Canal preparation with Hero 642 rotary Ni–Ti instruments compared with stainless steel hand K-file assessed using computed tomography

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Abstract

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Aim To compare *ex vivo* root canal preparation with conventional stainless steel K-files and Hero 642 rotary Ni–Ti instruments.

Methodology Mesiobuccal canals of 20 maxillary first molars (with angles of curvature between 25° and 35°) were used. After preparation with Hero 642 rotary instruments and stainless steel K-files, the amount of transportation that occurred was assessed using computed tomography. The teeth were scanned by computed tomography before instrumentation. One millimetre thick slices were prepared from the apical end point to the pulp chamber. The first two sections were 3 mm from the apical end of the root (apical level) and 3 mm below the orifice (coronal level). A further section (mid-root level) was recorded, dividing the distance between the sections of apical and coronal levels into two equal lengths. Ten teeth were instrumented using Hero 642 rotary instruments and another 10 teeth were instrumented using stainless steel K-files. Following the completion of the instrumentation, the teeth were again scanned and compared with the cross-sectional images taken prior to canal preparation. Amount of transportation and centreing ability was assessed. Student's *t*-test was used for statistical analysis.

Results Less transportation occurred with Hero 642 rotary instruments than stainless steel K-files at the mid-root and coronal levels (mid-root: $P < 0.05$ and coronal: $P < 0.001$). Hero 642 rotary instruments had better centreing ability than K-files at all three levels (apical: $P < 0.05$, mid-root: $P < 0.05$ and coronal: $P < 0.001$).

Conclusions Hero 642 rotary instruments transported canals less, especially at the middle and coronal thirds of the root canals than stainless steel K-files. Hero 642 instruments had better centreing ability.

Keywords: canal transportation, computed tomography, nickel–titanium, rotary instrumentation.

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Introduction

Root canal preparation aims to remove infected debris from the root canal system. Shaping the root canal provides more efficient disinfection by creating a reservoir for irrigants and medicaments and also provides space for root canal filling (Pitt Ford *et al.* 2002).

A prepared root canal should have a shape that flares from apical to coronal regions maintaining the apical foramen and not changing the original canal curvature (Schilder 1974). However, it is almost impossible to achieve the desired root canal shape in narrow and curved canals. During instrumentation; procedural errors such as transportation of the apical foramen or the creation of zips, elbows, ledges can occur along with loss of working length (WL), perforation and

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separation of instruments (Deplazes *et al.* 2001, Hülsmann *et al.* 2001).

Whilst a number of root canal preparation techniques have been developed to overcome these problems, some changes have been suggested in the design of root canal instruments. Rotary systems have been developed to reduce the duration of canal preparation and decrease patient and operator fatigue. Early studies which compared these systems with conventional instrumentation reported various problems such as canal blockage, straightening, loss of tactile sense, inadequate cleaning and file separation (Turek & Langeland 1982, Campos & del Rio 1990, Hülsmann & Stryga 1993).

Reports have shown that nickel–titanium (Ni–Ti) instruments are two to three times more flexible than conventional stainless steel files and that they have more resistance torsional fracture (Walia *et al.* 1988).

In the last decade, various Ni–Ti instruments have been developed for use with either rotary endodontic handpieces or by hand in order to facilitate cleaning and shaping by shortening working time and improving the quality of canal shaping. To improve preparation safety and to prepare more flared preparations, new instrument designs with non-cutting tips, radial lands and varying tapers have been developed. Because of these new instrument designs, advanced preparation concepts have been developed, most of the Ni–Ti instruments with greater tapers being used with 'crown-down' preparation technique (Versümer *et al.* 2002).

The main parameters used to evaluate a technique or an instrument which has been developed for root canal preparation should be 'shaping the root canal whilst protecting the curvature of the canal' and 'adequately cleaning the root canal walls'. Moreover, the further pre-requisite for an instrument or a technique is its safety (Versümer *et al.* 2002).

Recently, techniques that allow teeth to be evaluated without destroying the specimens have been suggested to compare root canal shape prior to and after instrumentation. With the use of computed tomography (CT), appropriate and measurable sections can be prepared and 3D images can be reconstructed. Root canal instruments and preparation methods can be compared by using CT (Gambill *et al.* 1996, Rhodes *et al.* 2000, Garip & Günday 2001, Gluskin *et al.* 2001, Peters *et al.* 2001a, Bergmans *et al.* 2003).

The aim of this study was to compare the quality of root canal preparation completed using Hero 642 instruments (Micro-Mega, Besançon, France) and conventional stainless steel K-files in the mesiobuccal canals of maxillary first molar teeth that had a canal curvature between 25° and 35°.

Materials and methods

The main mesiobuccal root canals of 20 maxillary first molar teeth, extracted for periodontal and prosthetic reasons were used. Tissue fragments and calcified debris were removed from teeth by scaling and the teeth stored in 10% formalin solution until used. Access cavities were prepared using round diamond burs (Mani Inc., Tochigi-Ken, Japan). To determine the angle of curvature and to verify the presence of the canal, periapical radiographs from the buccolingual view were taken with a size 10 K-file (Mani Inc.).

To be included the mesiobuccal roots had to have completely formed apices and angles of curvature ranging between 25° and 35° according to the criteria described by Schneider (1971). Second mesiobuccal canals were not included.

Distobuccal and palatal roots of all teeth were separated by using a stainless steel disc (Finzier Schrock & Kimmel GmbH, Bad Ems, Germany) at the furcation. To determine the WL, a size 10 K-file was inserted into the remaining mesiobuccal canal until it was visible at the apical foramen. The WL of each canal was calculated to be 1 mm less than the length obtained with this initial file. Mesiobuccal roots were embedded into transparent acrylic (Orthoplast; Vertex, Zeist, Netherlands). The teeth were randomly divided into two experimental groups. All teeth were scanned by spiral CT (Toshiba-002A; Toshiba, Tochigi-Ken, Japan) to determine the root canal shape before instrumentation. The sections were 1 mm thick from apical to the canal orifice. Three sections from each tooth, the number of the tooth and its level were archived onto a magnetic optical disc (EDM 650B; Sony Corp., Tokyo, Japan). The first two sections were 3 mm from the apical end of the root (apical level) and 3 mm below the orifice (coronal level). A further section (mid-root level) was recorded, dividing the distance between the sections into two equal lengths. After initial scans, root canals were instrumented. Ten teeth were prepared using Hero 642 instruments according to the manufacturer's recommendations for the teeth which had narrow canals and angle of curvature more than 25°.

1. The shaping procedure commenced with 0.06 taper size 20 instruments. The coronal 1/3 or 2/3 of the root canal was shaped if passive penetration was possible.
2. A 0.04 taper size 20 instrument was inserted and used until 2 mm short of working length (WL).

3. Shaping continued with 0.02 taper size 20 instrument to the WL.
4. A 0.04 taper size 25 instrument was taken 2 mm short of WL.
5. A 0.02 taper size 25 instrument was taken to WL.
6. A 0.02 taper size 30 instrument was taken to WL.

Each instrument was used with the 1:75 reduction rotary handpiece (06 XE; Micro-Mega); the speed of rotation was maintained at 400 rpm. A liquid chelating agent with 15% EDTA (Wizard, Rehber Kimya San., Istanbul, Turkey) was used, instruments were inserted into the canal and moved apically inwards and outwards. Canals were irrigated copiously with 2 mL of a 5% NaOCl solution (Wizard). Each instrument was changed after five canals according to the manufacturer's recommendation.

The remaining 10 teeth were shaped using 'watch-winding' manipulation of hand instruments using a stepback technique (Ingle & Bakland 1994). Size 25 and larger size K-files were pre-curved. The cross-sections of the K-files were square until size 40, and triangular for larger sizes (Mani Inc.). The manipulation of instruments included a half or three quarter turn clockwise followed by a similar counter-clockwise movement and withdrawal. Upon removal, the instruments were wiped clean, re-curved and repositioned into the canal and 'watch-winding' motion continued. This procedure was repeated until the instrument was loose in canal and then the next size file was used. After the size 30 K-file had been used to full length, the procedure continued with a size 35 K-file 1 mm short of WL, 2 mm short of WL with size 40 instrument, 3 mm short of WL with size 45 instrument, 4 mm short of WL with size 50 instrument and 5 mm short of WL with size 55 instrument. (15% liquid EDTA) was used as lubricant. Before proceeding to the next file, recapitulation with a size 30 K-file was carried out to avoid ledge formation. After use of each file, root canals were irrigated with 2 mL of 5% NaOCl solution. Coronal preparation was completed using size 1–4 Gates Glidden drills (Mani Inc.). After final irrigation, canals were dried with paper points (Meta, Meta Dental Co., Seoul, South Korea). K-files were changed after five canals.

The teeth were then scanned under the same conditions as the initial scans. Data were stored on a magnetic optical disc.

Evaluation of canal transportation

To compare the degree of canal transportation, a technique developed by Gambill *et al.* (1996) was used. The amount of canal transportation was determined by measuring the shortest distance from the edge of

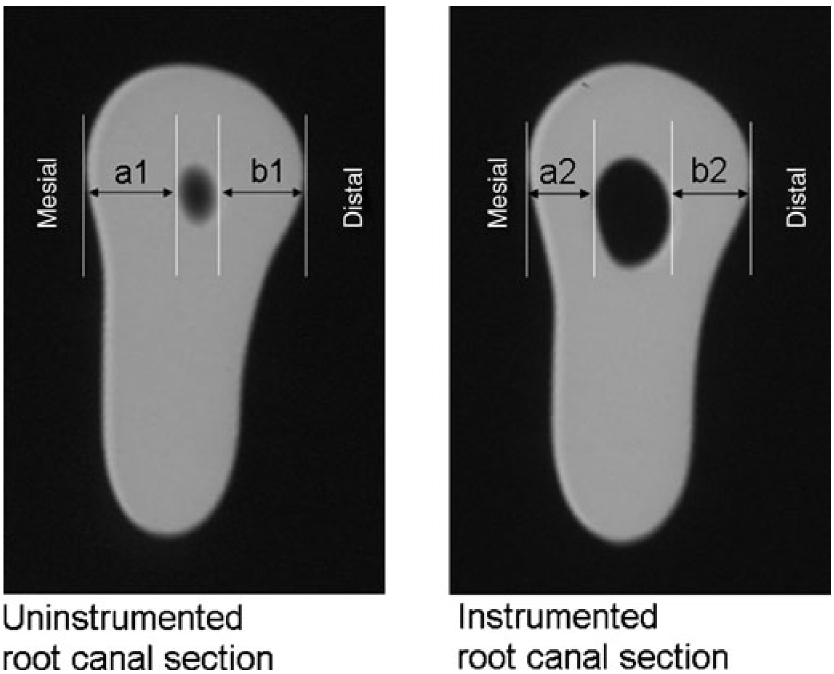

Figure 1 Comparison of same level CT images before and after the instrumentation.

uninstrumented canal to the periphery of the root (mesial and distal) and then comparing this with the same measurements obtained from the instrumented images (see Fig. 1). The following formula was used for the calculation of transportation:

$$|(a_1 - a_2) - (b_1 - b_2)|$$

where a_1 is the shortest distance from the mesial edge of the curved root to the mesial edge of the uninstrumented canal; b_1 is the shortest distance from distal (furcation) edge of the curved root to the distal edge of the uninstrumented canal; a_2 is the shortest distance from the mesial edge of the curved root to the mesial edge of the instrumented canal; b_2 is the shortest distance from distal (furcation) edge of the curved root to the distal edge of the instrumented canal.

According to this formula, a result of '0' indicates no canal transportation (Gambill *et al.* 1996). A result other than '0' means that transportation has occurred in the canal. The student's *t*-test was used for statistical analysis.

Evaluation of centreing ability

According to Gambill *et al.* (1996) 'The mean centreing ratio' indicates the ability of the instrument to stay centred in the canal. This ratio was calculated for each section using the following ratio:

$$(a_1 - a_2)/(b_1 - b_2)$$

or

$$(b_1 - b_2)/(a_1 - a_2)$$

If these numbers are not equal, the lower figure is considered as the numerator of the ratio. According to this formula, a result of '1' indicates perfect centreing (Gambill *et al.* 1996). The student's *t*-test was used for statistical analysis.

Results

Canal transportation

Seven canals instrumented with Hero 642 were transported toward the outside of the curve (mesial) and three canals were transported toward the inside of the curve (distal) on the apical 3 mm sections. Mean transportation in this group was 0.13 ± 0.09 mm (Table 1). In the group instrumented with K-files, all canals were transported toward the outside of the curve and mean transportation was 0.24 ± 0.14 mm. There was no significant difference between the groups for canal transportation ($P > 0.05$).

Table 1 Mean transportation ($\bar{X}$ ± SD) mm

	Level of section			
Group	*n*	Apical	Mid-root	Coronal
Hero 642	10	0.13 ± 0.09	0.10 ± 0.05	0.08 ± 0.07
K-file	10	0.24 ± 0.14	0.21 ± 0.13	0.33 ± 0.10
		$P > 0.05$	$P < 0.05$	$P < 0.001$

In the mid-root sections; five canals were transported toward the outside of the curve and five canals were transported toward the inside of the curve with the Hero 642 system; mean transportation was 0.10 ± 0.05 mm. In the K-file group, eight canals were transported toward the inside of the curve and two canals were transported toward the outside of the curve; mean transportation was 0.21 ± 0.13 mm. The difference between these two groups was statistically significant ($P < 0.05$).

In the coronal 3 mm sections; four canals were transported toward the outside of the curve, six canals were transported toward the inside of the curve in the Hero 642 group; mean transportation was 0.08 ± 0.07 mm. In the K-file group, all canals were transported toward the inside of the curve and mean transportation was 0.33 ± 0.10 mm. The difference between two groups was statistically significant ($P < 0.001$).

Centreing ratio

The best centreing ratio was determined in the coronal sections of Hero 642 group (0.80 ± 0.15) and the worst centreing ratio was determined in the coronal sections of the K-file group (0.34 ± 0.12) (Table 2). The difference between these two groups was statistically significant ($P < 0.001$).

In the mid-root sections; the mean centreing ratio was 0.70 ± 0.14 in the Hero 642 group and centreing ratio 0.46 ± 0.23 in the K-file group. In the apical 3 mm sections, the mean centreing ratio was 0.70 ± 0.17 for the Hero 642 group and

Table 2 Mean centreing ratio ($\bar{X}$ ± SD)

	Level of section			
Group	*n*	Apical	Mid-root	Coronal
Hero 642	10	0.70 ± 0.17	0.70 ± 0.14	0.80 ± 0.15
K-file	10	0.46 ± 0.23	0.46 ± 0.23	0.34 ± 0.12
		$P < 0.05$	$P < 0.05$	$P < 0.001$

0.46 ± 0.23 for the K-file group. The difference between groups in both apical and mid-root sections was statistically significant ($P < 0.05$).

Discussion

One of the main objectives of root canal preparation is to develop a shape that tapers from apical to coronal maintaining the original canal shape and whilst ensuring the smallest diameter is at the apical end-point (European Society of Endodontology 1994, Thompson & Dummer 2000b). A number of procedural errors can occur when shaping narrow and curved canals. These are canal transportation, apical zip, elbow, danger zones, ledge formation, perforations, file separation and canal blockage (Abou-Rass *et al.* 1980, Hülsmann & Stryga 1993, Gutmann *et al.* 1997).

A number of devices and preparation techniques have been developed to make root canal preparation easier and more efficient. The aim of this study was to compare the efficacy of Hero 642 rotary Ni–Ti instruments with K-files. The K-files were used with reaming motion which has been shown to be efficient and cause less transportation than filing (Wildey *et al.* 1992).

Two experimental methods have been used in studies that investigated Ni–Ti rotary instruments. Preparations were completed either in extracted human teeth or simulated canals in clear resin blocks. Simulated root canals provide standardization for root canal diameter, length and curve angle. This method enables the observation of the preparation in three dimensions in whole canal length. On the other hand, the resin may not represent clinical conditions because of its round shape and resin content that reflects neither dentinal structure nor its rigidity (Bertrand *et al.* 2001). Moreover, the heat developed by the rotary instruments through friction may cause the resin to melt (Rhodes *et al.* 1999).

Gani & Visvisian (1999), reported that in the sections taken from maxillary first molar teeth in mesiobuccal canals, the flat shapes predominated over the oval, and the round shapes were scarce. They also reported that the characteristics of mesiobuccal canals allow for clinical instrumentation, with techniques designed for curved canals. Because of this, mesiobuccal canals of extracted maxillary first molars were used in the study. Second mesiobuccal canals were not included because they were not suitable since they did not continue as separate canals along the root and had extreme anatomic variations.

To investigate the efficiency of instruments and techniques developed for root canal preparation, a number of methods have been used to compare canal shape before and after preparation. One of these methods is radiography. Its advantage is that no physical intervention is required, however, it only provides a two-dimensional image and a cross-section of the root canal is impossible to observe (Dowker *et al.* 1997). The 'Serial Sectioning Technique' was introduced by Bramante *et al.* (1987) and is a commonly used method. In this technique, the teeth are mounted in resin blocks, sectioned from apical to coronal and then photographed. The photographs of original and shaped canal sections are subsequently compared. This technique allows comparison between instrumented and uninstrumented canals but a complicated set-up is required and physical sectioning of the teeth before preparation can result in unknown tissue changes and loss of material (Gambill *et al.* 1996). CT imaging techniques have been evaluated as noninvasive methods for the analysis of canal geometry and efficiency of shaping techniques (Gambill *et al.* 1996, Rhodes *et al.* 2000, Bergmans *et al.* 2001, Garip & Günday 2001, Gluskin *et al.* 2001, Peters *et al.* 2001b). With this technique, it is possible to compare the anatomic structure of root canal before and after instrumentation.

Various studies have investigated rotary root canal preparations and they have shown that rotary Ni–Ti instruments maintained the original canal shape even in extremely curved canals (Glosson *et al.* 1995, Short *et al.* 1997, Bryant *et al.* 1998, Jardine & Gulabivala 2000, Park 2001, Versümer *et al.* 2002, Hülsmann *et al.* 2003). In the present study, canals shaped by Hero 642 instruments transported less at all levels. In the apical third, canals shaped by Hero 642 instruments usually transported toward the outside of the curve, in the middle third towards both sides of the curve and in the coronal third the canals were transported toward the inside of the curve. On the other hand, in the K-file group root canals were transported toward the outside of the curve in the apical third whilst in the middle and coronal third they were transported towards the inside of the curve. Transportation in the middle and coronal thirds was significantly greater than in the Hero 642 group.

In previous studies, it was shown that stainless steel files removed excessive material from the outer wall at the end of the curve and from the inner wall at the beginning of the curve (Al-Omari *et al.* 1992, Backman *et al.* 1992). The present results are consistent with the other studies which compared Hero 642 instruments with stainless steel files. Schäfer (2001), reported that in both 28° and 35° curved canals, the preparations completed using Hero 642 rotary instruments provided better canal geometry, formed less canal transportation and straightening and WL was maintained better. Bertrand *et al.* (2001) compared Gates Glidden drills and hand files with Hero 642 instruments and reported that the latter maintained the original canal shape better. Thompson & Dummer (2000a) reported that Hero 642 instruments shaped artificial canals without blockage and with minimal WL changes but taper was generally poor. This was the result of the limited penetration depth of 4 and 6% tip angled instruments. Thompson & Dummer (2000b) also reported that 40° curved artificial canals were enlarged more than 20° curved canals because in the more curved canals, more material were removed from the outer side.

In the present study, Hero 642 instruments were better than stainless steel K-files when centreing ratio was compared and the difference was significant in all regions but especially in the coronal third. The reason of this might be the use of Gates Glidden drills at the coronal portion of the canals in the hand technique. The flexibility of Ni–Ti instruments is able to explain their better centreing ability. A number of studies have shown that centreing ratio of rotary Ni–Ti instruments were better than stainless steel files (Zmener & Benegas 1996, Short *et al.* 1997, Portenier *et al.* 1998, Schäfer & Lohmann 2002, Schäfer & Florek 2003).

In studies that compared various rotary Ni–Ti systems, Hero 642 instruments have produced successful results. Schäfer & Fritzenschaft (1999) have shaped simulated canals in resin blocks with Hero 642 and ProFile 0.04/0.06 system with a very small deviation from original canal shape. Hero 642 instruments also had better centreing ratio.

Hülsmann *et al.* (2001) compared Hero 642 and Quantec SC systems and found that Hero 642 system straightened the canal curve less; possibly as a result of the rounded tips of Hero 642 instruments.

Conclusions

Hero 642 rotary instruments maintained the original canal shape better than stainless steel files. They also produced a better centreing ratio.

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