

Apical transportation of nickel titanium reciprocating instruments.

An in vitro study

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Abstract

Introduction. The introduction of Nickel-Titanium (NiTi) has revolutionized the field of endodontics. This alloy allows for easy navigation of the canal curvatures, enabling more conservative root canal preparations in a significantly reduced time. This capability stems from superelasticity, a property that enables NiTi to flex and adapt to the canal's shape. Superelasticity allows the instrument to maintain a centered position even in the presence of pronounced curvatures, minimizing the restoring force typical of steel instruments and reducing negative effects, such as perforations, stripping, and blockages, on the canal's original trajectory. Aim of this study is to evaluate the transportation tendency of NiTi instruments *in vitro*.

Materials and methods. Fifteen EndoTraining Blocks were divided into three groups of five blocks each: Group A was treated using WaveOne #25.08 files; Group B was shaped with Reciproc #25.08 instruments; and Group C was shaped using TF Adaptive #25.08 files. All groups were reamed to a working length of 18 mm without the use of lubricants, following the establishment of a glide path with a #15.02 k-file. The instruments were utilized in a "back and forth" motion, applying very light pressure and cleaning the coils of debris after each movement. The WaveOne and Reciproc reciprocating instruments were mounted on a 6:1 reduction handpiece controlled by a torque-controlled motor (Silver Reciproc VDW), using the pre-set programs WaveOne ALL for Group A and Reciproc ALL for Group B, respectively. The blocks in Group C were prepared with an Elements Adaptive engine set to the dedicated program for TF Adaptive.

Results. All the external sides of the blocks registered statistically significant different apical transportation amongst groups ($p < 0.05$). No statistical differences were found between the WaveOne and TF Adaptive groups regarding internal and external cutting surfaces at the apical third ($p > 0.05$). Statistically significant differences were found between internal and external sides of the Reciproc's blocks ($p < 0.05$).

Conclusions. From the examination of the data obtained in this experimental thesis, we conclude that all three types of instruments analyzed can lead to alterations in the original anatomy when operated inside a curved canal. Reciproc and WaveOne instruments demonstrated a significant tendency for canal transport, while the TF Adaptive system, exhibited superior maintenance of the original anatomy in both the coronal and more delicate apical regions.

Keywords: Nickel Titanium; Endodontic Instruments; WaveOne; Reciproc; TF Adaptive.

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Introduction

The introduction of Nickel-Titanium (NiTi) has revolutionized the field of endodontics. This alloy allows for easy navigation of the canal curvatures, enabling more conservative root canal preparations in a significantly reduced time. This capability stems from superelasticity, a property that enables NiTi to flex and adapt to the canal's shape. Superelasticity allows the instrument to maintain a centered position even in the presence of pronounced curvatures, minimizing the restoring force typical of steel instruments and reducing negative effects, such as perforations, stripping, and blockages, on the canal's original trajectory.^{1,2}

The preparation of the root canal is a critically important phase of endodontic treatment, fundamentally serving two purposes: to remove all pulp tissue, bacteria, and necrotic debris from within (Cleaning) and to adequately shape the canal (Shaping) to facilitate three-dimensional obturation with materials that seal the entire canal system, thereby preventing bacterial microinfiltration and the potential survival of pathogenic microorganisms.³

A key objective during the shaping phase is to widen the canal without deviating from its original curvature, in order to maintain the canal's configuration and preserve as much root structure as possible, thus avoiding iatrogenic injuries such as perforations, stripping, or root fractures.²

For over a decade, Nickel-Titanium instruments have been utilized with continuous rotation; however, a new approach has recently been proposed by Yared: the reciprocating movement.⁴ This movement is considered an evolution of Roane's balanced forces technique and can be described as an oscillating motion of an instrument that briefly reverses direction before completing a full revolution. Recent studies have shown that the reciprocating movement enhances the resistance to cyclic fatigue of NiTi instruments compared to continuous rotation, primarily because it reduces the stress placed on the instrument, thereby prolonging its lifespan. However, it is important to note that the reciprocating movement does not affect the instrument's intrinsic rigidity; if a relatively rigid, high-taper NiTi instrument is slightly forced into a curved canal, it will create greater canal transport than a more flexible instrument due to its inherent tendency to straighten.^{5,6}

The currently marketed reciprocating systems⁷, such as Reciproc and WaveOne, consist of instruments with relatively high tapers (0.05, 0.06, 0.08). In contrast, the TF Adaptive system offers two series of three varying tapers: the "small" series (0.04, 0.06, 0.08) and the "medium-large" series (0.08, 0.06, 0.04), designed for use based on the specific canal being instrumented. The objective of this experimental thesis is to compare the shaping capabilities of these three types of reciprocating instruments by assessing changes to the original canal anatomy in the last 6 millimeters of the apical region.

The introduction of NiTi alloys in endodontics has enabled the development of rotating endodontic instruments with increased taper, allowing for efficient and effective

shaping of root canals in just a few minutes. Utilizing these tools, while adhering to established operational sequences, now facilitates: canal preparations that are morphologically advantageous (taper suitable for subsequent three-dimensional obturation), canal preparations that minimize alterations to the original canal morphology, A reduction in the number of instruments used and saving time.^{8,9}

The ability to determine the exact taper of the canal both before and after preparation allows the operator to exactly know the diameter of the shaped canal at various preparation levels.¹⁰

NiTi rotary instruments can be employed as an alternative or in conjunction with traditional steel instruments, offering several advantages and some disadvantages. The benefits of using NiTi alloy include: Enhanced flexibility, which better preserves the original anatomy, particularly in instruments with a diameter greater than #25, improved maintenance of the bending angle post-instrumentation, resulting in fewer instances of ledges, stripping, and false pathways. However, NiTi instruments also present some drawbacks: a higher incidence of instrument separation, reduced tactile sensitivity, lower surface hardness, leading to increased susceptibility to wear and "peening." Less effectiveness in cleaning the apical third, due to the greater accumulation of debris and smear layer. Challenges in shaping oval-shaped canals, as the NiTi alloy tends to keep the instrument centered within the canal. Difficulty in pre-curving instruments, although this has improved with the introduction of innovative heat-treated alloys.¹¹

Maintaining the original curvature of a canal during reaming is a fundamental objective of the shaping phase. This is crucial for preserving the canal's configuration and maximizing the remaining root structure, thereby avoiding iatrogenic injuries such as perforations, stripping, or root fractures.¹²

The introduction of Nickel-Titanium (NiTi) has revolutionized endodontics, allowing for easier navigation of canal curvatures and enabling more conservative root canal preparations. NiTi rotary instruments significantly enhance the shaping of root canals, reduce operating time, and minimize the risk of complications commonly associated with manual instrumentation, particularly in the apical region of curved canals. However, it is important to note that NiTi files have elastic limits; in cases with high bending angles and low bending radii, they must be used with specific precautions due to an increased risk of fractures, primarily from bending stress (fatigue fracture) and torsional stress (torque fracture).¹³⁻¹⁵

For over a decade, NiTi instruments have been employed with continuous rotation; however, a new approach—reciprocating movement—was recently proposed by Yared. Studies have shown that this reciprocating motion can enhance the resistance to cyclic fatigue in NiTi instruments compared to continuous rotation, mainly by reducing the stress experienced by the instrument, thus prolonging its lifespan.⁴

It is important to emphasize that the reciprocating movement does not alter the intrinsic rigidity of the instrument. If a relatively rigid, high-taper NiTi

instrument is slightly forced into a curved canal, it may create more canal transport than a more flexible instrument due to its inherent tendency to straighten. Additionally, the instrument's design can influence the preservation of the original anatomy; a more active tip poses a greater risk than a dull pilot tip.^{14,16}

The aim of the present study is to compare the shaping capabilities of three different types of reciprocating instruments (WaveOne, Reciproc, and TF Adaptive) by evaluating the changes to the original canal anatomy in the last 6 millimeters of the apical region.

Materials and methods

Fifteen EndoTraining Blocks were divided into three groups of five blocks each: Group A was treated using WaveOne #25.08 files; Group B was shaped with Reciproc #25.08 instruments; and Group C was shaped using TF Adaptive #25.08 tools.

All groups were reamed to a working length of 18 mm without the use of lubricants, following the establishment of a glide path with a #15.02 k-file. The instruments were utilized in a "back and forth" motion, applying very light pressure and cleaning the coils of debris after each movement. The WaveOne and Reciproc reciprocating instruments were mounted on a 6:1 reduction handpiece controlled by a torque-controlled motor (Silver Reciproc VDW), using the preset programs WaveOne ALL for Group A and Reciproc ALL for Group B, respectively. The blocks in Group C were prepared with an Elements Adaptive engine set to the dedicated program for TF Adaptive.

Each block was scanned before and after shaping using an Epson Stylus Photo RX500 scanner. Images were acquired at a resolution of 1200 dpi and subsequently overlaid using Adobe Photoshop CS2 software (Adobe, San Jose, CA, USA). To facilitate the superposition process, each block was numbered, and two points were marked approximately 3 mm from the corners on the side opposite the orifice of the flume. The images were then enlarged using the zoom tool at 50% (Figure 1).

To adequately highlight the differences in canal

dimensions before and after shaping with reciprocating instruments, the images of the treated blocks were modified to produce negatives of the original scans. The resulting images were analyzed using AutoCAD 18.1 (Autodesk, San Francisco, CA, USA).

For each block, the outline of the original canal was marked, and a median line was constructed, allowing for the drawing of perpendicular lines at intervals of 0.05 cm along the median line. Since the last 6 mm of the apical region were evaluated, twelve perpendicular lines were drawn, labeled from "a" to "l" in the apico-coronal direction. Each line was divided by the midline into two segments: one representing the internal curvature of the canal and the other representing the external curvature. Using AutoCAD, the dimensions of the shaped canals were measured at each segment, starting from the point of intersection of the perpendicular line with the midline up to the edge of the instrumented canal.

The overall measurement values obtained for each block were recorded in tables created with Microsoft® Excel® for Microsoft 365 MSO (Version 2409 Build 16.0.18025.20030) 64-bit (Microsoft, Redmond, WA, USA). For each block, the shear difference between the inner and outer curvatures was calculated for all twelve perpendicular lines, and these values were graphically represented. Additionally, for each group of blocks, the mean and standard deviation were calculated for each segment. Results were analyzed using the Student's t-test to assess significant differences between the measurements.

Results

Results are shown in Tables 1-3.

All the external sides of the blocks registered statistically significant different apical transportation amongst groups ($p < 0.05$). No statistical differences were found between the WaveOne and TF Adaptive groups regarding internal and external cutting surfaces at the apical third ($p > 0.05$). Statistically significant differences were found between internal and external sides of the Reciproc's blocks ($p < 0.05$).



Figure 1. Scannerized block divided in different sectors at the apical third.

Table 1. Cutting values and differences between internal and external cutting surface of the instruments in millimeters. Mean and standard deviations measured for the WaveOne #25.08 group.

Waveone #25.08	block 1	difference block 2		difference block 3		block 4	difference block 5		difference mean		std dev ±	
a	0,252		0,232		n/a	0,312		0,336		0,283	0,049	
a'	0,274	0,022	0,254	0,022	n/a	0,257	-0,055	0,274	-0,062	0,265	0,011	
b	0,281		0,252		n/a	0,312		0,316		0,29	0,03	
b'	0,251	-0,03	0,262	0,01	n/a	0,257	-0,055	0,273	-0,043	0,261	0,009	
c	0,296		0,255		n/a	0,312		0,315		0,295	0,028	
c'	0,235	-0,061	0,255	0	n/a	0,257	-0,055	0,264	-0,051	0,253	0,012	
d	0,34		0,298		n/a	0,344		0,336		0,33	0,021	
d'	0,225	-0,115	0,257	-0,041	n/a	0,274	-0,07	0,278	-0,058	0,259	0,024	
e	0,345		0,311		n/a	0,333		0,322		0,328	0,015	
e'	0,234	-0,111	0,25	-0,061	n/a	0,331	-0,002	0,333	0,011	0,287	0,052	
f	0,332		0,316		n/a	0,316		0,305		0,317	0,011	
f'	0,278	-0,054	0,254	-0,062	n/a	0,38	0,064	0,382	0,077	0,324	0,067	
g	0,308		0,325		n/a	0,281		0,285		0,3	0,021	
g'	0,35	0,042	0,301	-0,024	n/a	0,467	0,186	0,443	0,158	0,39	0,078	
h	0,282		0,296		n/a	0,263		0,261		0,276	0,017	
h'	0,431	0,149	0,36	0,064	n/a	0,542	0,279	0,512	0,251	0,461	0,082	
i	0,258		0,269		n/a	0,236		0,235		0,25	0,017	
i'	0,511	0,253	0,42	0,151	n/a	0,601	0,365	0,567	0,332	0,525	0,079	
l	0,238		0,244		n/a	0,214		0,223		0,23	0,014	
l'	0,574	0,336	0,476	0,232	n/a	0,65	0,436	0,629	0,406	0,582	0,078	
m	0,215		0,233		n/a	0,199		0,198		0,211	0,016	
m'	0,631	0,416	0,533	0,3	n/a	0,675	0,476	0,658	0,46	0,624	0,063	
n	0,2		0,266		n/a	0,187		0,193		0,202	0,017	
n'	0,661	0,461	0,574	0,348	n/a	0,715	0,528	0,679	0,486	0,657	0,06	

Table 2. Cutting values and differences between internal and external cutting surface of the instruments in millimeters. Mean and standard deviations measured for the Reciproc #25.08 group.

Reciproc #25.08	block 6	difference block 7		difference block 8		difference block 9		difference block 10		difference mean		std dev ±	
a	0,323		0,416		0,363		0,328		0,324		0,351	0,04	
a'	0,18	-0,143	0,204	-0,212	0,237	-0,126	0,241	-0,087	0,222	-0,102	0,217	0,025	
b	0,333		0,369		0,331		0,276		0,321		0,326	0,033	
b'	0,203	-0,13	0,252	-0,117	0,286	-0,045	0,276	0	0,237	-0,084	0,251	0,033	
c	0,336		0,335		0,291		0,277		0,324		0,313	0,027	
c'	0,214	-0,122	0,293	-0,042	0,332	0,041	0,321	0,044	0,256	-0,068	0,283	0,049	
d	0,343		0,315		0,292		0,277		0,337		0,313	0,028	
d'	0,26	-0,083	0,357	0,042	0,367	0,075	0,374	0,097	0,291	-0,046	0,33	0,051	
e	0,337		0,316		0,288		0,278		0,337		0,311	0,027	
e'	0,295	-0,042	0,413	0,097	0,414	0,126	0,419	0,141	0,333	-0,004	0,375	0,057	
f	0,342		0,314		0,269		0,266		0,329		0,304	0,035	
f'	0,327	-0,015	0,454	0,14	0,473	0,204	0,458	0,192	0,334	0,005	0,409	0,072	
g	0,333		0,299		0,265		0,271		0,324		0,298	0,03	
g'	0,375	0,042	0,513	0,214	0,521	0,256	0,506	0,235	0,41	0,086	0,465	0,068	
h	0,317		0,276		0,244		0,245		0,309		0,278	0,034	
h'	0,427	0,11	0,576	0,3	0,571	0,327	0,552	0,307	0,457	0,148	0,517	0,07	
i	0,295		0,254		0,227		0,231		0,292		0,26	0,032	
i'	0,48	0,185	0,618	0,364	0,63	0,403	0,6	0,369	0,512	0,22	0,568	0,068	
l	0,264		0,225		0,213		0,207		0,268		0,235	0,029	
l'	0,536	0,272	0,658	0,433	0,669	0,456	0,63	0,423	0,557	0,289	0,61	0,06	
m	0,245		0,218		0,188		0,2		0,256		0,221	0,029	
m'	0,576	0,331	0,681	0,463	0,681	0,493	0,643	0,443	0,595	0,339	0,6355	0,048	
n	0,228		0,206		0,194		0,193		0,25		0,214	0,024	
n'	0,584	0,356	0,681	0,475	0,7	0,506	0,642	0,449	0,609	0,359	0,643	0,048	

Table 3. Cutting values and differences between internal and external cutting surface of the instruments in millimeters. Mean and standard deviations measured for the TF Adaptive #25.08 group.

TF Adaptive #25.08	block 11	difference block 12		difference block 13		difference block 14		difference block 15		difference mean		std dev ±
a	0,22		0,137		0,194		0,178		0,182		0,182	0,03
a'	0,13	-0,09	0,192	0,055	0,188	-0,006	0,19	0,012	0,14	-0,042	0,168	0,03
b	0,241		0,141		0,211		0,204		0,188		0,197	0,037
b'	0,16	-0,081	0,206	0,065	0,194	-0,017	0,203	-0,001	0,15	-0,038	0,183	0,026
c	0,27		0,176		0,242		0,228		0,215		0,226	0,035
c'	0,175	-0,095	0,211	0,035	0,203	-0,039	0,213	-0,015	0,144	-0,071	0,189	0,029
d	0,296		0,227		0,275		0,256		0,259		0,263	0,025
d'	0,168	-0,128	0,211	-0,016	0,203	-0,072	0,215	-0,041	0,151	-0,018	0,19	0,028
e	0,323		0,261		0,298		0,281		0,287		0,29	0,023
e'	0,161	-0,162	0,201	-0,06	0,208	-0,09	0,222	-0,059	0,161	-0,126	0,191	0,028
f	0,333		0,287		0,326		0,304		0,303		0,311	0,019
f'	0,186	-0,147	0,203	-0,084	0,22	-0,106	0,234	-0,07	0,178	-0,125	0,204	0,023
g	0,337		0,306		0,324		0,307		0,301		0,315	0,015
g'	0,234	-0,103	0,239	-0,067	0,253	-0,071	0,256	-0,051	0,19	-0,111	0,234	0,026
h	0,302		0,296		0,333		0,308		0,301		0,308	0,015
h'	0,3	-0,002	0,266	-0,03	0,277	-0,056	0,303	-0,005	0,233	-0,068	0,276	0,029
i	0,269		0,273		0,33		0,295		0,272		0,288	0,026
i'	0,367	0,098	0,325	0,052	0,317	-0,013	0,343	0,048	0,285	0,013	0,327	0,031
l	0,232		0,239		0,319		0,287		0,243		0,264	0,038
l'	0,42	0,188	0,374	0,135	0,348	0,029	0,377	0,09	0,357	0,114	0,375	0,028
m	0,224		0,235		0,329		0,287		0,218		0,259	0,048
m'	0,48	0,256	0,428	0,193	0,378	0,049	0,422	0,135	0,392	0,174	0,42	0,039
n	0,24		0,256		0,331		0,275		0,228		0,266	0,04
n'	0,483	0,243	0,443	0,187	0,424	0,093	0,466	0,191	0,444	0,216	0,452	0,023

Table 4. Mean values of the cutting measurements of the internal and external (°) sides of the instruments.

sector	waveone	waveone'	reciproc	reciproc'	tfadaptive	tfadaptive'
a	0,283	0,265	0,351	0,217	0,182	0,168
b	0,29	0,261	0,326	0,251	0,197	0,183
c	0,295	0,253	0,313	0,283	0,226	0,189
d	0,33	0,259	0,313	0,33	0,263	0,19
e	0,328	0,287	0,311	0,375	0,29	0,191
f	0,317	0,324	0,304	0,409	0,311	0,204
g	0,3	0,39	0,298	0,465	0,315	0,234
h	0,276	0,461	0,278	0,517	0,308	0,276
i	0,25	0,525	0,26	0,568	0,288	0,327
l	0,23	0,582	0,235	0,61	0,264	0,375
m	0,211	0,624	0,221	0,6355	0,259	0,42
n	0,202	0,657	0,214	0,643	0,266	0,452

Discussion

The Results of this experimental thesis are highlighted by the analysis of the measurements obtained. A general evaluation of the data clearly indicates that all the instruments used in this study, when operated inside a curved canal, can lead to alterations in the original anatomy. These alterations are characterized by a non-homogeneous and uneven cut on the two sides of the curvature (internal and external).

This phenomenon is referred to as “canal transport.” According to the American Association of Endodontists’ Glossary of Endodontic Terms, canal transport is defined as the “removal of canal wall structure at the external curvature in the apical portion of the canal, due to the tendency of the instruments to return to

their original shape during root canal preparation.” This inherent tendency towards straightening is influenced by three key factors: the design of the instrument, the alloy used in its construction, and the method of use.

The instrument’s design determines its rigidity for the same dimensions; a greater mass corresponds to increased rigidity. A more rigid instrument, particularly one with an active tip, is more likely to straighten a curve, thereby approaching the apex in a more direct manner. During the exit phase, the elastic return of the alloy further encourages the instrument to straighten, which can promote canal transport.^{1,2,12}

Generally, it is believed that the reciprocating movement helps to reduce canal transport. The incoming motion, resembling balanced forces, allows the tip to move slightly, enabling it to follow the original trajectory

more effectively during the apical progression phase, thus minimizing the risk of eccentric cutting. Moreover, during the exit phase, the alternating clockwise and counterclockwise movement facilitates a more gradual elastic return, resulting in less alteration of the canal anatomy. In the present study, the differences between the movements were not analyzed; instead, the focus was solely on the final outcomes, reflecting what typically occurs in clinical practice.¹⁶⁻¹⁸

Regarding the characteristics of the alloy, the current trend is to minimize canal transport by utilizing NiTi alloys in the manufacture of instruments and/or production processes that enhance the flexibility of the metal. WaveOne and Reciproc instruments are made with a special NiTi alloy known as M-Wire, which is produced through innovative thermal processes¹⁹ that provide greater flexibility and resistance to cyclic fatigue compared to traditional NiTi. TF Adaptive tools undergo a specific hot heat treatment that completely modifies their crystalline structure, allowing the files to be produced by twisting rather than carving. This method reduces the likelihood of surface fractures, resulting in instruments that are both resistant and flexible.

Concerning the method of use, it is likely that the different reciprocating movements employed by various instruments influence their final performance.²⁰ However, the aim of this study is not to evaluate the specific factors determining canal transport but to compare the different systems and assess the final Results.

The analysis of the Results indicates, as seen in other studies, a tendency toward straightening of the curvatures. This tendency is characterized by greater shear on the internal side of the curvature in the coronal portion (3-6 mm from the apex) and on the external side in the apical region (the last 3 mm). Despite the same operator, motor, batches of instruments, and original anatomy, variations in clinical operation may occur among instruments within the same group. These variations are mainly due to differences in blade engagement during the progression phase and/or the amount of pressure exerted during advancement. Additionally, clogging of the instrument threads with debris can lead to decreased shear and increased torque requirements for progression, resulting in minor variations in the final anatomy of the specimen.

Nevertheless, within each group of instruments, fairly consistent behaviors were observed, particularly in the coronal portion of the analyzed canal section.

In analyzing the cutting differences between the internal and external sides of the curvature for WaveOne instruments, a tendency toward canal transport is evident. This is particularly noticeable in the apical portion of the canal (0-3 mm), where transport occurs on the external side, while in the middle section (3-6 mm from the apex), it is observed on the internal side. Notably, in two cases, transport occurred toward the interior of the canal curvature near the root apex (at 0.5 mm).

During the shaping phase of the resin blocks, only one instrument from the WaveOne group fractured. It is important to emphasize that these numerical data are indicative rather than absolute, as cutting in resin

blocks differs from that in dentin. Thus, they should be interpreted as a comparative evaluation of the tendency toward specific performances. When considering this limitation, the data from the blocks are quite intriguing and clinically useful for assessing different techniques, as supported by other studies.

Regarding the blocks treated with Reciproc instruments, the overall cutting values closely resemble those obtained with WaveOne instruments. This similarity likely arises from the use of the same alloy and the comparable reciprocating movement; the primary variable is the different design of the coils, which feature a lower mass in the Reciproc instruments.

Specifically, the two groups exhibit similar performance in the coronal portion of the analyzed canal section, and they are quite comparable in the apical region as well, both highlighting the tendency of Reciproc instruments to straighten the canals. In the last 1.5 mm of the apical portion, greater transport is observed in the measured values. Similar behavior is noted in the coronal section, while in the apical region, transport on the external side is consistently found in the last millimeter. Between 1 and 3 mm from the apex, however, no transport was evident, indicating a degree of homogeneity in the Results.

The best Results were achieved with the TF Adaptive system, which demonstrates superior maintenance of the original anatomy not only in the coronal portion of the curvature but also in the more delicate apical region. Overall shear values are somewhat reduced compared to those observed in the other two groups, particularly in the last 3 mm of the apical portion.

Regarding the difference in shear between the internal and external sides of the curvature, it is noteworthy that internal transport was recorded in the apical third in two samples.

These Results can be attributed to the greater flexibility of the TF Adaptive instruments and their distinct reciprocating movement. The TF Adaptive system employs an exclusive patented technology that automatically adapts to the stresses encountered during instrumentation. When the instrument is not subjected to stress within the canal, its movement resembles continuous rotation, which enhances cutting efficiency and facilitates debris removal. This is particularly effective due to the cross-section and design of the grooves, which are optimized for clockwise motion. More specifically, it features an interrupted movement with rotation angles in the clockwise and counterclockwise directions of 600°-0°. This interrupted motion not only matches the effectiveness of continuous rotation in lateral cutting – allowing for optimal circumferential brushing and improved debris removal in oval canals – but also minimizes iatrogenic errors by reducing the tendency to “twist,” a common issue with large taper NiTi instruments.²¹

As the stress on the instrument increases, the TF Adaptive’s movement transitions to a reciprocating mode, with clockwise and counterclockwise rotation angles ranging from 600°-0° to 370°-50°. These angles are not fixed but vary based on anatomical complexities and the intracanal stress exerted on the instrument.

The enhanced flexibility afforded by TF technology

enables the TF Adaptive instruments to widen canals safely, with minimal risk of iatrogenic errors such as canal carriage, tooth weakening, steps or false path formation, perforations, stripping, and damage to the apical foramen. The use of a more rigid alloy would not have yielded the Results achieved, particularly in curved canals.

Conclusions

From the examination of the data obtained in this experimental thesis, we conclude that all three types of instruments analyzed can lead to alterations in the original anatomy when operated inside a curved canal. These alterations are characterized by a non-homogeneous and uneven cut on the internal and external sides of the curvature.

This tendency toward straightening, referred to as “canal transport,” is an inherent characteristic linked to the instruments and is influenced by three key factors: instrument design, alloy composition, and method of use.

In this study, the Reciproc and WaveOne instruments demonstrated a significant tendency for canal transport, with inward transport observed in the coronal portion of the curvature and outward transport in the apical portion.

In contrast, the best Results were achieved with the TF Adaptive system, which exhibited superior maintenance of the original anatomy in both the coronal and more delicate apical regions.

TF Adaptive instruments represent a valuable asset for endodontists, facilitating effective preparation while preserving the root canal anatomy in critical areas such as the apical third. These favorable outcomes are likely attributable to advancements in movement technology and the specific alloy used.

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