
The use of computed tomography when comparing nickel–titanium and stainless steel files during preparation of simulated curved canals

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Abstract

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Aim The aim of this study was to compare canal preparations completed with Hedstrom and K-files of ISO size 15–40, made of nickel–titanium (Ni–Ti) and stainless steel (SS).

Methodology Eighty simulated canals with 20° and 30° curvatures were prepared using the step-back technique and quarter turn/pull instrument manipulation. Middle and apical level canal sections were taken using computed tomography.

Results No significant difference was found between any of the file types at either level with respect to canal curvature (20° or 30°). At the middle level, the stainless steel files caused more enlargement toward the inner part, compared to nickel–titanium files. At the apical

level, nickel–titanium canal files caused more enlargement toward the inner part, whereas more outward enlargement was caused by stainless steel instruments. No significant difference could be observed at the middle level ($P > 0.05$) related to the enlargement toward the outer side of the canal curvature.

Transportation at both levels was significantly less ($P < 0.001$) for the Ni–Ti files than the SS ones. Centring ratios of the file types at the middle level were low, but not significantly different ($P > 0.05$), whereas at the apical level the centring ratios were significantly higher for the Ni–Ti files ($P < 0.001$).

Conclusions Ni–Ti instruments produced preparations with adequate enlargement, less transportation, and a better centring ratio.

Keywords: CT, curved canal, endodontics, Ni–Ti files, simulated canals.

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Introduction

The ideal prepared root canal should have a progressively tapering conical shape which preserves the apical foramen and the original canal curvature without transportation (Schilder 1974).

Canal anatomy varies greatly (Willey *et al.* 1992), and root canals have been reported to have curves beginning at almost any level. Even canals that are apparently straight may have curvature and irregularities in the apical one-third (Skidmore *et al.* 1971). When treating cases with curved root canals, the shaping process may

result in various defects, such as ‘ledges’, ‘zips’, and ‘elbows’; apical foramen and canal transportation, straightening of the root canal, ‘strip’ perforations on the canal wall, and perforations at the apical and furcation regions (Schilder 1974, Abou-Rass *et al.* 1980). Obstruction of the apical foramen with dentine debris, and deformation of instruments are other problems encountered during root canal preparation.

Civjan *et al.* (1975) were some of the first to suggest the use of Ni–Ti alloys for endodontic therapy. Since then Ni–Ti instruments have been used extensively as an alternative to stainless steel. Apart from its superior bio-compatibility and corrosion resistance compared to other alloys, it is also super-elastic (Stoeckel & Yu 1991, Serene *et al.* 1995).

Ni–Ti instruments are superior in maintaining the original canal anatomy and reducing the risk of transportation and perforation. It has been reported that

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preparations made using Ni–Ti instruments require less force and at least 20% less preparation time (Serene *et al.* 1995). Numerous studies on Ni–Ti files have examined their efficacy for preparing curved root canals (Glosson *et al.* 1995, Gambill *et al.* 1996, Thompson & Dummer 1998, Elliot *et al.* 1998).

In this study, computed tomography was used to compare the efficacy of nickel–titanium and stainless steel files in curved simulated resin canals.

Materials and methods

Eighty transparent simulated resin canals (Frasaco, Franz Sachs & Co. GmbH, Tettang, Germany) were used. Half of them (40) had canal curvatures of 20° (group 1), whereas the other group had 30° curvatures (group 2). All canals were 18 mm long, consisting of a 12-mm long straight coronal region, and a 6-mm long curved apical region. Each group was again divided into four subgroups of 10 blocks each: Nitiflex K-Files (Dentsply Maillefer, Ballaigues, Switzerland), Ni–Ti Hedstrom files (Brasseler, Savannah, GA, USA), Stainless steel (SS) K-Flexofiles (Dentsply Maillefer, Ballaigues, Switzerland) and Stainless Steel Hedstrom files (Brasseler, Savannah, GA, USA).

Preparation technique

All root canals were prepared using the step-back preparation method (Glosson *et al.* 1995, Gambill *et al.* 1996) with a quarter turn/pull technique with files ranging from size 15 to size 40. Each file was inserted passively into the canals without being rotated, and when the instrument touched a solid surface, it was turned a quarter revolution in a clockwise direction. In all groups the apical preparation was performed using instruments of sizes between 15 and 30. The subsequent step-back preparation involved 1 mm steps with files 35 and 40. The files were used only once and no irrigation solution was used. Before the preparation with stainless steel files, all instruments were manually adapted to the canal curve with small sponges (Weine *et al.* 1970, 1975, Harris 1976), whereas Ni–Ti files were used without precurving.

Imaging system

Images of all the simulated canals were obtained before and after preparation, using computed tomography (Sytec Sry General Electric, Yoko-gava, Japan).

The sections were 3 mm thick, with a field of view (FOV) of 200 mm. The matrix resolution of the CT imag-

ing system was 512 × 512 Pixel. The image in unit area is defined as FOV divided by the matrix (= 200/512). In order to find out the Volume Element (Voxel) of the CT scan, the Pixel value is multiplied with section thickness, which in our study corresponded to 200/512 (Pixel) × 3 (thickness) = Voxel = 1.17.

Simulated canals in groups of 10 were placed in special plastic moulds and then scanned with CT. In order to obtain a sharp image, a contrast medium (Urografin, Schering AG, Berlin, Germany) was injected into the canals using a syringe and distributed throughout the canal with a size 15 file before preparation and size 30 after preparation, in order to ensure the material reached all sections of the canal. All canals were orientated in the same direction. The canals were scanned perpendicular to their long axis using the bone algorithm and edge staining methods at two levels, 1.5 (apical) and 6 mm (middle) from the apex, which are the regions where most preparation defects are observed. The measurements were performed on both the pre- and postpreparation scan displays, under 10× magnification, separately for the inner and outer surface of the root canal (Fig. 1).

Criteria used for evaluation of this study

Measurements for each canal were evaluated according to the following criteria (see Fig. 1):

Width, where enlargement to the inner aspect of the curve was Rpreop minus Rpostop and that to the outer Lpreop minus Lpostop.

Transportation, the absolute value of the difference between the enlargement to the inner and outer, i.e. (Rpreop minus Rpostop) – (Lpreop minus Lpostop) (Gambill *et al.* 1996).

Centring ratio, i.e.
 $(R_{preop} - R_{postop}) / (L_{preop} - L_{postop})$
 for [inner (R) enlargement] < [outer (L) enlargement]
 OR
 $(L_{preop} - L_{postop}) / (R_{preop} - R_{postop})$
 for [inner enlargement] > [outer enlargement].

According to this formula, a centring ratio of 1 denotes optimal centring (Gambill *et al.* 1996).

Student's *t* tests and Mann–Whitney *U*-tests were performed to compare the apical and middle level measurements between curvature groups (groups 1 and 2) for each file group. Variance analysis (ANOVA) and Tukey – HSD, as well as the non-parametric Kruskal–Wallis test, were performed to compare between files at the same measurement point within curvature groups. SPSS 5.0 for Windows (SPSS Inc., Chicago, IL, USA) was used.

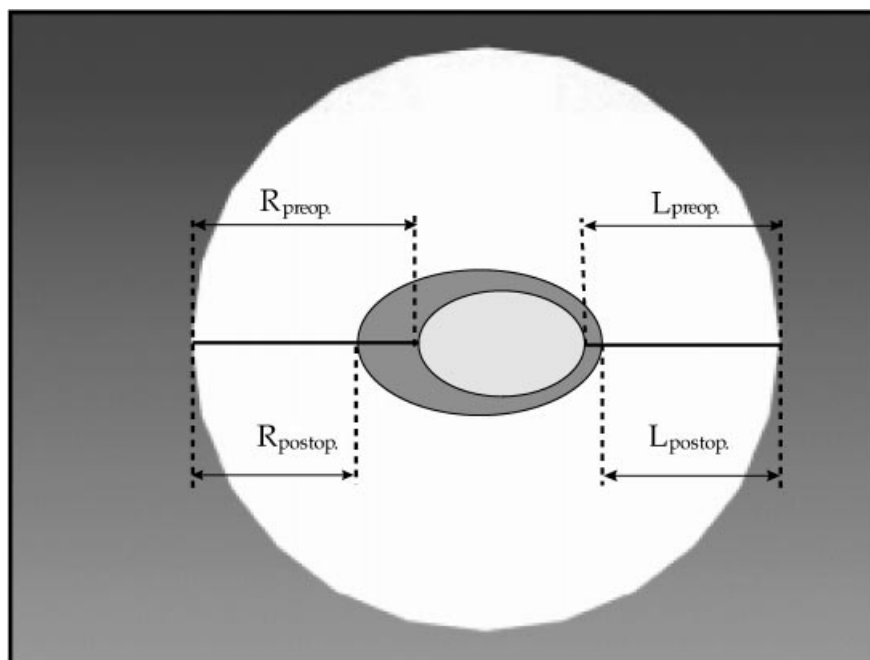


Figure 1 Measurement for image cross section.

Table 1 Mean enlargement (mm \pm SD) toward the inner side of the curvature, for canal curvatures of 20° and 30°

	Middle level (6 mm from apex)			Apical level (1.5 mm from apex)		
	20°	30°	<i>P</i> -value*	20°	30°	<i>P</i> -value*
Nitiflex K-File	0.20 \pm 0.04	0.20 \pm 0.04	<i>P</i> > 0.05	0.10 \pm 0.00	0.11 \pm 0.03	<i>P</i> > 0.05
Ni-Ti Hedstrom	0.18 \pm 0.06	0.23 \pm 0.10	<i>P</i> > 0.05	0.14 \pm 0.05	0.16 \pm 0.08	<i>P</i> > 0.05
SS K-Flexofile	0.34 \pm 0.08	0.37 \pm 0.06	<i>P</i> > 0.05	0.05 \pm 0.05	0.06 \pm 0.05	<i>P</i> > 0.05
SS Hedstrom	0.34 \pm 0.09	0.40 \pm 0.08	<i>P</i> > 0.05	0.03 \pm 0.04	0.10 \pm 0.14	<i>P</i> > 0.05
<i>P</i> -value**	<i>P</i> < 0.001	<i>P</i> < 0.05		<i>P</i> < 0.01	<i>P</i> > 0.05	

*Comparison of angles, for same canal instruments at same level.

**Comparison of canal instruments at same level and same angle.

Results

No significant differences ($P > 0.05$) in any of the canal preparation criteria, were observed between the files, with respect to canal curvature (20° or 30°).

Enlargement

Inner

Middle This was greatest in 30° canals using the SS Hedstrom files (0.40 \pm 0.08 mm), and least in 20° canals at the apical level with SS Hedstrom files (0.03 \pm 0.04 mm) (Table 1). Middle level enlargement for both curvature groups was significantly greater ($P < 0.001$ for 20°,

$P < 0.05$ for 30°) for the stainless steel instruments, compared to Ni-Ti instruments.

Apical level enlargement for the 20° curvature group was significantly greater for the Ni-Ti canal instruments ($P < 0.01$).

Outer

Middle This was greatest at the apical level in the 20° canals for the SS Hedstrom instruments (0.55 \pm 0.13 mm) and least at the middle level in the 20° canals for the SS K-Flexofile instruments (Table 2). There was no outer enlargement at middle level in the 20° canals for the SS K-Flexofile instrument. There were no significant differences between file type groups at the middle level for either curvature.

Table 2 Mean enlargement (mm \pm SD) toward the outer side of the curvature for canal curvatures of 20° and 30°

	Middle level (6 mm from apex)			Apical level (1.5 mm from apex)		
	20°	30°	<i>P</i> -value*	20°	30°	<i>P</i> -value*
Nitiflex K-File	0.01 \pm 0.03	0.01 \pm 0.03	<i>P</i> > 0.05	0.19 \pm 0.03	0.19 \pm 0.03	<i>P</i> > 0.05
Ni-Ti Hedstrom	0.01 \pm 0.03	0.02 \pm 0.04	<i>P</i> > 0.05	0.21 \pm 0.08	0.23 \pm 0.08	<i>P</i> > 0.05
SS K-Flexofile	0.00 \pm 0.00	0.01 \pm 0.03	<i>P</i> > 0.05	0.44 \pm 0.07	0.44 \pm 0.05	<i>P</i> > 0.05
SS Hedstrom	0.03 \pm 0.06	0.01 \pm 0.03	<i>P</i> > 0.05	0.55 \pm 0.13	0.53 \pm 0.17	<i>P</i> > 0.05
<i>P</i> -value**	<i>P</i> > 0.05	<i>P</i> > 0.05		<i>P</i> < 0.001	<i>P</i> < 0.001	

*Comparison of angles, for same canal instruments at same level.

**Comparison of canal instruments at same level and same angle.

Table 3 Transportation (mm \pm SD) for canal curvatures of 20° and 30°

	Middle level (6 mm from apex)			Apical level (1.5 mm from apex)		
	20°	30°	<i>P</i> -value*	20°	30°	<i>P</i> -value*
Nitiflex K-File	0.19 \pm 0.05	0.19 \pm 0.05	<i>P</i> > 0.05	0.09 \pm 0.03	0.08 \pm 0.04	<i>P</i> > 0.05
Ni-Ti Hedstrom	0.17 \pm 0.08	0.21 \pm 0.09	<i>P</i> > 0.05	0.11 \pm 0.07	0.11 \pm 0.12	<i>P</i> > 0.05
SS K-Flexofile	0.34 \pm 0.08	0.36 \pm 0.07	<i>P</i> > 0.05	0.39 \pm 0.11	0.38 \pm 0.07	<i>P</i> > 0.05
SS Hedstrom	0.31 \pm 0.12	0.39 \pm 0.08	<i>P</i> > 0.05	0.52 \pm 0.13	0.45 \pm 0.23	<i>P</i> > 0.05
<i>P</i> -value**	<i>P</i> < 0.001	<i>P</i> < 0.001		<i>P</i> < 0.001	<i>P</i> < 0.001	

*Comparison of angles, for same canal instruments at same level.

**Comparison of canal instruments at same level and same angle.

Table 4 Mean centring ratios (\pm SD) for canal curvatures of 20° and 30°

	Middle level (6 mm from apex)			Apical level (1.5 mm from apex)		
	20°	30°	<i>P</i> -value*	20°	30°	<i>P</i> -value*
Nitiflex K-File	0.05 \pm 0.15	0.05 \pm 0.15	<i>P</i> > 0.05	0.55 \pm 0.15	0.60 \pm 0.21	<i>P</i> > 0.05
Ni-Ti Hedstrom	0.10 \pm 0.31	0.08 \pm 0.16	<i>P</i> > 0.05	0.54 \pm 0.18	0.63 \pm 0.36	<i>P</i> > 0.05
SS K-Flexofile	0.00 \pm 0.00	0.03 \pm 0.07	<i>P</i> > 0.05	0.13 \pm 0.13	0.14 \pm 0.12	<i>P</i> > 0.05
SS Hedstrom	0.10 \pm 0.22	0.02 \pm 0.07	<i>P</i> > 0.05	0.05 \pm 0.08	0.20 \pm 0.29	<i>P</i> > 0.05
<i>P</i> -value**	<i>P</i> > 0.05	<i>P</i> > 0.05		<i>P</i> < 0.001	<i>P</i> < 0.001	

*Comparison of angles, for same canal instruments at same level.

**Comparison of canal instruments at same level and same angle.

Apical At the apical level, enlargement with SS files was significantly greater than that for the Ni-Ti files. In the 20° canals, apical enlargement for the SS Hedstrom group was significantly higher than that for the SS K-Flexofiles (*P* < 0.001).

Transportation

This was greatest at the apical level in the 20° canals for the SS Hedstrom instruments (0.52 \pm 0.13 mm) and least at the apical level in the 30° canals for the Nitiflex K-File instruments (0.08 \pm 0.13 mm) (Table 3). Transportation at both middle and apical levels for both angles was significantly higher for the SS files than the Ni-Ti files (*P* < 0.001). At the middle level, transportation was

toward the inner side of the curvature and at the apical level toward the outer side of the curvature, for all file groups.

Centring ratio

The best centring ratio was obtained at the apical level for the 30° canals for the Ni-Ti Hedstrom instruments (0.63 \pm 0.36) and worst at the middle level in the 20° canals for the SS K-Flexofile instruments (0.00 \pm 0.00) (Table 4).

Middle There were no significant differences between file type groups for either angle at the middle level.

Apical At the apical level the centring ratio was significantly higher for the Ni-Ti canal instruments (*P* < 0.001).

A total of four perforations (5%) occurred with SS K-Flexofile canal instrument preparations, which were determined visually.

Discussion

One of the most important stages of root canal treatment is the bio-mechanical preparation of the root canals. During the shaping process of curved canals, the original canal curvature should be preserved, especially at the apex and inner side of the root curvature; straightening that might interfere with canal integrity has to be prevented (Schilder 1974, Abou-Rass *et al.* 1980).

The reason for choosing simulated resin canals for this study was that canal length, curvature, and shape could be standardized. Furthermore, dentine hardness varies greatly in natural teeth (Lim & Webber 1985, Dummer *et al.* 1991, Coleman & Svec 1997). Computed tomography is a relatively new technique in the field of endodontics. Tachibana & Matsumoto (1990) first evaluated its use for scanning canal preparations. Gambill *et al.* (1996) examined preparations performed with Ni-Ti and stainless steel hand instruments on extracted teeth, using computed tomography. This CT method was chosen, as it simulated the Bramante technique (Bramante *et al.* 1987) without actually cutting the sample.

The contrast medium injected into the canal clearly outlined the canal cavity on the monitor where the measurements were performed, as well as on the film print-outs which were developed later. Initial test scans, however, showed that this material did not penetrate to the apex of the canal in all samples, resulting in distortion of the apical CT scans. Leaving the instrument *in situ*, in order to ensure diffusion of the contrast medium into this region, reduced this distortion problem, although it did not eliminate it completely. Gambill *et al.* (1996) encountered the same problem in their study.

As in the studies of Briseño & Sonnabend (1991), Schäfer & Tepel (1993), Coleman *et al.* (1996) and Coleman & Svec (1997), no irrigation solution was used. Briseño & Sonnabend (1991) did not use any irrigation solutions in their preparations performed on simulated resin canals with nine types of instruments; they found that regular cleaning of files led to a small amount of debris within the root canals.

This study found that stainless steel instruments led to more inner enlargement at the middle level (curved region), than did nickel-titanium files. This demonstrates that nickel-titanium instruments decrease the risk of strip perforations and danger zones in curved root canals. At the apical level, the nickel-titanium canal

instruments caused more enlargement toward the inner side of the curve than stainless steel files. This result supports the hypothesis that superelastic instruments follow the canal curvature (Serene *et al.* 1995). Elliot *et al.* (1998) had used Balanced Force technique at the apical region and reported similar results.

Stainless steel instruments caused more transportation at the middle level than did nickel-titanium files. The fact that the direction of transportation at the curve was inwards in all groups, was again indicative of the tendency of instruments to straighten in curved canals (Willey *et al.* 1992). Glosson *et al.* (1995) and Thompson & Dummer (1997) reported that some nickel-titanium instruments also have a tendency to straighten.

Stainless steel files created more transportation at the apical level, indicating that Ni-Ti canal instruments may lead to less zipping or apical perforation defects (Serene *et al.* 1995). This finding is consistent with several other studies (Glosson *et al.* 1995, Gambill *et al.* 1996, Coleman *et al.* 1996, Coleman & Svec 1997).

The finding that middle level centring ratios for all groups were much less than 1 and that there was no significant difference between any of them indicates that even the higher flexibility of the nickel-titanium canal instruments had no profound effect on centring. Glosson *et al.* (1995) reported that Mity files (Ni-Ti) caused less transportation than K-flex (SS) files, at the middle level of the roots; they also reported that the higher flexibility of the nickel-titanium instruments did not improve the centring ratio. Similarly, Gambill *et al.* (1996) reported no significant difference in centring ratio between the Ni-Ti and SS files at the middle level when using the quarter turn/pull technique. They did, however, report significantly better middle level centring ratios for Ni-Ti when using a reaming technique.

Our findings related to better apical centring ratios for Ni-Ti files are consistent with the results obtained by Coleman *et al.* (1996) and Coleman & Svec (1997) and Carvalho *et al.* (1999), whilst they differ from those of Glosson *et al.* (1995), who found out that Ni-Ti Mity files did not significantly increase the centring ratio of the canal.

References

- Abou-Rass M, Frank AL, Glick DH (1980) The anticurvature filing method to prepare the curved root canal. *Journal of American Dental Association* **101**, 792-4.
- Bramante CM, Berbert A, Borges RP (1987) A methodology for evaluation of root canal instrumentation. *Journal of Endodontics* **13**, 243-5.

- Briseño BM, Sonnabend E (1991) The influence of different root canal instruments on root canal preparation: an *in vitro* study. *International Endodontic Journal* **24**, 15–23.
- Carvalho LAP, Bonetti Í, Borges MAG (1999) A comparison of molar root canal preparation using stainless-steel and nickel–titanium instruments. *Journal of Endodontics* **25**, 807–10.
- Civjan S, Huget EF, Desimon LB (1975) Potential applications of certain nickel–titanium (Nitinol) alloys. *Journal of Dental Research* **54**, 89–96.
- Coleman CL, Svec TA, Rieger MR, Suchina JA, Wang MM, Glickman GN (1996) Analysis of nickel–titanium versus stainless steel instrumentation by means of direct digital imaging. *Journal of Endodontics* **22**, 603–7.
- Coleman CL, Svec TA (1997) Analysis of Ni–Ti versus stainless steel instrumentation in resin simulated canals. *Journal of Endodontics* **23**, 232–5.
- Dummer PMH, Alodeh MHA, Al-Omari MAO (1991) A method for the construction of simulated canals in clear resin blocks. *International Endodontic Journal* **24**, 63–6.
- Elliott LM, Curtis RV, Pitt Ford TR (1998) Cutting pattern of nickel–titanium files using two preparation techniques. *Endodontics and Dental Traumatology* **14**, 10–15.
- Gambill JM, Alder M, del Rio CE (1996) Comparison of nickel–titanium and stainless steel hand-file instrumentation using computed tomography. *Journal of Endodontics* **22**, 369–75.
- Glosson CR, Haller RH, Dove SB, del Rio CE (1995) A comparison of root canal preparations using Ni–Ti hand, Ni–Ti engine-driven, and K-Flex endodontic instruments. *Journal of Endodontics* **21**, 146–51.
- Harris WE (1976) A simplified method of treatment for endodontic perforations. *Journal of Endodontics* **2**, 126–34.
- Lim KC, Webber J (1985) The validity of simulated root canals for the investigation of the prepared root canal shape. *International Endodontic Journal* **18**, 240–6.
- Schäfer E, Tepel J (1993) Formveränderungen gekrümmter Wurzelkanäle nach standardisierter Aufbereitung. *Deutsche Zahnärztliche Zeitschrift* **48**, 653–8.
- Schilder H (1974) Cleaning and shaping the root canal. *Dental Clinics of North America* **18**, 269–96.
- Serene TP, Adams JD, Saxena A (1995) *Nickel–Titanium Instruments: Applications in Endodontics*. St. Louis, MO, USA: Ishiyaku EuroAmerica, Inc., 1–110.
- Skidmore AE, Bjorndal AM, Iowa IC (1971) Root canal morphology of the human mandibular first molar. *Oral Surgery, Oral Medicine and Oral Pathology* **32**, 778–84.
- Stoeckel D, Yu W (1991) Superelastic Ni–Ti wire. *Wire Journal International* **3**, 45–50.
- Tachibana H, Matsumoto K (1990) Applicability of X-ray computerized tomography in endodontics. *Endodontics and Dental Traumatology* **6**, 16–20.
- Thompson SA, Dummer PMH (1997) Shaping ability of ProFile. 04 Taper Series 29 rotary nickel–titanium instruments in simulated root canals. Part 2. *International Endodontic Journal* **30**, 8–15.
- Thompson SA, Dummer PMH (1998) Shaping ability of Mity Roto 360° and Naviflex rotary nickel–titanium instruments in simulated root canals. Part 1. *Journal of Endodontics* **24**, 128–34.
- Weine FS, Healey HJ, Gerstein H, Evanson L (1970) Pre-curved files and incremental instrumentation for root canal enlargement. *Journal of the Canadian Dental Association* **4**, 155–7.
- Weine FS, Kelly RF, Lio PJ (1975) The effect of preparation procedures on original canal shape and on apical foramen shape. *Journal of Endodontics* **1**, 255–62.
- Willey WL, Senia ES, Montgomery S (1992) Another look at root canal instrumentation. *Oral Surgery, Oral Medicine and Oral Pathology* **74**, 499–507.