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**Rotary Nickel-titanium GT and ProTaper files for root canal shaping by novice operators:
a radiographic and micro computed tomography evaluation**

Diana Gekelman¹ (DDS MS), Ramya Ramamurthy¹ (DDS MS), Sahar Mirfarsi¹ (DDS), Frank Paqué F² (Dr med dent), Ove A. Peters OA³ (DMD MS PhD)

1 University of California School of Dentistry, Endodontic Division, Department of Preventive and Restorative Dental Sciences, San Francisco, CA

2 University of Zurich Dental School, Division of Endodontology, Zurich, Switzerland

3 Arthur A. Dugoni School of Dentistry, University of The Pacific, Department of Endodontics, San Francisco, CA

Corresponding author: Dr Diana Gekelman
Department of Preventive and Restorative Dental Sciences
School of Dentistry
University of California, San Francisco
707 Parnassus Avenue, Box 0758
San Francisco, CA 94143-0758
tel:415-514 2459
fax:415-476 0858
e-mail:gekemand@dentistry.ucsf.edu

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Abstract

Introduction The purpose of the present radiographic and micro-computed tomography study was to assess canal preparation outcomes achieved *in vitro* by novice clinicians after a brief standardized teaching session. **Methods** All participating student clinicians received a specially designed 1hr long training session. In experiment 1, twenty canals in mesial roots of mandibular molars were prepared with GT and ProTaper rotaries by 10 students before their preclinical endodontic course. Standardized radiographs were exposed before and after canal preparation and canal curvature measured as Schneider's angle; canals were assessed for patency and preparation time was measured. In experiment 2, mandibular molars (20 canals) were submitted to micro-computed tomography before and after canal preparation with ProTaper and GT rotaries by two 3rd year dental students. Canals were metrically assessed for changes (volume, surface, cross-sectional shape, transportation) during canal preparation using a custom-made software package. **Results** In experiment 1, canal curvature decreased by 7.6 and 7.8° for GT and ProTaper preparations; there were no fractured instruments and patency was lost in 2/20 canals. The time needed for GT preparation was longer than for ProTaper (29.7±6.8 vs. 19.4±8.1 min, p<0.05). In experiment 2, canal volumes and surface areas increased (p<0.001); after shaping canals were rounder in cross-section and more tapered. Mean canal transportation ranged between 0.14±0.05 mm and 0.23±0.09 mm for apical and coronal canal thirds. There were no significant differences between the two instruments or the two operators regarding center of mass shifts; qualitative and quantitative data for canal transportation was similar to earlier studies using the same evaluation system but experienced operators. **Conclusion** Both types of Nickel-titanium

rotary instruments investigated, performed adequately with inexperienced operators that had received a brief structured training session.

Key words: root canal shaping, rotary instruments, micro-computed tomography, education

Introduction

Cleaning and shaping of the root canal system is the primary method for removing debris and microorganisms responsible for endodontic pathosis. Nickel-titanium (NiTi) rotary instruments of various designs let clinicians perform shaping procedures more easily, quickly, and predictably (1). However, experience has been identified as a major factor for successful use of NiTi rotaries (2,3). Therefore, the introduction of NiTi rotaries to undergraduate training has met with some resistance, despite several reports indicating low numbers of complications (4,5).

Evaluation of root canal shapes may be done with standardized radiographs (6), measuring for example changes in canal curvature. Moreover, high resolution micro-computed tomography (micro-CT) has been used as a research tool in various applications in dentistry, amongst them the evaluation of root canal geometry (7,8). The effect of instrumentation on root canal morphology has been assessed by a number of studies using micro-CT (9-13).

The mentioned studies and most others evaluate root canal instrumentation were carried out by experienced operators; however, many root canal treatments are performed by general dentists and potentially less experienced practitioners. An exception is one of the earlier studies looking at the impact of instrument flexibility on shaping outcomes. In their clinical study, Pettiette *et al.* showed using a cross-over design that undergraduate students could prepare root canals in mandibular with less procedural errors with NiTi compared to stainless steel hand files (14) and achieved better clinical outcomes in the NiTi group (15).

Gluskin *et al.* (12) showed that novice dental students were able to prepare curved root canals with rotary GT files with less transportation and greater conservation of tooth structure, compared to canals prepared with hand instruments. In two earlier studies on NiTi rotaries, inexperienced dental students were able to prepare simulated root canals with Flexmaster (5) and mesial root canals in lower molars with ProTaper and GT (16) rotary files with lower risk of procedural errors and faster than with hand instruments. However, little is known about the comparative efficacy in teaching different rotary instrument techniques to novice clinicians. Therefore, the purpose of the present study was to qualitatively and quantitatively assess canal preparation outcomes achieved *in vitro* by undergraduate dental students after a brief standardized teaching session.

Materials and methods

Specimen preparation

Forty mandibular molars with of similar root shape, with slightly to moderately curved mesial roots, were selected from a pool of extracted teeth and stored in 0.1% thymol solution until used. The teeth had been extracted for reasons unrelated to this study.

Twenty specimens were accessed and the patency of the apical foramen was verified by inserting a size #10 K-file (Dentsply-Maillefer, Ballaigues, Switzerland) so that its tip was just visible. Templates made from silicone putty permitted standardized radiographs (Schick CDR digital radiographic system, Long Island City, NY) to be taken. Canal curvatures were assessed (ImageJ, downloaded from <http://rsbweb.nih.gov/ij/>) according to Schneider's method (17) and data was tabulated. Ten teeth that had two canals with independent apical foramina and similar degrees of curvature were selected for experiment 1.

Curvatures were also determined for the second group of 20 teeth, which were subsequently mounted on SEM stubs (014001-T, Balzers Union AG, Balzers, Liechtenstein, Liechtenstein) and embedded in Stycast resin (Emerson & Cuming, Westerlo, Belgium) using a holding device described earlier (13). Access cavities were prepared and patency in mesial root canals verified with a K-file size #10. Ten teeth with two independent mesial canals and apical foramina were then submitted to micro-computed tomography (see below). Teeth were randomly allocated to two groups in experiment 2 such that canal curvatures were evenly distributed with respect to the two clinicians and the two NiTi rotaries used (see below).

Canal preparation

All endodontic procedures were carried out by volunteer dental students, 10 first years prior to their first preclinical endodontic course and 2 third year students. All received a standardized calibration lecture of 60 minutes length on both preparation systems to be compared in this study (GT rotary files, and ProTaper rotary files, Dentsply Tulsa Dental, Tulsa OK) and the basic parameters for root canal shaping (e.g., working length definition, orifice location). The lecture contained structured information about the instruments (e.g., design, sizing), their handling parameters (e.g., rpm, apical force) and clinical application (e.g., sequence, expected tactile sensations).

Lots were drawn to assign the teeth to the students so that each operator prepared the same number of mesiolingual and mesiobuccal canals; thus, both techniques were used in each mesial root. For experiment 1, each student used both instruments and half of the group started with each file type.

Root canal preparation was performed as specified in manufacturer's guidelines. Teeth were hand-held during preparation and irrigation was with tap water. After determining working length with a K-file size #10, apical root canal preparation commenced to establish a glide path with a K-file size #20. Sequentially, rotary preparation was performed. With either technique, instrumentation was carried out until a size #25 K-file could be placed to working length.

Student clinicians had access to preoperative radiographs but were not allowed to see micro-CT images before treatment, in order to simulate clinical conditions. Instruments were used for one canal only and then discarded.

Experiment 1, radiographic analysis

Radiographs after canal preparation were read into ImageJ software and canal curvature changes tabulated. Using a stopwatch, time periods required for complete preparation, beginning with the first instrument that was placed into an orifice and ending with the definitive canal shape, were measured to the nearest minute. The canals were assessed for patency and gross preparation errors, i.e., instrument fracture, perforation and loss of working length. These data were tabulated along with changes in canal curvature.

An experienced endodontist (O. P.) was blinded regarding the instrument used and assessed preparation errors based on radiographs as present or absent.

Experiment 2, micro-CT analysis

Scanning and evaluation procedures were described previously in more detail (7,13).

Briefly, specimens were scanned before canal preparation at a resolution of 34 μm (μCT -20, Scanco Medical, Bassersdorf, Switzerland) and three-dimensional images of the root canals were constructed. The canals were again scanned after shaping; mounting on precision made stubs that connected to a special attachment assured a close approximation of scanned teeth based on root anatomy. A second software-driven step assured superimposition with a precision of 1 voxel or better (13).

Canal models were used to detect gross preparation errors such as straightening, apical zips, perforations and retained fractured instruments and data were tabulated. An experienced endodontist (D. G.) was blinded regarding the instrument used and assessed canal transportation based on micro-CT postoperative images as present or absent.

Matched root canals were evaluated for changes in volume and surface area. Preoperative canal models were indicated in green color, postoperative canal models in red (Fig. 1).

Two volumetric parameters, the structure model index, ranging from 1 to 4 and describing cross sections, and a three-dimensional canal axis were constructed as described earlier (7).

Statistics

Scores were expressed as means \pm standard deviations (S.D.); means were compared using one- and two-way ANOVAs with Scheffé tests for post-hoc comparisons.

Measurements from micro-CT data were considered dependent variables, while the two instruments as well as the two operators were independent measures. When appropriate, repeated-measures ANOVAs were constructed. Presence and absence of preparation errors were statistically contrasted using chi-square tests. A level of $p < 0.05$ was considered significant.

Results

Experiment 1

In 20 root canals prepared by students with no prior endodontic experience, no instrument fractured; two canals, one with ProTaper and one with GT preparation lost apical patency. No other obvious preparation errors were detected; however, canal straightening of typically about 7 to 8° was noted in both groups. With ProTaper preparation, Schneider's angles changed from 23.7±7.1° to 15.9±5.7° and with GT preparation, angles changed from 21.6±6.6° to 14.0±7.2°. The difference between the two instruments was not significant. Preparation times varied from 12 to 40 min with means of 19.4±8.1 min for ProTaper and 29.7±6.8 min for GT ($p<0.05$).

Experiment 2

One GT instrument out of 30 used in this experiment fractured; none of the canals became ledged or blocked during preparation. Micro-CT scans and reconstructions of unprepared (Fig. 1a) and instrumented root canals (Fig. 1b) yielded detailed three-dimensional canal images; volume rendering was used to illustrate the relationship between root canals pre and post-operatively (Fig. 1 c, d).

There were no metric differences comparing mesiobuccal and mesiolingual canals before shaping ($p>0.05$). However, there were significant differences in all measures comparing pre- and postoperative canal models (Tab. 1). Postoperative canals were larger, had greater surface area and were rounder in cross section ($p<0.05$). Moreover, after canal preparation, canal curvature was reduced and taper increased from about .06 to .08 (Tab. 1).

Based on the position of the three-dimensional canal axis, mean center of mass shift (CM shift) scores were calculated for the coronal, middle and apical thirds; scores in individual canals ranged from 0.048 to 0.357 mm, with the lowest scores recorded in the middle root canal thirds. Analysis of variance indicated no significant differences with respect to rotary instrument or operator, in any canal level ($p>0.05$) (Tab. 2).

There were no statistically significant difference between the rotary instruments and the operators, on the final outcome of the root canal preparation, regarding the change in the curvature, volume, area, or CM shift ($p>0.05$).

Discussion

Several studies concluded that Nickel-titanium rotary instrumentation of the root canal, is faster, more centered in the canal space, produce rounder preparations, and better maintain original root canal anatomy than stainless steel hand files (1,18-20).

Each of the recently marketed Nickel-titanium rotary instruments claims better canal preparation than the previous ones. Consequently, analytical methods are required to confirm or reject such claims by exactly comparing canal geometry in three-dimensions, before and after preparation.

Traditionally, morphometric evaluation of root canal instrumentation was performed by physically cross-sectioning the specimen, as described by Bramante and colleagues (21). However, sectioning the root invariably results in a loss of dental hard tissues.

Furthermore, previous authors reported difficulties in metrical assessment because of the projection errors they encountered (9). Conversely, micro-CT allows a noninvasive three-dimensional evaluation of both external and internal morphology of a tooth, being an excellent and reproducible resource to examine the shape of the root canal before and after preparation in a nondestructive manner (9,11,22).

Efficient root canal instrumentation technique should create definite apical stops, smooth canal walls and good flow and taper after preparation (23). These goals should be achieved whether the treatment is performed by experienced or novice operators.

Consequently, the ideal instrumentation technique should be one that can be safely and effectively accomplished by any operator.

Previous studies suggested that undergraduate dental students can successfully prepare molar root canals with rotary instrument, and these instruments are increasingly being integrated into clinical courses (4,12,16,24-27).

It is noteworthy that the student clinicians performing the preparations in the present study received a very brief standardized introduction to the use of GT and ProTaper rotaries. However, the presentation relied on basic established, evidence-based principles that are also available to general dentists (28) and permitted the students to shape root canals successfully despite having no clinical or laboratory training.

Considering the large number of Nickel-titanium rotary instruments available on the market place, it is desirable to research the most appropriate and safe one(s) to be used by novice operators. Based on these premises, the current paper comprehensively analyzed changes in canal geometry in three dimensions after root canal preparation performed by novice operators.

In our quantitative analysis, there was no significant statistical difference between GT and ProTaper rotary instruments on the final root canal preparation outcome, regarding the changes in all measures: curvature, volume, area, or center of mass shift. These results were consistent for all novice operators in this study. Moreover, the results in the present study were similar to qualitative and quantitative data from earlier studies assessing canal preparation with NiTi instruments by experienced operators (13).

Qualitative analysis was used to assess procedural errors; considering the inexperience of the novice clinicians in the present study, the number of procedural errors encountered was small, consisting of one fractured instrument, and some degree of canal straightening. No obstructions were noticed and most of the treated canals exhibited

appropriate overall shapes (Fig. 1). Therefore, we consider both GT and ProTaper rotaries as safe for the use in the undergraduate clinic, provided that standardized instruction is ensured.

In conclusion, numerous *in vitro* and *ex vivo* experiments have already demonstrated improved canal shapes with Nickel-titanium rotary instruments; even though, it is not clear if this correlates to improved clinical outcomes. Based on the results of this study, it seems reasonable to recommend the use of Nickel-titanium rotary instruments, for example GT or ProTaper files, in the pre-doctoral clinical setting.

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Figure legend

FIG. 1: Three-dimensional reconstruction of a root canal system and the outer tooth contour from micro-CT at 34 μm resolution. Changes in overall canal shape are visible comparing the preoperative (a) and postoperative (b) reconstructions. The volumes of interest in the mesiobuccal and mesiolingual canal are shown as superimpositions of unprepared (green) and prepared (red) canal areas (c). Length bar is 1 mm.

Tables

TABLE 1: Changes in mesial root canal volumes of lower molars (mean \pm S.D., n=10 each), surface areas and cross-sectional shape. Statistically different values are denoted by the same letters.

TABLE 2: Mean (\pm S.D., n=10 each) changes in canal center of mass [mm] after preparation with GT and ProTaper rotary instruments. Center of mass shift was significantly larger coronally than in the other two sections ($p<0.05$) but there were no differences between the two techniques at any level.

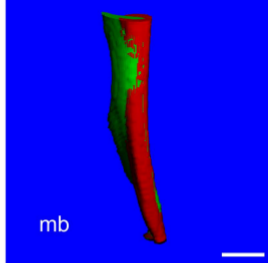
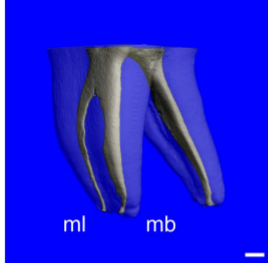
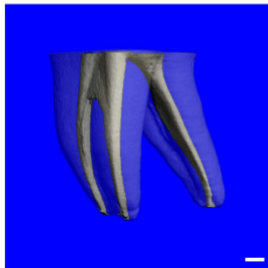
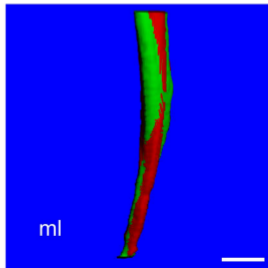
A**B****C**

TABLE 1: Changes in mesial root canal volumes of lower molars (mean±S.D., n=10 each), surface areas and cross-sectional shape. Statistically different values are denoted by the same letters.

	Pre-operative		Post-operative		
	GT	ProTaper	GT	ProTaper	
Volume [mm ³]	1.40±0.84a	1.53±0.89b	2.86±1.63a	2.98±1.48	p<0.001
Area [mm ²]	12.94±5.51c	12.38±4.46d	17.03±7.24c	17.49±6.45d	p<0.001
SMI	2.88±0.57e	2.72±0.68f	3.32±0.49e	3.16±0.39f	p<0.05

TABLE 2: Mean (\pm S.D., n=10 each) changes in canal center of mass [mm] after preparation with GT and ProTaper rotary instruments. Center of mass shift was significantly larger coronally than in the other two sections ($p < 0.05$) but there were no differences between the two techniques at any level.

	GT	ProTaper
Coronal third	0.23 \pm 0.09	0.20 \pm 0.10
Middle third	0.14 \pm 0.05	0.16 \pm 0.07
Apical third	0.14 \pm 0.09	0.19 \pm 0.11