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ORIGINAL ARTICLE/ARTICOLO ORIGINALE

Shaping ability of several nickel—titanium systems in double-curved simulated canals

Capacità di diversi sistemi in nichel-titanio nella preparazione di canali artificiali con doppia curvatura

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KEYWORDS
Shaping;
Nickel—titanium;
Simulated canal;
Double curvature.

Abstract

Aim: The aim of the study was to evaluate the shaping ability of four nickel—titanium systems (iRaCe, ProTaper Next, Wave One, and TF) in simulated double-curved (S-shaped) root canals.

Materials and methods: This study was conducted using simulated S-shaped root canals ($n = 40$). The specimens were divided into four experimental groups ($n = 10$ each). Each group was prepared using one of the following NiTi systems: iRaCe, ProTaper Next, Wave One, and TF. The canals were injected with black ink before instrumentation, and a series of photographs of each canal was saved to a computer using a set protocol. The canals were reinjected using red ink postoperatively to define their outlines, and images were taken in the same standardized manner. Photoshop software was used to superimpose pre- and post-instrumentation images in two different layers. Canal transportation was evaluated at five positions from the apical end (D1, D2, D3, D5, and D7) by measuring the amount of removed resin using ImageJ Software. The data were analyzed using SPSS ver. 20.0. Statistical significance was set at $P < 0.05$.

Results: There were no significant differences ($P > 0.05$) in shaping time (in seconds) among the NiTi systems, and there were no significant differences ($P > 0.05$) in canal transportation values among the systems at D1, D2, D3, D5, and D7 among the NiTi systems.

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Conclusion: The iRaCe, ProTaper Next, Wave One, and TF systems preserved the original shape of the double-curved (S-shaped) canal with minimum root canal transportation. These systems produced satisfactory root canal instrumentation in S-shaped canals.

PAROLE CHIAVE
Preparazione canalare;
nichel.titanio;
canali artificiali;
doppia curvatura.

Riassunto
Obiettivo: Lo scopo dello studio è stato quello di valutare la capacità sagomatura di quattro sistemi in nichel-titanio (iRaCe, ProTaper Avanti, WaveOne, e TF) in canali artificiali con doppia curvatura (a forma di S).
Materiali e Metodi: Lo studio è stato condotto utilizzando canali artificiali a forma di S (n = 40). I campioni sono stati divisi in quattro gruppi sperimentali (n = 10). Ogni gruppo è stato preparato utilizzando uno dei seguenti sistemi NiTi: iRaCe, ProTaper Avanti, WaveOne, e TF. I canali sono stati iniettati con inchiostro nero prima della strumentazione ed una serie di fotografie di ogni canale è stata scattata e salvata su un computer. I canali sono stati reiniettati con inchiostro rosso dopo l'intervento per definirne meglio i contorni, e nuove immagini sono state ottenute nello stesso modo standardizzato dopo la preparazione. Il software Photoshop è stato utilizzato per sovrapporre le immagini pre e post-strumentazione ed il trasporto canalare è stato valutato in cinque punti differenti a partire dal forame apicale (D1, D2, D3, D5 e D7), misurando la quantità di resina rimossa e utilizzando per questo scopo il software ImageJ. I dati sono stati analizzati utilizzando SPSS ver. 20.0 e la significatività statistica è stato fissato a $P < 0{,}05$.
Risultati: Non ci sono state differenze significative ($P > 0.05$) nel tempo di preparazione dei canali artificiali (in secondi) tra i diversi sistemi NiTi e non sono state riscontrate differenze significative ($P > 0.05$) dei valori di trasporto del canale tra i vari sistemi ai differenti livelli analizzati.
Conclusioni: Gli strumenti iRaCe, ProTaper Next, WaveOne, e TF hanno mantenuto la forma originale della doppia curvatura del canale artificiale (a forma di S) con un minimo trasporto canalare producendo una soddisfacente forma finale di preparazione.

Introduction

The complex nature of root canal anatomy could complicate canal shaping during root canal treatment, and may cause insufficient disinfection of the root canal system or lead to mishaps during cleaning and shaping such as instrument separation, transportation, ledges, or perforations.[1–3] Curved canal instrumentation—especially for S-shaped canals—is considered a great mission in root canal treatment.[4] Flexible nickel—titanium (NiTi) rotary instruments are considered more efficient and safe than traditional stainless steel instruments, reducing procedural errors during root canal instrumentation.[5,6] Recent technological advancements have led to new NiTi instruments with unique properties, and movement has made canal preparation easier and faster.[7] M-Wire is a new development in NiTi instrumentation resulting from a patented thermomechanical process for NiTi wires. ProTaper Next (Dentsply Maillefer) instruments, made of this M-Wire alloy, with a variable taper design and an off-center axis with a rectangular cross section, present improved cyclic fatigue resistance in comparison with instruments made of conventional super elastic NiTi alloys.[8,9] A single-file system with unique working motions is a new concept that has recently been introduced to root canal cleaning and shaping. Wave One (Dentsply Maillefer) is a single file system made of M-Wire alloy to increase flexibility and improve cyclic fatigue of the instrument. Instruments with a reciprocating motion swing a shorter angular distance than a rotary instrument does, reducing stress values, giving reciprocating instruments prolonged fatigue life.[10] Twisted File (TF; SybronEndo, Orange, CA, USA) is a NiTi rotary system; new features such as R-phase heat treatment, twisting of the metal, and special surface conditioning are used during the manufacturing process.[11] iRaCe (FKG, La Chaux-de-Fonds, Switzerland) NiTi rotary instruments have recently been developed to simplify the RaCe system FKG (FKG Dentaire-Switzerland) sequence. RaCe instruments remove debris effectively while maintaining the original outline form of the canal.[12] iRaCe instruments have the same features as RaCe instruments, The manufacturer has claimed that this new sequence is fast, safe, and effective in curved root canal instrumentation.[13] The shaping ability of NiTi instruments can be evaluated through several methods, one of which uses simulated resin blocks that contain curved canals.[14,15]

The aim of this study was to evaluate the shaping ability of four different NiTi systems (iRaCe, ProTaper Next, Wave One, and TF) in simulated S-shaped root canals.

Materials and methods

Simulated canals

This study used simulated double-curved (S-shaped) root canals in clear resin blocks (Endo Training Bloc-S; Dentsply Maillefer, Ballaigues, Switzerland), The size of the canal equaled ISO file size 15#, with 02 taper and 20 degree apical curvature (3.5-mm radius), 30 degree coronal curvature (5-mm radius),[16,17] and 16-mm canal length. The simulated root canals were randomly assigned to four groups (n = 10): the ProTaper Next group, Wave One, TF, and iRaCe groups.

Photographic procedures

To provide standardized photographs of each canal, a special mold was used to position the camera (Nikon D3200, Nikon, Inc.) precisely. To improve the color contrast of photos, all canals were injected with black ink (Fig. 1) before instrumentation in a standardized manner, and a series of photographs of each canal was saved to a computer using a set protocol. The canals were reinjected using red ink postoperatively (Fig. 2) to define their outlines, and images were taken in the same standard manner. To reduce the margin of error, all photography was performed by the same operator.

Instrumentation

A glide path was not created before instrumentation of the S-shaped canals because all canals had an initial diameter compatible with ISO size 15.

Group one was prepared using the iRaCe system according to the manufacturer's instructions to R3 instrument (size 30, taper 4%). The instrument was replaced after preparing three canals.

Group two was prepared using the ProTaper Next system according to the manufacturer's reference guide to X2 (size 25, taper 6%) file. The instrument was replaced after preparing three canals.

Group three was prepared using the Wave One system according to the manufacturer's reference guide. The canals were prepared using a primary single file instrument (size 25, taper 8%).

Group four was prepared using the TF system according to the manufacturer's instructions until TF instrument (size 25, taper 6%). The instrument was replaced after preparing three canals.

Copious irrigation with tap water was used repeatedly as an irrigant after using each instrument.

All simulated canals were prepared by the same operator, who had more than 7 years' experience in root canal therapy.

Figure 1 Photo of resin block before instrumentation where injected with black ink to improve the color contrast.

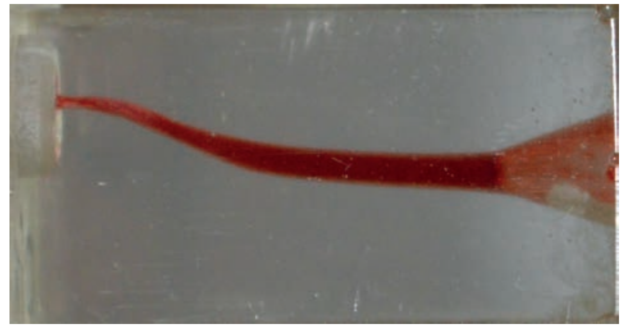

Figure 2 Photo of resin block after instrumentation where injected with red ink to improve the color contrast.

Assessment of root canal preparation

The time taken to prepare each canal was recorded, including active instrumentation, instrument changes, and irrigation. Shaping efficiency was evaluated by measuring the amount of material lost at various levels (1 mm [D1], 2 mm [D2], 3 mm [D3], 5 mm [D5], 7 mm [D7]) from the apical foramen of the root canal. Photoshop (Adobe Systems, San Jose, CA, USA) was used to superimpose pre- and post-instrumentation images in two layers (Fig. 3). Measurements were made using ImageJ 1.38× (National Institutes of Health, Bethesda, MD) computer software while viewing the superimposed images at 200% to measure transportation values of the central location (values in mm) after instrumentation of root canals as follows: D (difference) = D_o (outer resin removed) − D_i (inner resin removed)

A positive values indicated a prevalence of outer resin removed (transportation toward curvature) and a negative values indicated a prevalence of inner resin removed (anticurvature transportation). The closer the value was to zero, the more balanced was the preparation.

Statistical analyses

Statistical analyses were carried out using SPSS software (ver. 20; SPSS, Inc., Chicago, IL, USA). To compare results, one-way ANOVA and the Bonferroni post hoc test were used. Statistical significance was set at $P < 0.05$.

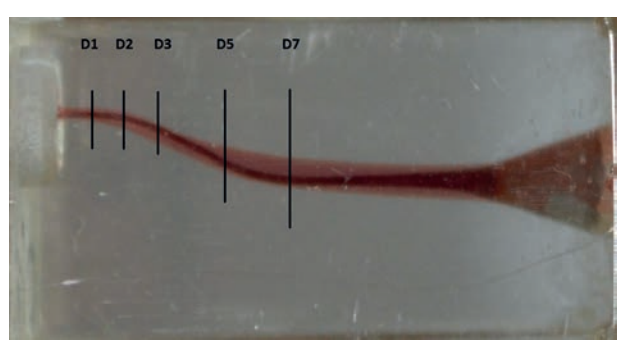

Figure 3 Superimposed of before and after instrumentation photos to measure transportation values at various levels (1 mm [D1], 2 mm [D2], 3 mm [D3], 5 mm [D5], 7 mm [D7]) from the apical foramen.

Results

Shaping time evaluation

There were no significant differences ($P > 0.05$) in shaping time (in seconds) among the four NiTi systems. Table 1 shows the shaping time values and averages (in seconds) according to NiTi system.

Canal transportation evaluation

Evaluation of canal transportation values

There were no significant differences ($P > 0.05$) in canal transportation values among the NiTi systems at D1, D2, and D5, but at D3, Wave One caused more transportation than the other systems did, and at D7, ProTaper Next caused the least transportation. Table 2 and shows canal transportation values according to NiTi system.

Evaluation of canal transportation direction

There were no significant differences ($P > 0.05$) in transportation direction among NiTi systems at the D2, D3, and D7 locations. At D1 and D5, the TF system caused more transportation toward the outside than the other systems did. Fig. 4 shows canal transportation values in mm and direction according to NiTi system.

Discussion

The instrumentation of an S-shaped root canal is still a challenge despite advances in NiTi systems and techniques of root canal preparation.[18] The aim of this study was to compare the shaping ability of several NiTi systems (iRaCe, ProTaper Next, Wave One, and TF) in simulated S-shaped canals. Simulated canals in resin blocks provide standardized conditions for study, which are obligatory for shaping ability comparison of different NiTi systems.[19] It is almost impossible to get S-shaped canals in human teeth with the same configurations.[19] Moreover, it is easy to photograph, measure, and compare the canal shape before and after instrumentation in simulated canals.[20,21] However, the differences between resin and dentin require prudence during clinical application of these results.[22] Reports have mentioned that 30—40% and 35—59% of distobuccal roots of maxillary molars and mesial roots of mandibular molars, respectively, have S-shaped canals.[22] Files of size 25 designed to deal with narrow and curved canals were used in this study according to the manufacturers' instructions.[19] Although there are advantages of apical enlargement increases, such as improvement of the irrigant effect and cleaning efficiency in part of the canal, this is associated with jeopardizing the canal due to transportation because of the decreased flexibility of large instruments. These issues must be taken into consideration when preparing S-shaped canals.[19,23] In our study, there was no significant difference in preparation time among the four NiTi systems (iRaCe, ProTaper Next, Wave One, and TF). The number of instruments used, preparation technique, and experience of the practitioner all influence the instrumentation time.[19] Our results showed significant differences in canal transportation values among NiTi systems (iRaCe, ProTaper Next, Wave One, and TF Adaptive) at D1, D2, and D5, but at D3, Wave One caused more transportation than other systems did, and at D7, ProTaper Next caused the least transportation. Recently manufactured rotary systems of size 25 and a taper varying from 0.06 to 0.08 could be used in instrumentation of curved canals with less transportation.[24] The taper of instruments is inversely associated with canal transportation.[19] The instruments used in this study had noncutting tips where light apical pressure was needed, and they could be guided to easy penetration; this may cause minimum transportation.[25] Our findings are similar to the results of several studies that showed that new NiTi systems prepared curved root canals with minimum shaping errors.[26—28] The RaCe instruments have a triangular cross-sectional shape with alternating cutting edges. Simulated S-shaped canals prepared with RaCe instruments did not have any canal transportation,[18,29] and in extracted teeth, RaCe instruments prepared canals without errors.[12] S-shaped canals could be prepared with the system effectively and economically.[4] ProTaper Next (PTN) shaped curved root canals in a satisfactory manner, preserving the constriction of the apical end.[30] PTN has a nonconcentric rectangular cross section, which makes the instruments work in a staggered manner.[31] This may make it suitable to shape more

Table 1 Mean shaping time and standard deviation (values in seconds) according to NiTi system.

Shaping time (in seconds)		
NiTi system	Mean	SD
iRaCe	143.40	14.06
ProTaper Next	139.80	8.47
Wave One	153.00	23.89
TF Adaptive	146.00	8.43

Table 2 Mean transportation values of the central location (values in mm) after instrumentation at five points from apical constriction in S-shaped root canals.

System	D1	D2	D3	D5	D7
iRaCe	0.10 ± 0.12	0.19 ± 0.15	0.19 ± 0.2	0.17 ± 4.66	0.44 ± 0.12
PTN	0.05 ± 0.11	0.18 ± 0.17	0.29 ± 0.19	0.23 ± 0.39	0.17 ± 0.12
WO	0.04 ± 0.2	0.28 ± 0.16	0.4 ± 0.24	0.13 ± 0.29	0.46 ± 0.33
TF	0.01 ± 0.03	0.01 ± 0.17	0.14 ± 0.22	0.08 ± 0.31	0.25 ± 0.16
P-value	$P > 0.05$	$P > 0.05$	$P > 0.05$	$P > 0.05$	$P > 0.05$

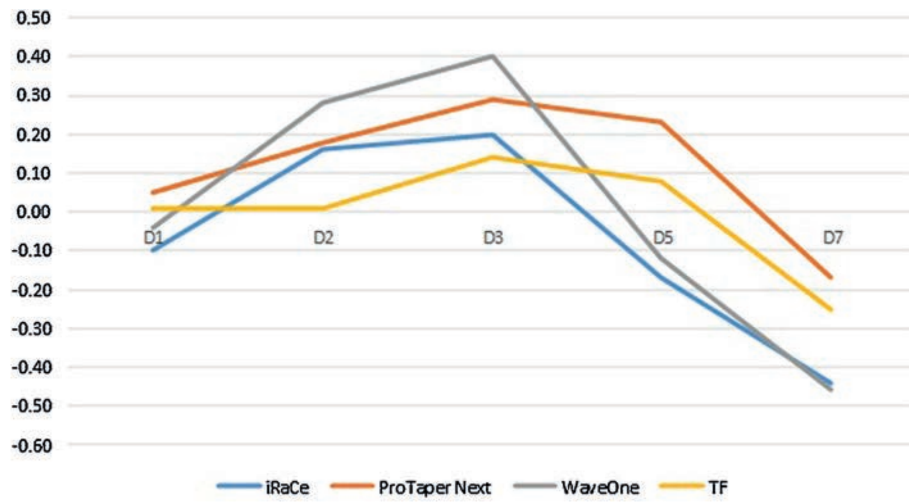

Figure 4 The directions and average values of canal transportation (in mm) according to NiTi system where positive values indicated transportation toward curvature and negative values indicated anticurvature transportation.

severely curved narrow canals. There is controversy regarding the advantages of reciprocal movement in canal shaping; some studies have demonstrated the superiority of reciprocation,[15] whereas another study showed that reciprocating files showed a marked tendency to straighten S-shaped canals.[19] The TF instruments manufactured with R-phase were able to maintain the original shape of the canal. These study results are consistent with the results of studies about TF shaping ability.[32–34] In our study, there were no significant differences in canal transportation values among NiTi systems at D1, D2, and D5, but at D3, Wave One caused transportation more than other systems did, and at D7, ProTaper Next caused the least transportation. A recent study showed that canal transportation at the curved part caused by Wave One instruments was more than that with PTN in severely curved canals. That is probably due to sharp cutting edges of the single-file system, which cause more cutting in canal walls and lead to more transportation than a multi-file system does.[30]

Conclusions

The results of this study revealed that the iRaCe, ProTaper Next, Wave One, and TF systems preserved the original shape of double-curved (S-shaped) canals with minimum root canal transportation. These systems produced satisfactory root canal instrumentation in S-shaped canals, and ProTaper Next caused the least transportation in the middle part of the canal. There is a need to conduct further studies on extracted teeth with 3D analysis to get accurate results.

Conflict of interest

The authors have no conflicts of interest to declare.

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