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Improved quality of root fillings provided by general dental practitioners educated in nickel–titanium rotary instrumentation

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Abstract

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Aim To test the hypothesis that an increased utilization of nickel–titanium rotary instrumentation (NTRI) by general dental practitioners will lead to an increased frequency of good quality root fillings. A second aim was to determine whether the educational format would exert influence on the quality.

Methodology Dentists were assigned at random to three intervention groups: a 4-h lecture (L-group, $n = 40$); a 4-h lecture plus a full day hands-on course (LH-group, $n = 40$); or a control group receiving no instruction ($n = 68$). The control group received education later on in the study. Radiographs of two root filled molar teeth per dentist were selected at random before the start of the education program and after a 6-month clinical learning period. Using length, seal and shape of root-fillings a 5-level variable was created.

Results The rate of good quality root fillings increased after the introduction of NTRI. Calculated over all types of roots the frequency of excellent (score 1) root fillings increased from 31% to 51% ($P = 0.006$) in the L-group and from 27% to 47% ($P = 0.016$) in the LH-group. The frequency of low quality root-fillings (score 5) dropped in the L-group from 22% to 16% ($P = 0.29$) and in the LH-group from 13% to 9% ($P = 0.48$). No statistically significant difference was seen among the controls.

Conclusions When NTRI technology replaced manual stainless steel techniques the rate of good quality root fillings increased. A significant drop in the rate of low quality root fillings was not found.

Keywords: education, general dentists, nickel–titanium rotary instrumentation, root canal preparation, technical quality.

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Introduction

Root fillings of substandard technical quality are prevalent findings in most population studies and are associated with a high rate of periapical inflammation (Kirkevang *et al.* 2001, Boucher *et al.* 2002, Lupi-Pegurier *et al.* 2002, Boltacz-Rzepkowska & Pawlicka 2003, Siqueira *et al.* 2005, Tsuneishi *et al.* 2005). Root canal procedures are technically demanding and it has been suggested that the replacement of stainless steel instruments with flexible files fabricated of nickel–titanium (NiTi) might facilitate canal preparation and result in an increased frequency of good quality root fillings. Several studies carried out in the laboratory have supported this hypothesis (Bishop & Dummer 1997, Kum *et al.* 2000, Rhodes *et al.* 2000, Thompson & Dummer 2000, Park 2001, Peters *et al.* 2001, Schäfer 2001, Schäfer & Florek 2003).

Observations made in the laboratory also suggest that technical quality may be further enhanced if NiTi rotary instrumentation (NTRI) is used instead of NiTi hand preparation. Baumann & Roth (1999) showed that inexperienced students as well as experienced

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dentists successfully used NTRI and achieved good root canal geometry after a 30-min introductory lecture. Gluskin *et al.* (2001) gave novice operators a 30-min tutorial and practical demonstration and found performance to be better in extracted molars when NTRI was used when compared with NiTi hand instruments. Similar results were reported by Sonntag *et al.* (2003) when dental students undertook canal preparation in simulated canals. Thus, a large number of laboratory studies indicate that patients would benefit if dentists changed from a conventional root canal preparation technique using stainless steel instruments to a technique based on NiTi technology and preferably NTRI. However, in the clinical situation factors not possible to reproduce in the laboratory will influence the quality of root canal treatment and therefore studies carried out in real-life situations are needed. To our knowledge, no such study of the impact of NTRI on quality of root fillings is available.

Reit *et al.* (2007) introduced NTRI to all general dentists employed at a Swedish Public Dental Health organization. After a compulsory educational programme, the overall utilization of NTRI increased from 4% to 73%. However, lectures in combination with hands-on training resulted in a better short-term acceptance rate (94%) compared with teaching given only in lecture format (53%). The aim of the present study, carried out among the same general dental practitioners, was to test the hypothesis that an increased utilization of NTRI will lead to an increased frequency of good quality root fillings. A second aim was to determine whether the educational format would influence the quality of root fillings.

Material and methods

Approval for the project was obtained from the Gothenburg Public Dental Health Service (DHS).

The dentists

The DHS organizes general dentistry at 25 clinics. All dentists employed at these clinics in April 2000 ($n = 148$) were enrolled in the study. The majority (67%) were women and the mean number of years in general practice was 19 (SD = 8) (Reit *et al.*, 2007). Most practitioners (63%) performed one to four root canal treatments per week, 15% less than one and 22% had five or more treatments per week. Root canal instrumentation was mainly carried out by means of stainless steel hand instruments of reamer (50%) or Hedström type (23%). NiTi hand instruments were used by 23% and NTRI by 4%. All dentists had graduated in Sweden and the majority had their undergraduate training in Gothenburg. The standard of equipment was similar among the clinics with only minor differences in the endodontic materials and medicaments used. The 25 clinics were randomized to one of two education programmes.

Education programmes

Lecture course (L-programme)

In a 4-h lecture root canal instrumentation and the concept of the NTRI technology was discussed by an experienced endodontist. The GT Rotary System (Dentsply Maillefer, Ballaigues, Switzerland) was presented in detail and canal preparation was demonstrated on video. Essentially, the technique included the use of GT instruments (corresponding to the current 20-series) for crown-down instrumentation of the root canal in combination with ProFile 0.04 instruments (Dentsply Maillefer) for apical stop preparation. The participants received handouts of slides shown during the course and a manual describing the recommended procedures. These were somewhat modified when compared with the manufacturers' instructions. Crown-down preparation was made with GT instruments having taper between 0.10 and 0.04. The objective was to use an 0.06 tapered instrument to the established working length. An apical stop up to size 40 was created with Profile 0.04 instruments. If a larger apical stop was required NiTi hand files were used. A contra-angle handpiece 128 : 1 (WD74M; W&H, Bürmoos, Austria) was suggested for the rotary instrumentation. Detailed information was given regarding where and how the instruments could be purchased and training simulated canals were sold on demand. The practitioners were urged to train on extracted teeth or resin blocks before they started to use the files clinically.

Hands-on training course (LH-programme)

All dentists in this group initially participated in the lecture course. In addition, they undertook a 6-h practical training course given by the same endodontist. Six or seven dentists at a time practised the GT Rotary System using simulated canals and extracted teeth.

Study design

The lay-out of the study is shown in Fig. 1. In April 2000, the clinics were randomized to either take part in one of the education programmes ('experimental' groups) or serve as a control. In May 2000, case samples were obtained. In each clinic a coordinator was appointed who randomly selected and coded radiographs of two root filled molars from the archives of every dentist. Cases with poorly processed radiographs were excluded.

In August 2000, dentists from the 13 clinics in the experimental group participated in the lecture course (Fig. 2). For six clinics, the lectures were combined with hands-on training. Following a 6-month clinical training period new case samples (as described above) were obtained. Only dentists submitting both pre- and post-education radiographs were included in the study.

From dentists working in the 12 control clinics a second set of case samples were obtained 6–7 months after the first one. Starting in January 2001 dentists in the control group were educated in NTRI technology. A division into the two education programmes was made and new cases were sampled after a 6-month clinical training period.

Assessment of root filling quality

Radiographs were scanned in a CanoScan 2700F (Canon Inc., Tokyo, Japan) using the Canon PI FS 3.6 software (Canon Inc.) and stored in PhotoShop (Adobe Systems Inc., Seattle, WA, USA) as JPEG images; the original radiographs were needed at the clinics for the continuation of treatment and follow up.

Four aspects of root filling quality were judged: apical distance, quality of seal, presence of taper and canal transportation. On the basis of these four factors, a quality score was constructed (Fig. 3).

Score 1: Correct length, adequate seal, tapered preparation, no transport.

Score 2: Correct length, adequate seal, lack of taper and/or transport.

Score 3: Incorrect length, adequate seal, (taper and transport not evaluated).

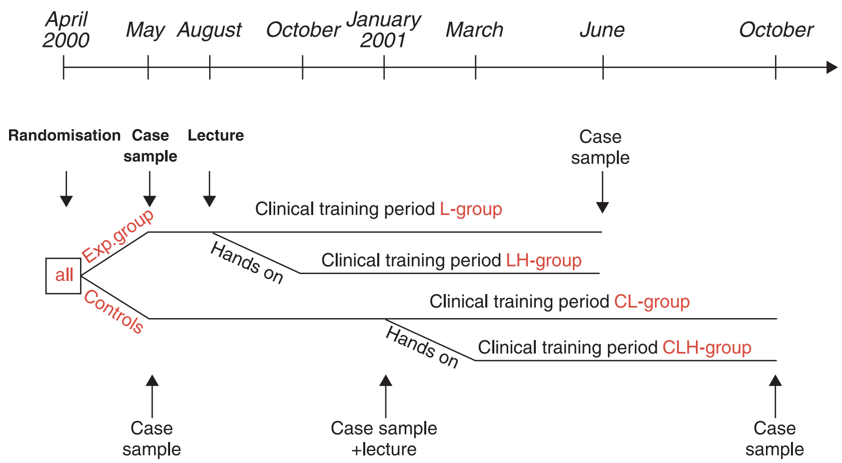

Figure 1 Experimental timetable and layout.

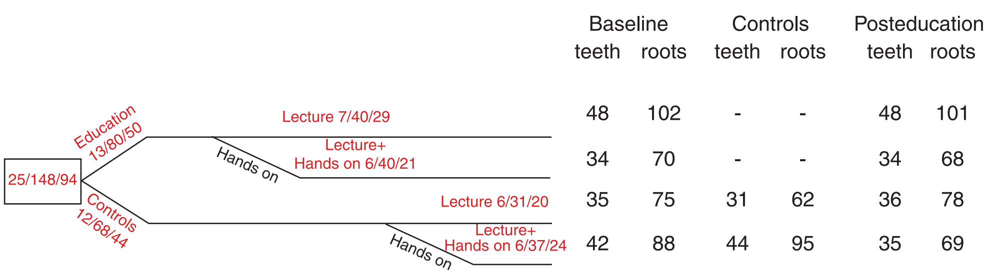

Figure 2 Number of clinics/enrolled dentists/dentists that submitted radiographs throughout the entire experiment. Given number of teeth and roots refer to the number that were submitted and analysed.

5-level quality score

	I	II	III	IV	V
Length	+	+	−	+	−
Seal	+	+	+	−	−
Taper	+	at least	not evaluated	not evaluated	not evaluated
Transportation	−	one defective	not evaluated	not evaluated	not evaluated

Figure 3 The five level quality score. Root was used as unit. In case of two canals per root poorest alternative was evaluated. Score 1: Correct length, good seal, tapered canal, no transportation. Score 2: Correct length, good seal, taper lacking and/or transportation. Score 3: Incorrect length, good seal (taper and transportation not evaluated). Score 4: Correct length, poor seal (taper and transportation not evaluated). Score 5: Incorrect length, poor seal (taper and transportation not evaluated).

Score 4: Correct length, defective seal, (taper and transport not evaluated).

Score 5: Incorrect length, defective seal, (taper and transport not evaluated).

Assessment criteria: The length of the root filling was evaluated as correct if it terminated within 2.5 mm short of the apex of the root. Cases with surplus of sealer material were judged as having correct length if the apical stop preparation was placed within the accepted distance from the apex. The quality of seal was assessed in the apical two-third of the canal. In the quality score, the ideal root canal preparation should be tapered (roughly corresponding to 0.06) and without signs of canal transportation (zipping or stripping). In roots with two canals only the highest score was used in the analyses.

Radiographs were not possible to identify by the observers and were presented in random order. Analyses were made simultaneously by two of the authors (AM & CR) at a 17-in computer screen. Brightness and contrast of the images could be manipulated. One year after the initial analysis 114 roots were re-analysed. The kappa value for intra-observer agreement was 0.66.

Statistics

All data were computerized and analysed using SAS software. Version 8.0 for Windows (Cary, NC, USA). Separate data sets were created to analyse root types separately (i.e. mesio-buccal, disto-buccal and palatal roots for maxillary molars; mesial and distal roots for mandibular molars) and paired *t*-tests were used to compare the percent of roots with score 1 or 5 at baseline and post-intervention within providers and root types.

Results

Cases from before and after education were available for analyses from 94 of the 148 dentists enrolled in the study (64%) (Fig. 2). Drop-outs were mostly practitioners who performed few root canal treatments and were not able to show any new molar cases within the study period. Other reasons were termination of employment ($n = 10$), parental leave ($n = 6$), long-time sick leave ($n = 4$) and long-time off duty ($n = 7$).

The main findings are displayed in Fig. 4 a-d. Generally, the rate of good quality root fillings increased after the introduction of NTRI. Calculated over all types of roots, the frequency of score 1 treatments increased from 31% to 51% ($P = 0.006$) in the L-group, from 27% to 47% ($P = 0.016$) in the LH-group and in the CL-group from 21% to 39% ($P = 0.026$) in the CL-group. The increase was most pronounced in curved canals as found in the mesiobuccal roots of maxillary molars and in the mesial root of mandibular molars (Fig. 4).

In the L-group the frequency of low quality root-fillings (score 5) dropped from 22% to 16% ($P = 0.29$) and in the LH-group from 13% to 9% ($P = 0.48$) (Fig. 4d). In all, 106 root fillings provided by 55 dentists (57%) were given a score of 5. Thirty of the practitioners submitted such root fillings only before education, 10 only after and 14 both before and after.

No statistically significant differences were seen among the controls. When the two educational programmes were compared, no statistical significance was found regarding effect on root filling quality.

For each group, a ratio was calculated between the number of good quality (score 1) and low quality (score 5) root-fillings (Table 1). The ratios increased after education in all groups except in the control group.

One separated instrument was observed in the pre-education radiographs and five in the post-education images. The latter corresponds to an incidence of 3.3% (tooth as unit) or 1.6% (root as unit).

Discussion

It was possible to retrieve cases treated before and after education from only 64% of the practitioners originally

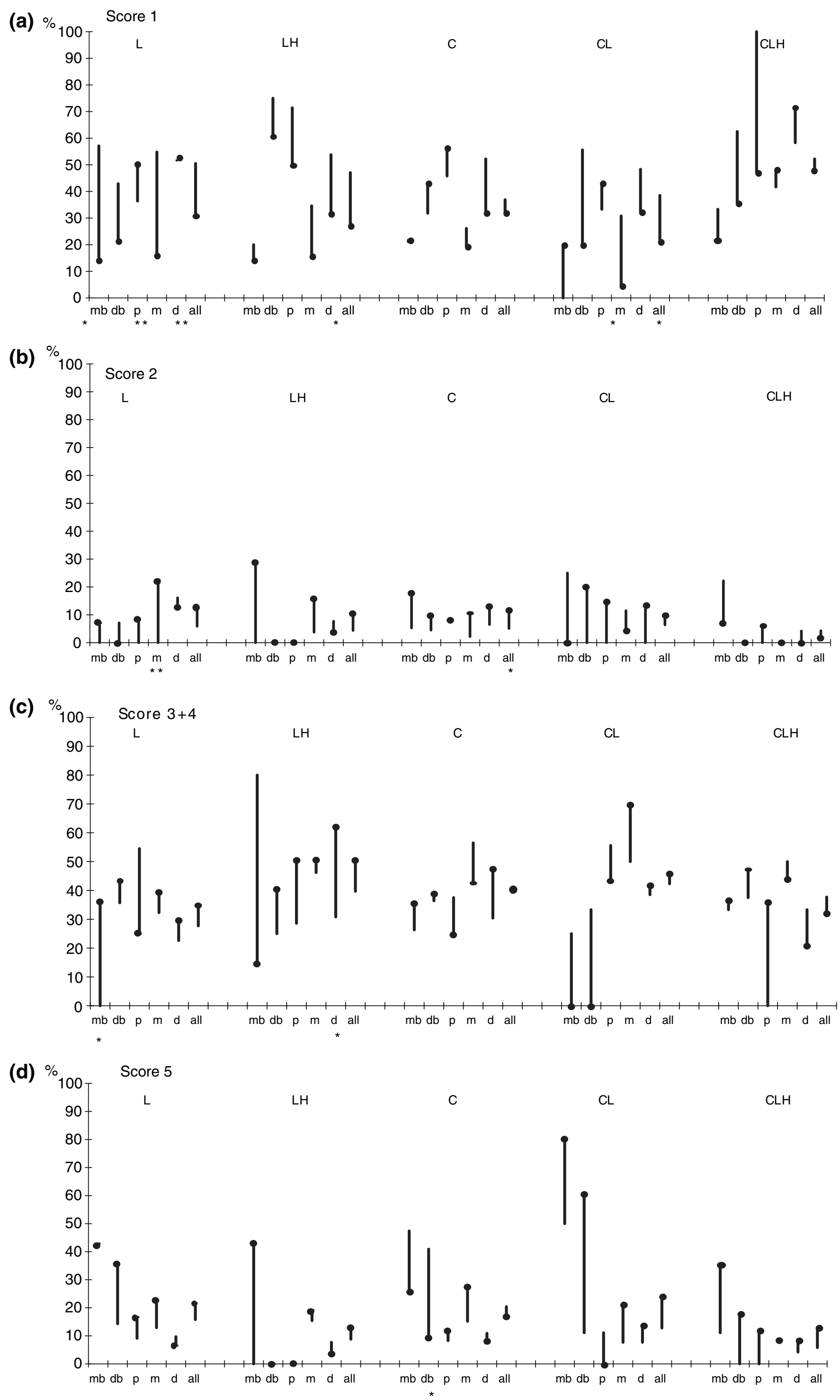

Figure 4 (a-d) Baseline and post-intervention frequency of quality scores per root for the experimental groups (mb, mesio buccal; db, disto buccal; *P*, palatal for upper molars; and m, mesial; d, distal for lower molars). (c) Scores 3 and 4 have been merged. The dot on each bar denotes the baseline frequency, whereas the opposite endpoint denotes the post-intervention frequency. *$P < 0.05$; and **$P < 0.01$.

Table 1 Ratios for quality scores 1 and 5 for each experimental group at baseline and post-intervention

Group	Baseline quality score 1/5 ratio	Post-intervention quality score 1/5 ratio
L	32/22 = 1.45	51/16 = 3.19
LH	19/9 = 2.11	32/6 = 5.33
C	52/28 = 1.86	58/32 = 1.81
CL	13/15 = 0.87	30/10 = 3.0
CLH	45/14 = 3.21	36/4 = 9.0

enrolled in the study. However, an analysis of the drop-out reasons gives no cause to think that the examined material was biased.

The material consisted of one radiograph of each tooth originally obtained as film and later scanned and analysed at a computer screen. Film quality was not always optimal and information might have been lost in the scanning procedure.

Images were assessed using the traditional criteria for root filling quality and included into a scoring system. Studies have shown the difficulty in reproducing and maintaining these criteria (Reit & Hollender 1983, Lambrianidis 1985, Eckerbom *et al.* 1986, Kersten *et al.* 1987). However, the intra observer kappa value in the present study was 0.66 which can be regarded as good agreement (Landis & Koch 1977).

Before the study most dentists used a technique based on stainless steel hand instruments. After education the use of NTRI increased from 4% to 73% (Reit *et al.*, 2007). However, with the protocol used it was not possible to determine the exact technique applied in the individual case, though, since only treatments in molar teeth were assessed a high usage rate of NTRI can be assumed.

Implementation of the education packages exerted influence on the quality of the dentist performance. The rate of good quality root-fillings increased and the rate of low quality root fillings decreased, the latter not to a statistically significant degree. It is important, however, to understand that the study not only brought about a technology shift, but also a general update in endodontology, discussions with colleagues and knowledge that cases later were to be sampled. Therefore, it is not possible to establish the precise influence of the adoption of the NTRI technique *per se*.

Before education flawless root fillings (score 1) were predominantly observed in rather straight roots such as the palatal of maxillary molars and the distal of mandibular molars. After education a significant increase of score 1 was found, as expected, mainly amongst the curved canals, in which the advantages of NTRI are most readily demonstrated.

In most roots the rate of low quality root fillings (score 5) decreased after education; however, the change was not statistically significant and could be due to chance. Thus, the education did not prevent dentists from substandard performance. The score 5 root fillings were spread amongst the dentists and not clustered around a few. Therefore, the production of unacceptable root fillings might be more a problem of attitude than a problem of skill. More research into this area of dentist behaviour is needed.

Reit *et al.* (2007) found that the educational format had an impact on the rate of NTRI adoption. A corresponding impact was not found when the effect on root filling quality was analysed. Thus, the much more resource demanding hands-on training course did influence people to take up the technology, but the technique *per se* was effectively learned by attending lectures and demonstrations.

The continuous cycle of tensile and compressive forces applied to NiTi files rotating in curved canals might result in instrument fracture (Pruett *et al.* 1997). Therefore, strict routines including a scheme for the prevention of instrument overuse and a continuous check-up for signs of plastic deformation were suggested (Saunders & Saunders 2003). Low-torque motors have been recommended (Gambarini 2000) to reduce the risk for fracture due to torsional load. In the present study dentists were advised to use each file not more than five times and to check for deformation. Motors with torque control were not used.

Five separated instruments left in the root canal were observed among the teeth treated after education. This corresponds to a 3.3% (tooth as unit) or 1.6% (root as unit) incidence. However, the radiographic characteristics of NiTi-files are similar to those of gutta-percha and cases may have been overlooked. This observation is consistent with that of Crump & Natkin (1970) who, in a study on stainless steel instruments, reported an incidence of 2.1% (tooth as unit). Ramirez-Salomon *et al.* (1997) found irretrievable fragments of Lightspeed instruments in 3.7% of investigated canals. In a study of endodontic specialists using NTRI as the primary technique for root canal preparation 4.4% of the teeth had retained fractured rotary NiTi files (Spili *et al.* 2005).

In conclusion, data from the present study supported the proposed hypothesis that if NTRI technology replaces the manual stainless steel technique the rate of good quality root fillings will increase. A significant drop in the rate of low quality root fillings was not found.

References

Baumann MA, Roth A (1999). Effect of experience on quality of canal preparation with rotary nickel–titanium files. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontics* **88**, 714–8.

Bishop K, Dummer PMH (1997) A comparison of stainless steel Flexofiles and nickel–titanium Ni–Ti flex files during the shaping of simulated canals. *International Endodontic Journal* **30**, 25–34.

Boltacz-Rzepkowska E, Pawlicka H (2003) Radiographic features and outcome of root canal treatment carried out in the Lodz region of Poland. *International Endodontic Journal* **36**, 27–32.

Boucher Y, Matossian L, Rilliard F, Machtou P (2002) Radiographic evaluation of the prevalence and technical quality of root canal treatment in a French subpopulation. *International Endodontic Journal* **35**, 229–38.

Crump MC, Natkin E (1970) Relationship of broken instruments to endodontic case prognosis: a clinical investigation. *Journal of American Dental Association* **80**, 1341–7.

Eckerbom M, Andersson J-E, Magnusson T (1986) Inter-observer variation in radiographic examination of endodontic variables. *Endodontics and Dental Traumatology* **2**, 243–6.

Gambarini G (2000) Rationale for the use of low-torque endodontic motors in root canal instrumentation. *Endodontics and Dental Traumatology* **16**, 95–100.

Gluskin AH, Brown DC, Buchanan LS (2001). A reconstructed coputerized tomographic comparison of Ni–Ti rotary GT files versus traditional instruments in canals shaped by novice operators. *International Endodontic Journal* **34**, 476–84.

Kersten HW, Wesselink PR, Thoden van Velzen SK (1987) The diagnostic reliability of the buccal radiograph after root canal filling. *International Endodontic Journal* **20**, 20–4.

Kirkevang L-L, Hörsted-Bindslev P, Ørstavik D, Wenzel A (2001) A comparison of the quality of root canal treatment in two Danish subpopulations examined 1974–1975 and 1997–1998. *International Endodontic Journal* **34**, 607–12.

Kum K-Y, Spångberg L, Cha BY, Il-Young J, Seung-Jong L, Chan-Young L (2000) Shaping ability of three Profile rotary instrumentation techniques in simulated resion root canals. *Journal of Endodontics* **26**, 719–23.

Lambrianidis T (1985) Observer variation in radiographic evaluation of endodontic therapy. *Endodontics and Dental Traumatology* **1**, 235–41.

Landis JR, Koch GG (1977) The measurement of observer agreement for categorical data. *Biometrics* **33**, 159–74.

Lupi-Pegurier L, Bertrand M-F, Muller-Bolla M, Rocca JP, Bolla M (2002) Perapical status, prevalence and quality of endodontic treatment in an adult French population. *International Endodontic Journal* **35**, 690–7.

Park H (2001) A comparison of greater taper files, Profiles, and stainless steel files to shape curved root canals. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontics* **91**, 715–8.

Peters OA, Schönenberger K, Laib A (2001) Effects of four Ni–Ti preparation techniques on root canal geometry assessed by microcomputed tomography. *International Endodontic Journal* **34**, 221–30.

Pruett JP, Clemet DJ, Carnes DL (1997) Cyclic fatigue testing of nickel–titanium endodontic instruments. *Journal of Endodontics* **23**, 77–85.

Ramirez-Salomon M, Soler-Bientz R, de la Garza-Gonzalez R, Palacios-Garza CM (1997) Incidence of lightspeed separation and the potential for bypassing. *Journal of Endodontics* **23**, 586–7.

Reit C, Hollender L (1983) Radiographic evaluation of endodontic therapy and the influence of observer variation. *Scandinavian Journal of Dental Research* **91**, 205–12.

Reit C, Bergenholtz G, Caplan D, Molander A (2007) The effect of educational intervention on the adoption of nickel-titanium rotary instrumentation in a Public Dental Serivce. *International Endodontic Journal* **40**, in press.

Rhodes JS, Pitt Ford TR, Lynch JA, Liepins PJ, Curtis RV (2000) A comparison of two nickel-titanium instrumentation techniques in teeth using microcomputed tomography. *International Endodontic Journal* **33**, 279–85.

Saunders WP, Saunders EM (2003) Root canal instrumentation. In: Bergenholtz G, Horsted-Bindslev P, Reit C, eds. *Textbook of Endodontology*. Oxford, UK: Blackwell Munskgaard, pp. 236–60.

Schäfer E (2001) Shaping ability of HERO 642 rotary nickel-titanium instruments and stainless steel hand K-Flexofiles in simulated curved root canals. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontics* **92**, 215–20.

Schäfer E, Florek H (2003) Efficiency of rotary nickel-titanium K3 instruments compared with stainless steel hand K-Flexofile. Part 1 Shaping ability in simulated curved canals. *International Endodontic Journal* **36**, 199–207.

Siqueira JF Jr, Rocas IN, Alves FRF, Campos LC (2005) Periradicular status related to the quality of coronal restorations and root canal fillings in a Brazilian population. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology* **100**, 369–74.

Sonntag D, Delschen S, Stachniss V (2003) Root-canal shaping with manual and rotary Ni–Ti files performed by students. *International Endodontic Journal* **36**, 715–23.

Spili P, Parashos P, Messer H (2005) The impact of instrument fracture on outcome of endodontic treatment. *Journal of Endodontics* **31**, 845–50.

Thompson SA, Dummer PMH (2000) Shaping ability of HERO 642 rotary nickel-titanium instruments in simulated root canals. Part 1. *International Endodontic Journal* **33**, 248–54.

Tsuneishi M, Yamamoto T, Yamanaka R et al. (2005). Radiographic evaluation of periapical status and prevalence of endodontic treatment in an adult Japanese population. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology* **100**, 631–5.