. Following the primary canal preparation with a No. 15 K-File (Dentsply Maillefer; Ballaigues, Switzerland), One Curve™ files (tip size 25 with a taper of 6%) were used in accordance with the manufacturer's instructions (Micro-Mega SA; Besançon, Cedex, France: [www.micro-mega.com](http://www.micro-mega.com))



**Figure 1.** Resin blocks with double-curved canals.

on the VDW Silver Reciproc Endodontic Motor (VDW GmbH; Munich, Germany) at 300 RPM and 2.5 Ncm torque setting.

In the second group of samples, preparation was carried out using NeoNiTi™ rotary files. Canal path assessment and length determination were performed in the same manner as in the previous group. After the initial canal preparation with a size 15 manual file, a NeoNiTi™ C1 file (tip size 25 with a taper of 12%) was used for orifice shaping and coronal third preparation of the canal. Then, a NeoNiTi™ A1 file (tip size 25 with a taper of 6%) was used at working length for canal shaping. According to the manufacturer's instructions, a speed of 350 RPM and a maximum torque of 1.5 Ncm were applied. Shaping was performed up to 2/3 of the working length with a circumferential motion, and at the end of the working length, a pecking motion was used.

To minimize variability arising from prolonged contact with the canal walls, all rotary files were operated under standardized time intervals and controlled apical pressure. Although the instruments differed in design and cross-sectional geometry, these variations were acknowledged, and the testing protocol was carefully adapted to ensure consistent mechanical exposure across all groups.

### Observation and standardization

All files were operated under controlled time intervals and standardized apical pressure. RC Lube (Master-Dent; St. Louis, USA) was used as lubricant, and irrigation was performed with 10 mL of 5.25% NaOCl (Cerkamed; Stalowa Wola, Poland). After each use, files were examined under x25 magnification with



**Figure 2.** Fractured file segment and measurement of its length.

a dental operating microscope (OPMI Pico, Carl Zeiss Meditec AG; Jena, Germany), cleaned with gauze soaked in NaOCl, and sterilized in an autoclave. Each file was used for five canals [18].

### Measurements

After this step, all One Curve™ and NeoNiTi™ files were used in artificial canals until fracture occurred, and the time to fracture was recorded using a digital stopwatch. If a file fractured first in the apical region, it was then continued for testing in the coronal curvature. Subsequently, a stereomicroscope (BX43 - Olympus Co.; Tokyo, Japan) was used to capture mesiodistal images of the resin blocks where file fractures had occurred (Figure 2).

The number of rotations performed by the files until fracture was calculated using the number of rotations until fracture (NRUF) formula based on the obtained time values, as described by Martins et al. [7]:

$$\text{NRUF} = \frac{\text{Number rotation per min}}{(\text{RPM})} \times \frac{\text{Time (sec)}}{60}$$

The length of the fractured segment was determined using the Image-Pro Plus 4.5 software (Media Cybernetics Inc.; Rockville, Maryland, USA) by an experienced operator (B.M.). The length of each pixel was calculated to be 6.9 μm, meaning that the smallest selectable length could be 6.9 μm. The measured line lengths were multiples of 6.9 μm, and the software's computational error was also 6.9 μm.

### Statistical analysis

All statistical analyses were performed using

IBM SPSS Statistics for Windows, Version 25.0 (IBM Corp.; Armonk, New York, USA).

The difference in deformation rates between One Curve™ and NeoNiTi™ A1 was analyzed using Fisher’s exact test, while the comparison of the mean number of rotations until fracture was performed using an independent t-test.

The mean and standard deviation (M [SD]) values for the number of rotations until fracture and fractured segment lengths were reported according to standard formatting requirements. Statistical significance was set at P < 0.05.

**RESULTS**

In the NeoNiTi™ group, only the NeoNiTi™ A1 files was analyzed for fracture resistance, as it was the shaping instrument used at full working length. The NeoNiTi™ C1 files was employed solely for orifice and coronal third preparation and was not included in the analysis.

In the NeoNiTi™ A1 system (n = 12), 5 (20.83%) files became deformed after canal preparation (Table 1). Two files (8.33%) deformed after preparing the fourth canal, while three files (12.5%) deformed after preparing the fifth canal.

In the One Curve™ system (n = 12), one file (8.33%) became deformed after preparing the fifth canal. According to Fisher’s exact test, the difference in deformation rates between the two groups was statistically significant (P = 0.036) (Table 1). File deformation in both systems was observed as unwinding of the spiral structure, and NeoNiTi™ A1 files also exhibited color changes during sterilization cycles, shifting from turquoise blue to black. Files without deformation were recorded as 11 (91.67%) in the One Curve™ group and 7 (79.17%) in the NeoNiTi™ A1 group.

**Table 1.** Comparison of file deformation in the two groups

Group	Deformations	Files without deformation	P-value
	N (%)	N (%)	
One Curve™ (n = 12)	1 (8.33)	11 (91.67)	0.036*
NeoNiTi™ A1 (n = 12)	5 (20.83)	7 (79.17)	

\*Statistically significant at level P < 0.05 (Fisher’s exact test).  
N = number.

The mean NRUF was significantly higher for One Curve™ files in the coronal curvature (666.49 [SD 32.3]) compared to NeoNiTi™ A1 files (398.16 [SD 32.8]). In the apical curvature, the mean NRUF was also significantly higher for One Curve™ files (450.37 [SD 35.74]) compared to NeoNiTi™ A1 files (134.12 [SD 49.34]) (P < 0.05, independent t-test) (Table 2). The mean fractured segment lengths were similar between groups: in the apical region, 3.06 (SD 0.08) mm for One Curve™ and 3.02 (SD 0.11) mm for NeoNiTi™ A1. In the coronal region, 7.24 (SD 0.05) mm and 6.82 (SD 0.18) mm, respectively (P > 0.05) (Table 2). All files fractured first in the apical curvature and subsequently in the coronal curvature.

**DISCUSSION**

In our study, the average hardness was obtained at 30.76 HVN, which aligns with values reported by Cirano et al. [19].

Several factors can contribute to instrument fracture during root canal preparation. These include the canal curvature angle, the central location of the curvature within the canal, as well as the alloy composition, design, movement type of the file, and the clinician’s experience - all of which influence the likelihood of file breakage [20].

**Table 2.** Mean number of rotations to fracture (NRUF) and fractured segment lengths for One Curve™ and NeoNiTi™ A1 in apical and coronal curvatures

Groups	Coronal		Apical	
	NRUF	Fractured length (mm)	NRUF	Fractured length (mm)
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
One Curve™ (n = 12)	666.49 (32.3)	7.24 (0.05)	450.37 (35.74)	3.06 (0.08)
NeoNiTi™ A1 (n = 12)	398.16 (32.8)	6.82 (0.18)	134.12 (49.34)	3.02 (0.11)
<b>P-value*</b>	< 0.05	> 0.05	< 0.05	> 0.05

\*Statistically significant at level P < 0.05 (independent t-test).  
n = number; SD = standard deviation.

The clinicians' knowledge of the characteristics of endodontic files enhances treatment success rates. Selecting instruments with higher resistance to fracture can reduce file breakages occurring in clinical settings [21].

The curvature angle of the tooth is a critical factor influencing cyclic fatigue fracture in endodontic files. In clinical conditions, double-curvature canals introduce more complex anatomical challenges and cause greater stress accumulation on files compared to single-curvature canals [22].

Double curvatures canals, known for their complexity, pose significant challenges for the use of NeoNiTi™ files, and their monitoring with conventional radiography is difficult [23]. Researchers have reported that fatigue occurs more rapidly in NeoNiTi™ files used within double curvatures canals [24]. The anatomical complexity of double curvatures canals makes their preparation more difficult than single-curvature canals, which remains a major challenge in endodontics. The findings of previous studies conducted by Pruett et al. [25] and Plotino et al. [26] support the results obtained in the present study as all indicate the heightened risk of file fracture in the presence of double curvatures, particularly under repeated use.

Furthermore, this study is among the first to evaluate the fracture behavior of the One Curve™ file within the NeoNiTi™ system under severely curved canal conditions, providing new insight into their relative performance.

Al-Sudani et al. [22] were the first to compare the cyclic fatigue resistance of files in artificial canals with double curvatures. Their study revealed that files fractured first in the apical region, followed by the coronal region, as each region imposed distinct mechanical stresses [22]. Our findings support this fracture sequence, as files were tested for their ability to resist coronal curvature stress after an initial apical fracture had occurred [22].

In a related study by Moushekhian et al. [27], the fracture rates of NeoNiTi™ and ProTaper Universal (Dentsply Sirona; Ballaigues, Switzerland) files were compared using resin blocks with severe 45° curvatures, considering certain preparation standards. According to the reported results, the statistical difference between the numbers of fractured files in the two systems was not significant. However, the present study demonstrated that the One Curve™ file exhibited significantly greater resistance to cyclic fatigue compared to the NeoNiTi™ file, suggesting its superior performance in similar challenging environments.

The clinical relevance of these findings is substantial.

Fractured files, especially in the apical region, are notoriously difficult to retrieve, and attempts at removal may lead to excessive dentin removal or root perforation [28]. Hence, selecting a file system with higher resistance to deformation and fracture is essential.

In the NeoNiTi™ system, the use of the NeoNiTi™ C1 file before applying the NeoNiTi™ A1 files facilitates their use. Therefore, the finishing file of this system, which is the NeoNiTi™ A1 file, usually penetrates the apex easily [14]. In contrast, the One Curve™ file, being a single-file system, lacks such preliminary steps, which may affect its penetration ability. Despite this, the higher fracture rate observed in the NeoNiTi™ system may also stem from methodological differences. For instance, Moushekhian et al. [27], limited each file's use to five canals, calculating fracture rates accordingly. In the present study, each file was used until fracture occurred, even beyond five canal preparations, thereby offering a more comprehensive view of fatigue-related failure.

The enhanced performance of One Curve™ files is likely due to the C-wire technology employed in their manufacture, in addition to alloy composition. This proprietary heat treatment with controlled memory properties increases flexibility and resistance to cyclic fatigue, critical in navigating complex curvatures [29]. The study by Staffoli et al. [30], which examined One Curve™ and One Shape™ files with identical designs (a single curve and single shape) in a single-file system (tip size 25 with a taper of 6%) to assess the impact of environmental temperature, heat treatment, and design on cyclic fatigue resistance, supports the findings of the present study. Their results confirm the superior cyclic fatigue resistance of One Curve™ files, supporting our own observations.

The location of the fractured file segment can provide valuable insights into canal cleanliness, obturation feasibility, and the potential for file retrieval. In this study, all files initially fractured in the apical region, typically the most difficult area for retrieval, followed by coronal fractures. This sequence aligns with previous reports [31], the higher vulnerability of the apical region can be attributed to its sharper curvature and smaller radius, which significantly increase localized mechanical stress. From an engineering standpoint, these geometric characteristics result in elevated cyclic stress concentrations and strain localization at the apical curvature, promoting the earlier initiation of microcracks and accelerating fatigue failure. Consequently, instruments are more prone to fracture in this region under repeated loading conditions [10,32].

However, since most fractures occurred during the final stages of preparation, it can be inferred that canal cleaning was largely completed before file failure. Ankrum et al. [33], also reported that fractures occurred predominantly in the apical third.

Determining the length of the fractured file segment is essential in identifying the structurally weak points. In this study, fractures consistently occurred at 3 mm (apical curvature) and 7 mm (coronal curvature), highlighting the vulnerability of these sections. The average fractured segment lengths were similar between groups, and in agreement with earlier studies, fractures mainly occurred near the start points of curvatures, where stress is highest [ ].

### Limitations

This study has certain limitations. First, the use of resin blocks, although standardized, does not fully replicate the anatomical complexity and variability of natural teeth. Second, the sample size was limited to 120 blocks, which may restrict generalizability. Third, only two rotary file systems were compared, and results may not be applicable to other instruments. Finally, the *in vitro* design cannot account for clinical

variables such as patient anatomy, operator variability, and intraoral conditions.

### CONCLUSIONS

This study demonstrated that double-curved canals significantly increase cyclic fatigue stress, particularly in the apical region, leading to higher fracture risk. Among the tested systems, One Curve™ files exhibited greater resistance to cyclic fatigue compared to NeoNiTi™ A1 files, highlighting the importance of metallurgical composition and heat treatment in instrument durability. Clinically, the consistent fracture locations observed emphasize the need for careful instrument selection in anatomically complex cases to reduce procedural errors and improve treatment outcomes.

### ACKNOWLEDGMENTS AND DISCLOSURE STATEMENTS

There is no conflict of interests.

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**To cite this article:**

Mobaraki B, Mobaraki-Omoumi ME.

Laboratory Evaluation of Fracture Resistance and Deformation Analysis of One Curve™ and NeoNiTi™ Systems in Double-Curvature Canals

J Oral Maxillofac Res 2026;17(1):e4

URL: <http://www.ejomr.org/JOMR/archives/2026/1/e4/v17n1e4.pdf>

doi: [10.5037/jomr.2026.17104](https://doi.org/10.5037/jomr.2026.17104)

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