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ORIGINAL ARTICLE/ARTICOLO ORIGINALE

Canal transportation caused by one single-file and two multiple-file rotary systems: A comparative study using cone-beam computed tomography

Trasporto canalare causato da un sistema rotante mono-strumento e due sequenze di strumenti rotanti: studio comparativo con tomografia computerizzata a fascio conico

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KEYWORDS
Canal transportation;
Nickel—titanium;
Rotary files;
CBCT.

Abstract
Aim: This *ex-vivo* study aimed to compare canal transportation in mesio-buccal canal of mandibular first molars prepared with Mtwo and Revo-S multi-file and Neoniti single-file nickel—titanium (Ni—Ti) rotary systems using cone-beam computed tomography (CBCT).
Methodology: CBCT scans were obtained from 60 extracted mandibular first molars and the teeth were randomly divided into three groups. Mesio-buccal canal of mesial root was prepared with Revo-S, Neoniti or Mtwo rotary systems according to the instructions of the manufacturers. Post-operative CBCT scans were also obtained. A single operator performed canal preparations while another operator blinded to the group allocation of teeth did the measurements. Data were analyzed using SPSS 20. The mean and standard deviation (SD) of the amount of canal transportation were calculated and compared between the groups using the Friedman test ($P \leq 0.05$).

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Results: No significant difference was noted in canal transportation among the groups in the middle and apical third ($P > 0.05$). The rotary single-file instrument caused significantly greater canal transportation in the coronal third.
Conclusion: No significant difference exists among different rotary systems in the amount of canal transportation caused in the middle and apical third of the mesio-buccal canal in mandibular first molars. Although all rotary files caused some degrees of canal transportation, the rotary single-file instrument caused significantly greater canal transportation than the multiple-file sequences in the coronal third.

PAROLE CHIAVE
Trasporto canalare;
Nichel-titanio;
Strumenti rotanti CBCT.

Riassunto
Obiettivi: Questo studio *ex-vivo* ha lo scopo di confrontare il trasporto canalare nel canale mesio-buccale di primi molari mandibolari preparati con i sistemi rotanti in nichel-titanio (Ni-Ti) Mtwo e Revo-S ed il sistema mono-strumento Neoniti, utilizzando la tomografia computerizzata a raggio conico (CBCT).
Materiali e metodi: Le scansioni CBCT sono state ottenute in 60 primi molari mandibolari estratti e i denti sono stati suddivisi in tre gruppi. Il canale mesio-buccale della radice mesiale è stato preparato con sistemi rotanti Mtwo, Revo-S o Neoniti seguendo le istruzioni del produttore. Sono state quindi ottenute scansioni CBCT post-strumentazione. Un singolo operatore ha eseguito le preparazioni dei canali mentre un altro operatore ha effettuato le misurazioni. I dati sono stati analizzati utilizzando SPSS 20. La media e la deviazione standard (SD) della quantità di trasporto canalare sono stati calcolati e confrontati tra i gruppi usando il test Friedman ($P \leq 0.05$).
Risultati: Nessuna differenza significativa è stata osservata tra i gruppi nel trasporto dei canali nel terzo medio e apicale ($P > 0.05$), ma la tecnica mono-strumento ha causato un trasporto più significativo del canale nel terzo coronale.
Conclusioni: Nessuna differenza significativa è stata riscontrata tra i diversi sistemi rotanti nella quantità di trasporto canalare nel terzo medio e apicale nel canale mesio-buccale di primi molari mandibolari. Anche se tutti i file rotanti hanno causato un certo grado di trasporto del canale, la tecnica mono-strumento rotante ha causato un trasporto del canale nel terzo coronale significativamente maggiore rispetto alle sequenze di file multipli.

Introduction

The main objective of endodontic treatment is to eliminate or minimize microorganisms in the root canal system while maintaining the original shape and path of root canals.[1] Variations in the anatomy and morphology of the root canal system, presence of isthmus, communications within the root canal system and with the periodontal ligament via the accessory canals, canal curvature and oval shape root canals, complicate an efficient disinfection of the root canal system.[2] According to Schilder, root canal must have a conical shape from the coronal to the apical region.[3] Moreover, the original shape of the apical foramen must be preserved and no significant change should be made in the original curvature of the root canal path during cleaning and shaping.[4]

Although most root canals have a curvature, endodontic instruments are often manufactured in a straight form. Thus, they tend to straighten up the canal path when in function. This results in occurrence of procedural errors such as ledge formation, transportation, zipping and perforation of canal, which adversely affect the quality of cleaning and shaping and obturation and compromise the success of treatment.[5,6]

Nickel—titanium (NiTi) instruments were introduced in the 1990s to enhance and accelerate the process of root canal preparation especially in curved canals since they are more flexible than stainless-steel instruments.[7] Evidence shows that NiTi rotary instruments enable the clinician to adequately and predictably prepare the root canal and decrease the risk of procedural errors.[8]

The *Mtwo* rotary system (VDW, Munich, Germany) was introduced worldwide in 2005. It has a S-shaped cross-section and two cutting blades, enabling efficient cutting of dentin. Moreover, the length of pitch from the tip to the shaft has increased in this system. This design has two advantages namely decreased screwing into the canal and decreased extrusion of debris through the apex.[9] The manufacturer of this system suggests the single-length preparation technique instead of crown-down technique.[10] A previous study showed that preparation of curved canals with *Mtwo* maintains the central path of canal.[9]

Revo-S (Micro-Mega, Besancon Cedex, France) is a NiTi rotary instrument with asymmetrical cross-section. This design should enhance the flexibility of the file and reduce the stress applied to it, making it a suitable instrument for canal negotiation.[11]

In a study on canal transportation and centering ability, no significant difference was noted between Revo-S and *Mtwo* rotary systems.[8] Another study compared preparation of severely curved canals with six rotary instruments including Revo-S and *Mtwo* and found no significant difference in canal transportation caused by rotary files; however, canal transportation was greater by use of the hand files compared to rotary files.[12]

Single-file systems were recently introduced on the market, mainly used in reciprocating movement.[13] These systems are efficient and require less time for bio-mechanical preparation of root canals.[14] Recently, a new single-file rotary system, known as Neoniti (Neolix SAS, Chatres-La-Foret, France), was introduced to the market. It operates with full rotation movement and has been recommended for efficient root canal preparation. This system is manufactured by electric discharge machining technology, which confers unique properties to the file such as greater flexibility, sharp cutting edges, changing profile and variable built-in abrasive properties.[15,16]

Moazzami et al.[1] compared the amount of canal transportation caused by the use of Neoniti and Reciproc files using cone-beam computed tomography (CBCT) and concluded that canal transportation was lower when Neoniti instruments were used; they attributed this finding to the non-homothetic rectangular cross-section and rounded tip of this file.

CBCT is among the recent techniques suggested for assessment of the quality and efficacy of root canal preparation techniques. CBCT has advantages such as low patient radiation dose and a small field of view, which enhances the resolution and diagnostic value.[16,17] CBCT scans are more accurate than the conventional radiographs and do not require destruction of samples. They have high reproducibility and can provide numerous images of a single canal.[18]

No previous study has compared canal transportation caused by *Mtwo* and Revo-S multi-file and Neoniti single-file systems. Thus, this study aimed to compare canal transportation in the mesio-buccal canal of mandibular first molars prepared with *Mtwo* and Revo-S multi-file and Neoniti single-file NiTi rotary systems evaluated using CBCT.

Materials and methods

This *ex vivo* study was conducted on 45 mandibular first molars extracted for periodontal or orthodontic reasons in the Oral and Maxillofacial Surgery Department of Zahedan University of Medical Sciences, School of Dentistry. The study protocol was approved in the ethics committee of this university (IR.ZAUMS.REC.1395.101). The teeth had closed apices and the mean root curvature was 20—40° according to the Schneider's method.[4] Root curvature had 5—9 mm distance from the apex and the mean length of root was 19—22 mm.

Tissue remnants and calcified debris were removed by a scaler. The teeth were immersed in 0.1% thymol solution for 24 ours at 9 °C for disinfection. They were rinsed under running water to eliminate thymol residues and stored in saline at 4 °C. Initial radiographs of the mesial root were obtained and degree of root curvature was measured. Mesial canals each had a separate apical foramen and had no signs of calcification or internal resorption. S- or C-shaped canals were excluded. All teeth were inspected under a stereomicroscope at 12× magnification to ensure absence of craze lines, cracks or fracture. The teeth with such defects were excluded and replaced with sound teeth. Access cavity was prepared by a diamond bur and high-speed hand-piece under water and air spray. To determine the working length of the mesio-buccal canal, a size 10 K-file (Mani, Tochigi, Japan) was introduced into the canal until its tip was visible at the apex. One millimeter was subtracted of this length to determine the working length.

Silicon impression material (Oranwash, Zhermack spa, Rovigo, Italy) was used to cover the cementum surface to simulate the periodontal ligament. Apical foramen was sealed with red wax to prevent intrusion of silicon material into the apical foramen. The teeth were then mounted in blocks measuring 5 × 5 cm filled with putty to the level of the cemento-enamel junction in a parallel fashion to standardize pre- and post-operative radiographs. A small piece of orthodontic wire was placed at the corner of silicon blocks as a reference to mark the direction of scanning. The teeth were randomly divided into three groups of 15. *Mtwo* was used in group 1, Revo-S was used in group 2 and Neoniti was used in group 3.

Root canal preparation

All canals were instrumented to the working length using a hand-piece (X-Smart; Dentsply-Maillefer, Baillagues, Switzerland) with the torque recommended by the manufacturer for each system along with irrigation with 2.5% sodium hypochlorite with 30 gage needle between instruments; 17% EDTA and 5.25% sodium hypochlorite were used for final rinse and elimination of smear layer.

Group 1. *Mtwo* rotary system (VDW GmbH, Germany) was used for root canal preparation in this group. First, a #10 K file was used to obtain a glide path to the working length. Then, 10/0.04, 15/0.05, 20/0.06 and 25/0.06 files were used at 280 rpm and 1.2 N/cm torque for instrumentation of the coronal, middle and apical thirds of the root canal to the working length. Frequent recapitulation was done using a #10 K-file. Root canals were rinsed with 2.5% sodium hypochlorite after using each instrument. Glyde (Dentsply-Maillefer, Konstanz, Germany) was used as the lubricant.

Group 2. Revo-S (Micro Mega, Besançon, France) NiTi file was used for root canal preparation, which was started with SC1 (25/0.06) at 300 rpm with 2 N/cm torque according to the manufacturer's instructions followed by SC2 (25/0.04) and SU (25/0.06) to the working length for final preparation. Recapitulation was repeatedly done using #10 K-file and rinsing with 2.5% sodium hypochlorite was performed after using each instrument. Glyde was used as the lubricant.

Group 3. Mesiobuccal canal in this group was prepared using Neolix (25/0.08) (Neoniti A1, France) at 300 rpm and 1.5 N/cm torque according to the manufacturer's instructions to the working length. Recapitulation was repeatedly done using #10 K-file and rinsing with 2.5% sodium hypochlorite was performed after using each instrument. Glyde was used as the lubricant.

Three-dimensional CBCT scans were obtained (Vatec, Korea) with high resolution, 50 × 50 mm, 89 kVp, 5.4 mA,

0.8 voxel size and 17 s time before root canal preparation. CBCT scans were obtained again with the same exposure settings after root canal preparation. Thickness of root canal wall before and after instrumentation was measured at 3, 6 and 9 mm distances from the apex. Canal transportation was calculated using the following formula: $CT = (A1 - A2) - (B1 - B2)$.

$A1$ is the shortest distance from the external root surface to the un-instrumented canal border; $A2$ is the minimum distance from the external root surface to the border of instrumented canal, $B1$ is the minimum distance from the internal root surface to the un-instrumented canal border and $B2$ is the minimum distance from the internal root surface to the instrumented canal border. In this formula, CT = 0 indicates no transportation while negative values indicate transportation toward the distal (furcation site) and positive values indicate transportation toward the mesial.

It should be noted that canal preparation was done by a single operator while measurements were made by another operator blinded to the group allocation of teeth. Data were analyzed using SPSS version 20. The mean and standard deviation (SD) of root canal transportation were calculated and compared using non-parametric Kruskal–Wallis test (since data were not normally distributed). $P \leq 0.05$ was considered statistically significant.

Results

Table 1 and Fig. 1 shows the mean and SD of canal transportation in mesio-distal direction in the three systems. No significant difference was noted in canal transportation among the three systems at the middle and apical third ($P > 0.05$); but this difference in the coronal third was statistically significant and Neoniti removed significantly more amount of dentin from the internal wall of the curvature in the coronal third and caused significantly greater canal transportation toward the furcation ($P = 0.008$).

Discussion

One major goal of root canal preparation is to create a conical shape from the apical to the coronal while maintaining the original canal path.[2] Mandibular molars that commonly require endodontic treatment usually present a curved mesial root.[19] The greatest curvature is usually seen in the mesio-buccal canal.[19] Thus, this canal is more susceptible to transportation during instrumentation compared to other canals. If transportation occurs, it would be impossible to regain the original canal shape and risk of ledge formation, perforation and zipping increases.[8,20]

CBCT is an efficient modality for assessment and measurement of dentin thickness, canal curvature, canal transportation and centering ability.[2] This experimental study assessed canal transportation in the mesio-buccal canal of extracted human mandibular first molars using CBCT and showed that the three types of NiTi rotary systems, irrespective of the number of files used (single-file or multi-file systems) were significantly different in terms of canal transportation.

The results of this study showed that Neoniti file caused significant transportation in the cervical third of canal toward the furcation. No significant difference was noted among the rotary instruments in the middle and apical thirds.

Evidence shows that dimensions of instrument, metallurgical properties, design of instrument and its application mode can all affect the amount of canal transportation during instrumentation.[21] Neoniti system has a single file with 8% taper and triangular-shaped cross-section. Greater tapering of this instrument compared to *Mtwo* and Revo-S can explain greater removal of dentin from the cervical third and greater transportation compared to other multi-file systems in the cervical third of the canal.[1]

Moazzami et al.[1] showed that Neoniti file caused significantly greater transportation in bucco-lingual compared to mesio-distal direction in the apical 5 mm of the canal. Revo-S has constant taper and a cross-section with three asymmetrical blades. This design decreases mechanical stress on the instrument and enhances canal preparation by snake-like movement. A previous study assessed the effect of asymmetry on three-helix cross-section and concluded that this modified performance decreases axial stress.[20] Another study compared the amount of canal transportation and centering ability of Revo-S and ProTaper and concluded that although no significant difference existed between the two systems, Revo-S had a superior performance than ProTaper.[22] In the present study, *Mtwo* caused the least amount of canal transportation; *Mtwo* has two cutting blades with a small S-shaped cross-section. This design aims to increase the flexibility of the instrument and to achieve higher cutting ability compared to triangular cross-section.[8] In the present study, the least amount of transportation caused by *Mtwo* was in the middle region, which can be attributed to the relatively low number of blades per each unit of length. Yang et al. reported results similar and concluded that *Mtwo* well preserves the original canal path.[23] Schäfer et al. showed that *Mtwo* preserved the original canal curvature significantly better than other instruments.[24]

Apical transportation more than 0.3 mm results in loss of seal in the apical region and compromises the prognosis of treatment.[25] In the present study, the amount of transportation ranged from 0.04 to 0.09 mm, which would not affect apical seal.

Table 1 Comparison of the mean canal transportation in the coronal, middle and apical thirds of root canals in the three groups ($n = 15$).

Region	System	Mean	Standard deviation	*P* value
Apical third	Neoniti A1	.0933	0.11238	0.102
	Revo-S	−.0400	0.10403	
	Mtwo	.0800	0.10862	
Middle third	Neoniti A1	−.0600	0.10593	0.443
	Revo-S	−.0200	0.08255	
	Mtwo	.0133	0.10024	
Coronal third	Neoniti A1	−.1733	0.09824	0.041
	Revo-S	.0267	0.11112	
	Mtwo	.0800	0.12509	

P value: Kruskal–Wallis test.

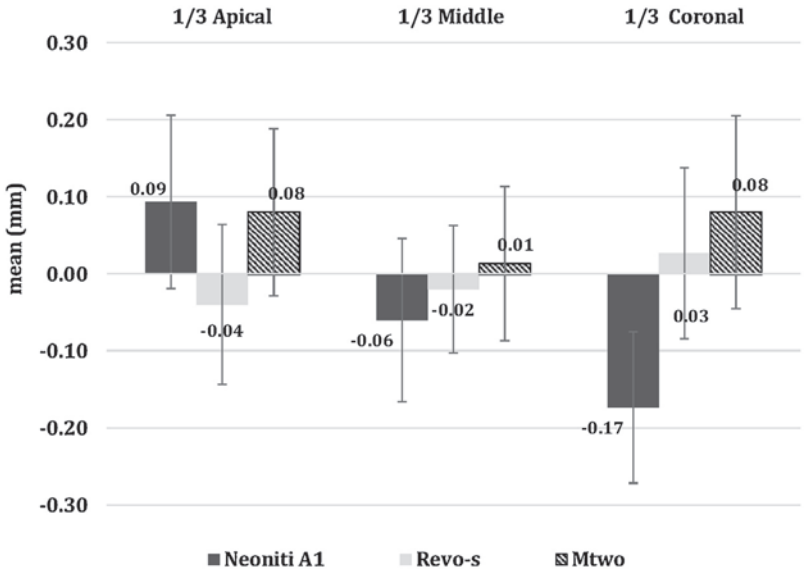

Figure 1 Comparison of canal transportation in the coronal, middle and apical thirds of root canals in the three groups (n = 15). In the 1/3 of coronal, the mean Revo-s was rounded up to 0.03.

Conclusion

No significant difference was noted in terms of the amount of canal transportation among different rotary systems in the apical and middle third. Although all rotary systems caused some degrees of canal transportation, Neoniti caused significantly greater canal transportation in the coronal third.

Conflict of interest

The authors deny any conflict of interest.

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