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Comparative Evaluation of the Shaping Ability of Five Different Nickel-Titanium Rotary File Systems in Simulated Canals

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Research Article

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ABSTRACT

Objectives: *The aim of this study was to compare the simulated canal shaping efficiencies of five different NiTi rotary file systems.*

Materials and Methods: *In the study, 100 transparent resin blocks with J-shaped canals were randomly divided into five groups (n = 20). Simulated canals were shaped with VDW.Rotate (VR), TruNatomy (TRN), HyFlex CM (HF), EdgeFile X7 (EF), or ProTaper Next (PTN) files. Ten measuring points were detected on the pre- and post-preparation images taken from the blocks and superimposed. After preparation, the total canal width and the amount of transportation were calculated for the determined measuring levels. Zipping and ledge formation, instrument fracture and deformation, and change in working length were evaluated. The data were statistically analyzed with the Kolmogorov-Smirnov test, one-way ANOVA, Tukey test, Chi-Square test, and a Monte Carlo version of the Fisher Exact tests. The error level was taken as 0.05.*

Results*: There were significant differences between the groups at all measuring levels in terms of total canal width after instrumentation (p = 0.001). Significant differences in the amount of transportation were found between the groups (p = 0.001) except at levels 4 (p = 0.169) and 10 (p = 0.054). Zip and instrument fractures did not occur in any group. 3 EF size 25/.04 files were deformed (p = 0.021). There was no significant difference between the groups in terms of ledge formation and working length change (p > 0.05).*

Conclusions: *According to findings obtained in the study, transportation occurred at all 10 measuring levels with all file systems used. HF and EF systems were found to be more reliable in terms of transportation in the middle and coronal regions. Wider canal preparation was obtained with the PTN system in the middle and coronal regions.*

Keywords: *Root canal transportation, NiTi, shaping efficiency, simulated canal.*

Beş Farklı Nikel-Titanyum Döner Eğe Sisteminin Yapay Kanallarda Şekillendirme Etkinliklerinin Karşılaştırmalı Olarak Değerlendirilmesi

Süreç

Geliş: 14/11/2022
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ÖZ

Amaç: *Bu çalışmanın amacı, beş farklı NiTi döner eğe sisteminin yapay kanalları şekillendirme etkinliklerinin karşılaştırılmasıdır.*

Gereç ve Yöntemler: *Çalışmada 100 adet J şekilli kanala sahip şeffaf rezin blok, rastgele beş gruba ayrıldı (n = 20). Yapay kanallar VDW.Rotate (VR), TruNatomy (TRN), HyFlex CM (HF), EdgeFile X7 (EF) veya ProTaper Next (PTN) eğeleriyle şekillendirildi. Bloklardan alınan ve çakıştırılan preparasyon öncesi ve sonrası görüntülerinin üzerinde 10 ölçüm seviyesi tespit edildi. Preparasyon sonrası toplam kanal genişliği ve transportasyon miktarı belirlenen ölçüm seviyeleri için hesaplandı. Zip, basamak oluşumu, alet kırığı, deformasyon ve çalışma boyunda meydana gelen değişim değerlendirildi. Veriler Kolmogorov-Smirnov testi, tek yönlü varyans analizi, Tukey testi, Khi-Kare testi ve Fisher Exact testlerden Monte Carlo modeliyle istatistiksel olarak analiz edilerek yanılma düzeyi 0,05 olarak alındı.*

Bulgular: *Tüm ölçüm seviyelerinde preparasyon sonrası toplam kanal genişliği yönünden gruplar arasında anlamlı farklar bulundu (p = 0,001). Seviye 4 (p = 0,169) ve 10 (p = 0,054) dışındaki ölçüm seviyelerinde gruplar arasında transportasyon miktarı açısından önemli farklılıklar bulundu (p = 0,001). Hiçbir grupta zip ve alet kırığı oluşmadı. 3 tane EF 25/.04 boyutlu eğe deforme oldu (p = 0,021). Basamak oluşumu ve çalışma boyu değişimi yönünden ise gruplar arasında anlamlı fark gözlenmedi (p > 0,05).*

Sonuçlar: *Çalışmada elde edilen bulgulara göre kullanılan tüm eğe sistemleriyle 10 ölçüm seviyesinde de transportasyon meydana geldi. HF ve EF sistem orta ve koronal bölgede transportasyon yönünden daha güvenilir bulundu. PTN sistemiyle orta ve koronal bölgede daha geniş kanal preparasyonu elde edildi.*

Anahtar Kelimeler: *Kök kanal transportasyonu, NiTi, şekillendirme etkinliği, yapay kanal.*

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Introduction

Adequate cleaning, shaping, and a three-dimensional sealing of the root canal system are required for successful root canal treatment.[1,2] Many endodontic file systems and shaping methods have been developed to maintain the original shape of the canal and to avoid complications during root canal preparation. Design features and manufacturing methods can significantly affect the clinical performance of NiTi files.

Newly designed VDW.Rotate system (VR; VDW, Munich, Germany) that preserves pericervical dentin has an off-centered design and a constant taper. Its double-bladed adapted S-shaped cross-section increases cutting efficiency and reduces the screw-in effect. The heat treatment applied to the files increases flexibility and fatigue resistance.[3,4] TruNatomy (TRN; Dentsply Sirona, Maillefer, Ballaigues, Switzerland) is also a newly introduced heat-treated file system that allows it to be pre-bent with high flexibility, manufactured from thin NiTi wire with a maximum 0.8 mm flute diameter instead of 1.2 mm. TRN instruments; preserve structural dentin and tooth integrity due to instrument geometry, regressive taper, and slim NiTi wire design.[3,5] HyFlex CM (HF; Coltene Whaledent, Cuyahoga Falls, OH) is a more flexible rotary file system with controlled memory. Hyflex CM files are made of NiTi alloy, which contains a lower percentage of nickel weight (52.1%) by weight than conventional NiTi alloys.[6] EdgeFile X7 system (EF; EdgeEndo; Albuquerque, NM) has a constant taper, triangular cross-section, and variable helix angle. The files are made of an annealed heat-treated NiTi alloy called Fire-Wire, which is claimed to increase the cyclic fatigue resistance and flexibility but reduce the shape memory effect inherent of NiTi files.[7,8] ProTaper Next (PTN; Dentsply Maillefer, Ballaigues, Switzerland) is a variable taper file system with an off-centered rectangular cross-section manufactured with M-Wire technology, which is reported to increase cyclic fatigue resistance and flexibility.[7,9]

The present in vitro study aimed to examine the shaping efficiency of the above-mentioned NiTi rotary file systems whose mechanical properties and flexibility were improved by applying heat treatment.

Materials and Methods

The present study design was approved by the Non-Interventional Clinical Research Ethics Committee of Sivas Cumhuriyet University with the decision number 2020-08/14. One hundred transparent resin blocks (FlexMaster Übungsblocks, Ref. V040245, Germany) with approximately 18.5 mm long canals having curvatures ranging from 30 to 38 degrees were used for this study. Resin blocks were randomly divided (https://www.randomizer.org/) into five groups (n = 20):

Group 1 – VR NiTi rotary file system: The simulated canals were shaped using VR files (size 15/.04 file with 1.3 Ncm torque, size 20/.05 file with 2.1 Ncm torque, and size 25/.04 file with 2.3 Ncm torque, respectively) with an up-and-down movement at 350 rpm until each file reached the working length.

Group 2 – TRN NiTi rotary file system: The simulated canals were shaped using TRN size 17/.02 and 26/.04 files with an up-and-down movement at 500 rpm and 1.5 Ncm torque until each file reached the working length.

Group 3 – HF NiTi rotary file system: The simulated canals were shaped using HF size 20/.04 and 25/.04 files with an up-and-down movement at 500 rpm and 2.5 Ncm torque until each file reached the working length.

Group 4 – EF NiTi rotary file system: Coronal parts of the simulated canals were shaped using EF size 25/.04 files with an up-and-down movement at 300 rpm and 3 Ncm torque until resistance was felt in the canal. Afterward, the preparation of the canals was completed to the working length using EF size 20/.04 and 25/.04 files at the same torque and speed settings.

Group 5 – PTN NiTi rotary file system: The simulated canals were shaped using PTN size 17/.04 and 25/.06 files with an up-and-down movement at 300 rpm and 3 Ncm torque until each file reached the working length.

The canal patency of each block was checked with a size 10 K-file (Shenzhen Denco Medical Co., Ltd., China) before shaping. The canal length was measured. The working length was established for each canal by subtracting 0.5 mm from the canal length. The blocks were covered with aluminum foil to prevent the canal from being seen. A glide path was created with a size 15 K-file for each canal. Each canal was shaped using the group's rotary file system and EndoMatic Endo Motor (Guilin Woodpecker Medical Instrument Co. Ltd., China). Copious irrigation with distilled water was performed after each instrument change and during the shaping processes. Each file was used to prepare only four canals.

Standardized pre- and post-instrumentation images obtained with a digital camera (Canon Digital IXUS 80 IS) were superimposed using Adobe Photoshop CS3 (Adobe System, San Jose, CA, USA) program. A total of 10 different points were marked from apical to coronal with a distance of 1 mm with the image analysis program (ImageJ 1.42q, National Institutes of Health, USA) on the superimposed images (Figure 1). The initial measuring level was determined to be 1.5 mm away from the apical end of the artificial root canal. The total canal width of the instrumented canal was measured for each level and recorded. In addition, a total of 20 distances were measured for each canal to determine the amount of resin removed from the inner and outer sides of the curve. The amount of transportation was recorded for each measuring level as the value of the difference between the amount of resin removed from the inner and outer sides of the canal. Images were evaluated in terms of zipping and ledge formation. Instrument deformation and separation were examined. The difference between the working length before preparation and the working distance measured by placing the master apical file in the canal after preparation was recorded as the change in working length.

Statistical Analysis

Statistical analysis was performed with IBM SPSS Statistics version 22.0 (SPSS, Inc., Chicago, IL, USA). Since the parametric test assumptions were fulfilled in the evaluation of the data (Kolmogorov-Smirnov), the one-way analysis of variance was used when comparing more than two independent groups, the Tukey test was used to find the group or groups that make a difference, and Chi-Square test was used to evaluate the data obtained by counting. When the assumptions were not met, a Monte Carlo version of the Fisher Exact tests was used and the error level was taken as 0.05.

Results

Table 1 shows the mean total canal widths at each measuring level for all groups. There were significant differences between the groups at all levels in terms of the total mean instrumented canal widths ($p = 0.001$). TRN caused more canal widening than the PTN, VR, and HF groups at level 1 ($p < 0.05$). The mean canal width value of the EF group was higher than the VR, HF, and PTN groups at levels 1 and 2 ($p < 0.05$). EF removed more resin than the VR, TRN, and HF at levels 3 and 4 ($p < 0.05$). The PTN group showed a greater amount of resin removal than the VR, TRN, and HF groups at levels 4 and 5 ($p < 0.05$). The mean canal widths of the PTN group were higher than all groups at levels 6-10 ($p < 0.05$). The total resin removal with TRN was greater than VR, HF, and EF at levels 7 and 8 ($p < 0.05$). For levels 9 and 10, while there were no differences in canal widths between VR and EF groups, there were differences between all other groups ($p < 0.05$).

The amount of absolute canal transportation for the measuring levels is detailed in Table 2. Significant differences in the amount of transportation were found between the groups ($p = 0.001$) except at levels 4 ($p = 0.169$) and 10 ($p = 0.054$). For level 1, TRN produced less transportation than VR, HF, and PTN; EF produced less transportation than PTN ($p < 0.05$). Less canal transportation was created by VR, TRN, and EF than PTN at level 2. The amount of canal transportation related to TRN was also less than HF at this level ($p < 0.05$). At level 3, PTN resulted in more canal transportation than VR and EF; HF produced more canal transportation than VR, TRN, and EF ($p < 0.05$). The mean absolute transportation at level 5 was statistically least with HF, while more canal transportation occurred with PTN compared to TRN, HF, and EF ($p < 0.05$). At level 6, TRN induced less canal transportation than PTN; HF and EF created less canal transportation than VR, TRN, and PTN ($p < 0.05$). The absolute transportation with PTN, VR, and TRN was greater than HF and EF at level 7 ($p < 0.05$). At level 8, PTN and TRN produced more transportation than HF and EF; VR produced more transportation than HF ($p < 0.05$). Transportation was significantly less following the use of TRN rather than VR, HF, and PTN at level 9 ($p < 0.05$).

Instrument fractures did not occur in any group; however, 3 EF size 25/.04 files were deformed ($p = 0.021$). No zips were observed. Ledge formation occurred in canals instrumented using PTN (1 ledge), VR (2 ledges), and EF (2 ledges) systems ($p = 0.554$). None of the canals became blocked with resin debris for all groups. There was no significant difference between the groups in terms of change in working length ranging from 0.115 to 0.237 ($p = 0.122$).

Discussion

In this study, simulated canals in transparent resin blocks with a severe curve according to Schneider's classification[10] were used to evaluate the shaping efficiency of five different NiTi rotary file systems. The use of simulated resin canals has limitations because their surface texture, hardness, and cross-section differ from those of real teeth.[11] However, resin blocks allow standardization of canal length, diameter, curvature angle, and radius of curvature.[12]

In the present study, TRN showed greater total canal width than VR, HF, and PTN at level 1 and this was attributed to the larger tip diameter of the TRN master apical file. However, similar canal widths were observed in the TRN group with the VR and HF groups at levels 2-5. This finding might be related to the regressive taper and slim design of TRN files. Thus, it can be said that the structural dentin and tooth integrity were better preserved in the curvature region. The PTN group had the highest total widths at levels 4-10. It may be explained by the larger taper of the PTN files. A previous study[13] comparing ProTaper Gold, TRN, VR, and Reciproc Blue files reported that the removed tooth structure was minimal in the TRN and VR groups. They stated that this result is related to the smaller taper sizes of the files and their slim design features. In this study, larger canal width was also obtained with PTN at levels 4-10 compared to TRN and VR systems.

Differences in the cross-sections, tip designs, taper angles, and metallurgical properties of the files and instrumentation techniques are effective in root canal transportation.[14-17] Saber *et al.*[18] found no significant difference in canal transportation between PTN, iRaCe, and HF files in the apical region. However, they reported significantly greater canal straightening with PTN files. Huang *et al.*[19] showed that HyFlex EDM caused greater volume increases than HFCM and PTN at all levels of the canal while HF removed the least resin in the coronal region compared to other files. They reported that this result could be related to the taper of the instruments. The use of the HF system also resulted in less canal transportation in the apical 2 mm. They attributed this finding to the flexibility of CM alloy. Likewise, in the present study, HF removed significantly less resin than the PTN system at all measuring levels 4-10. However, HF and PTN created a similar amount of transportation at levels 1-4, while PTN produced more canal transportation than HF at levels 5-8.

Kim *et al.*[20] reported that TRN caused less canal transportation than ProTaper Gold and WaveOne Gold at the 3 and 5 mm levels in simulated S-shaped resin canals because it is made of thin NiTi wire and has a small regressive taper. In the present study, TRN showed significantly less canal transportation than PTN at levels 1, 2, 5, and 6, while no difference was observed between the two groups at levels 3 and 4. This might be related to the larger taper of the PTN system and a decrease in flexibility. These findings show that TRN files provide safe preparation, especially in the apical and middle regions of the canal.

Wu *et al.*[21] showed that after the preparation of single-rooted teeth with a curvature of 21°–39°, the apical sealability of root canal obturation was adversely affected by apical transportation greater than 0.3 mm. In this study, when all measuring levels were assessed maximum amount of canal transportation was 0.128 mm. It was 0.077 mm at levels 1-3.

Large sizes files might cause zipping and perforation due to their tendency to straighten inside the canal. The decrease in flexibility of the larger size files was associated with the formation of zip.[22] No zip formation was observed in any group in this study due to the metallurgical properties of the files, their flexibility, and the use of the files by the manufacturer's instructions.

The working length loss may occur due to canal straightening and the canals becoming blocked with resin debris during canal enlargement.[6,23] It has been reported that heat-treated NiTi files preserve the original shape of the canal better and cause less loss in working length.[24] In this study, none of the canals became blocked with resin residues. The change in working length in the range of 0.11-0.24 could be occurred due to the straightening of the canals.

Conclusions

All file systems created canal transportation at each measurement point. However, they exhibited minimal transportation values within the range of 0.001-0.128 mm. These mean values show that all file systems used are reliable in terms of canal transportation. The EF system provided a wider preparation in the apical region compared to other files, while the system was found to be reliable in terms of transportation. Wider canal preparation was obtained with the PTN system in the middle and coronal regions. Since the EF size 25/.04 file showed more deformation, controlled clinical use of this file is recommended, especially in teeth with narrow and curved canals.

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Conflict of Interest

The authors declare no conflict of interest.

Table 1. The mean total canal widths at each measuring level for different file systems.

	VDW. Rotate	TruNatomy	HyFlex CM	EdgeFile X7	ProTaper Next	p values
Level 1	0.343 ± 0.166[a]	0.377 ± 0.013[b]	0.342 ± 0.015[a]	0.376 ± 0.021[b]	0.350 ± 0.019[a]	**p = 0.001***
Level 2	0.393 ± 0.021[a]	0.412 ± 0.023[ab]	0.397 ± 0.021[a]	0.431 ± 0.021[b]	0.410 ± 0.024[a]	**p = 0.001***
Level 3	0.436 ± 0.020[a]	0.433 ± 0.014[a]	0.439 ± 0.020[a]	0.458 ± 0.018[b]	0.448 ± 0.022[ab]	**p = 0.001***
Level 4	0.469 ± 0.017[a]	0.460 ± 0.024[a]	0.467 ± 0.016[a]	0.489 ± 0.022[b]	0.493 ± 0.018[b]	**p = 0.001***
Level 5	0.499 ± 0.021[a]	0.478 ± 0.102[a]	0.498 ± 0.009[a]	0.520 ± 0.023[ab]	0.560 ± 0.021[b]	**p = 0.001***
Level 6	0.535 ± 0.018[a]	0.548 ± 0.016[a]	0.539 ± 0.015[a]	0.544 ± 0.020[a]	0.635 ± 0.019[b]	**p = 0.001***
Level 7	0.575 ± 0.016[a]	0.620 ± 0.026[b]	0.581 ± 0.011[a]	0.587 ± 0.016[a]	0.697 ± 0.023[c]	**p = 0.001***
Level 8	0.611 ± 0.017[a]	0.684 ± 0.023[b]	0.605 ± 0.014[a]	0.621 ± 0.016[a]	0.756 ± 0.033[c]	**p = 0.001***
Level 9	0.655 ± 0.018[a]	0.725 ± 0.016[b]	0.630 ± 0.014[c]	0.663 ± 0.016[a]	0.831 ± 0.024[d]	**p = 0.001***
Level 10	0.702 ± 0.014[a]	0.768 ± 0.015[b]	0.660 ± 0.014[c]	0.697 ± 0.015[a]	0.894 ± 0.020[d]	**p = 0.001***

Superscripts with different letters indicate the significance of differences between groups. (*p < 0.05)

Table 2. Mean values of absolute canal transportation (mm) at each measuring level for different file systems.

	VDW. Rotate	TruNatomy	HyFlex CM	EdgeFile X7	ProTaper Next	p values
Level 1	0.042± 0.025[ac]	0.012 ± 0.032[b]	0.041 ± 0.027[ac]	0.015 ± 0.033[ab]	0.048 ± 0.032[c]	**p = 0.001***
Level 2	0.035 ± 0.024[ab]	0.029 ± 0.040[a]	0.059 ± 0.033[b]	0.040 ± 0.035[ab]	0.077 ± 0.031[cb]	**p = 0.001***
Level 3	0.011 ± 0.024[a]	0.018 ± 0.039[ac]	0.050 ± 0.037[b]	0.003 ± 0.030[a]	0.042 ± 0.026[cb]	**p = 0.001***
Level 4	0.031 ± 0.024[a]	0.007 ± 0.039[a]	0.026 ± 0.027[a]	0.001 ± 0.148[a]	0.007 ± 0.030[a]	**p = 0.169**
Level 5	0.058 ± 0.024[ac]	0.034 ± 0.035[a]	0.005 ± 0.017[b]	0.033 ± 0.031[a]	0.067 ± 0.039[c]	**p = 0.001***
Level 6	0.114 ± 0.023[ac]	0.086 ± 0.034[a]	0.032 ± 0.023[b]	0.042 ± 0.042[b]	0.128 ± 0.052[c]	**p = 0.001***
Level 7	0.101 ± 0.032[a]	0.115 ± 0.041[a]	0.029 ± 0.022[b]	0.042 ± 0.041[b]	0.114 ± 0.069[a]	**p = 0.001***
Level 8	0.049 ± 0.035[ac]	0.067 ± 0.039[a]	0.001 ± 0.022[b]	0.012 ± 0.038[cb]	0.067 ± 0.063[a]	**p = 0.001***
Level 9	0.009 ± 0.033[a]	0.042 ± 0.037[b]	0.005 ± 0.027[a]	0.011 ± 0.041[ab]	0.007 ± 0.042[a]	**p = 0.001***
Level 10	0.009 ± 0.039[a]	0.019 ± 0.041[a]	0.009 ± 0.031[a]	0.008 ± 0.044[a]	0.013 ± 0.040[a]	**p = 0.054**

Superscripts with different letters indicate the significance of differences between groups. (*p < 0.05)

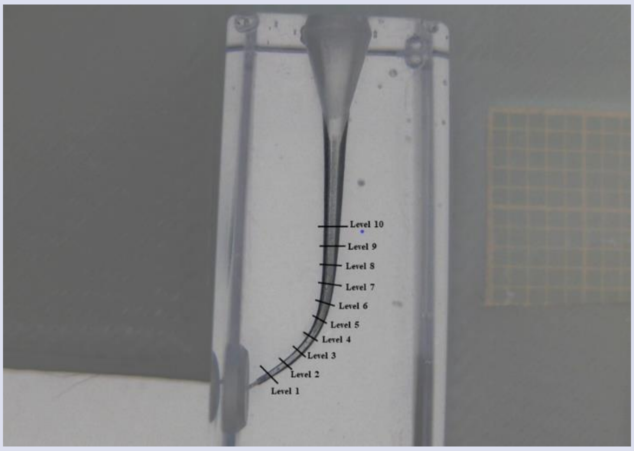

Figure 1. Superimposed pre- and post-instrumentation images with 10 measuring levels.

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