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ORIGINAL ARTICLE

Influence of operator experience on vertical force during instrumentation using Neoniti rotary files

ABSTRACT

Aim: *This study aimed to measure the vertical force developed during canal instrumentation with Neoniti rotary files at predetermined torque in relation to the operator's experience.*
Methodology: *The research was performed on 60 human maxillary and mandibular incisors extracted for periodontal reasons. Each group of 20 teeth (10 maxillary and 10 mandibular incisors) was prepared by three different operators with different levels of experience in endodontics: a fresh dental school graduate, a postgraduate student training in endodontics and an endodontic specialist. Maxillary incisors represented the experimental model of wide root canals while mandibular incisors represented a model of narrow root canals. Root canals were prepared employing Neoniti files and TCM Endo unit at speed and torque recommended by the manufacturer. Vertical force measurement was performed utilizing device constructed for this purpose. Statistical analysis was accomplished using Mann-Whitney U test, Kruskal-Wallis test and Spearman's rank correlation.*
Results: *The amount of vertical force was significantly higher in narrow than in wide root canals (P=0.001). Comparison of vertical forces developed by three different operators demonstrated significant differences (P<0.001). Median vertical force developed by postgraduate student was significantly lower than in other two operators (both P<0.01). In postgraduate student, a significant positive correlation between number of shaped root canals and vertical force was demonstrated (ρ=0.490; P=0.003).*
Conclusions: *The postgraduate with limited experience in rotary instrumentation had on average lowest values of vertical force as opposed to other two operators. However, these values increased with the number of shaped root canals.*

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Received 2020, November 26
Accepted 2021, February 2

KEYWORDS *force, nickel-titanium, rotary files*

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Peer review under responsibility of Società Italiana di Endodonzia

10.32067/GIE.2021.35.01.17

Introduction

Shaping of the root canal space is one of the most challenging issues of endodontic treatment, particularly in narrow and curved root canals. It ensures proper mechanical debridement, facilitates irrigation and provides a suitable shape for the placement of the root canal filling material. Over the past few decades, motor driven instrumentation systems have become a standard in root canal shaping due to flexibility and mechanical properties of the nickel- titanium (NiTi) files, decreased operating time in comparison to hand instruments and application simplicity (1). NiTi alloys enabled construction of superelastic instruments, a feature that ensures flexibility and facilitates preparation of curved canals. In recent years, new manufacturing processes and alloys have been introduced to improve conventional NiTi systems (2). The Neoniti rotary files (Neolix Neoniti, Evron, France) are manufactured through the Wire-Electric Discharge Machining (wire-EDM). According to the manufacturer, this specific process of manufacturing is responsible for high flexibility and surface hardness which together with a rectangular cross-section ensure cutting efficacy and optimal flexibility (3).

However, despite improvements in the mechanical properties, NiTi instruments are still prone to fracture if certain conditions are met. Among many factors associated with failure of the NiTi instruments are their construction design, cyclic fatigue and torsional stress, rotational speed, curvature angle of the canal and operator's experience (4). The occurrence of cyclic fatigue and torsional stress in NiTi instruments is directly influenced by vertical force and torque and may result in instrument separation (5-8). Methods used to reduce instrument separation include use of torque-controlled electrical motors that identify when torsional limits are reached, modification of the instruments' cross-sectional geometry to reduce contact areas and increase cutting efficiency and introduction of reciprocating files with increased cyclic fatigue resistance (2, 9, 10). The experience of the operator has been identified as an important factor in the success of the endodontic therapy. Differences between the experienced and inexperienced operator are observed in the number of procedural errors, fractured instruments and time required to prepare a root canal. Several studies observed a statistically higher occurrence of canal transportation in the group of inexperienced operators (11, 12). Munoz et al (11) reported more frequent instrument separation among the inexperienced operators in comparison to the experts. However, studies regarding operator's experience and instrument separation are not unanimous in their finding. A study performed by Generali et al (13) demonstrated that operator's experience was not significant in relation to instrument fracture. Since it has been advocated that vertical force is one of the factors that can directly influence instrument separation, it is necessary to explore if a particular motor driven instrumentation system can be used by beginner and experienced operator with the same degree of safety.

The aim of this study was to measure the vertical force developed during canal instrumentation with Neoniti rotary files at predetermined torque in relation to the operator's experience. The null hypothesis tested was that operator's experience does not affect the amount of the vertical force developed during canal shaping.

Materials and Methods

This study received approval from the Institutional Ethical Committee (No.818101218). The research was performed on 60 human maxillary and mandibular incisors extracted for periodontal reasons. Following extraction, the teeth were stored in 0.1% thymol solution up to 2 months to prevent bacterial growth. Two initial radiographs of each tooth were taken from bucco-lingual and mesio-distal projection to assess the shape and cross-sectional diameter of the canals as well as to detect their number and possible obstructions. The radiographs were ob-

tained utilizing X-ray unit (Trophy Elitys, Trophy Radiologie, Marne-la-Vallee, France) and intraoral sensor (One, Owandy Radiology, Roslyn, NY, USA). Canals with morphological abnormalities, obstructions, curvatures or multiple canals were excluded from the study. Only incisors with a single straight root canal, oval cross-section in the coronal and middle third and round cross-section in the apical third were included in the study.

Access cavity was prepared using the Cavity Access Set (Dentsply Sirona, Ballaigues, Switzerland). The root canal length was determined utilizing a size 10 K-file (Dentsply-Sirona, Ballaigues, Switzerland) in mandibular and 15 K-files (Dentsply-Sirona, Ballaigues, Switzerland) in maxillary incisors group, depending on the initial apical diameter of the canal. Files with rubber stops were inserted into the canal until their tips became just visible through the apical foramen. The position of the file in each canal was confirmed by digital radiographs. To standardize root lengths, all teeth were shortened coronally to a length of 19 mm. The working length of 18 mm was set by subtracting 1mm from the adjusted length of the root.

The apical diameter of all root canals was standardized by manual instrumentation up to a size 20 K file (Dentsply-Sirona, Ballaigues, Switzerland) in mandibular incisors and size 30 K-file (Dentsply-Sirona, Ballaigues, Switzerland) in maxillary incisors. During manual preparation 3 ml of 3% sodium hypochlorite (NaOCl) per canal was used for irrigation. Final irrigation was performed with 2 mL of 17 % ethylenediaminetetraacetic acid (EDTA; Vista Dental Products, Racine, WI, USA) for 1 min followed by irrigation with 6 mL of 3% NaOCl for 3 min and 2 mL sterile saline solution for 1 min (14).

The prepared teeth were randomly divided into three experimental groups. Each group consisted of 10 maxillary and 10 mandibular incisors. Maxillary incisors represented the experimental model of wide root canals while mandibular incisors represented a model of narrow root canals. The cervical portion of teeth was immersed into auto acrylate mold (Polirepar S, Polident, Volčja Draga, Slovenia) to secure specimen placement into the measuring device (Figure 1). Canal orifices were shaped and enlarged with Neoniti C1 orifice opener nº25/.12 (Neolix Neoniti, Evron, France). The narrow root canals were prepared employing Neoniti A1 nº25/.06 shaping files (Neolix Neoniti, Evron, France) with new files used for every specimen. Wide root canals were instrumented utilizing Neoniti A1 nº40/.04 (Neolix Neoniti, Evron, France) with files discarded after each specimen preparation. Before use, each rotary instrument was lubricated with RC Prep (Well-Prep,Vericom Co, Anyang, Korea), whilst a rinse with 3 ml of 3% NaOCl solution was made after the use of each instrument. Apical patency was obtained using a size 10 K-file. The rotational speed was preset at 300 rpm and the shaping files were introduced in pecking and upward circumferential brushing motions from the bottom up according to the manufacturer's instructions. The preparations were performed utilizing the TCM Endo unit (Nouvag, Goldenstein Switzerland) at a preset torque value of 1.5 Ncm according to the manufacturer's recommendations.

Each group of 20 teeth was prepared by different operator depending on their experience. Group 1 was shaped by beginner, a fresh dental school graduate. Group 2

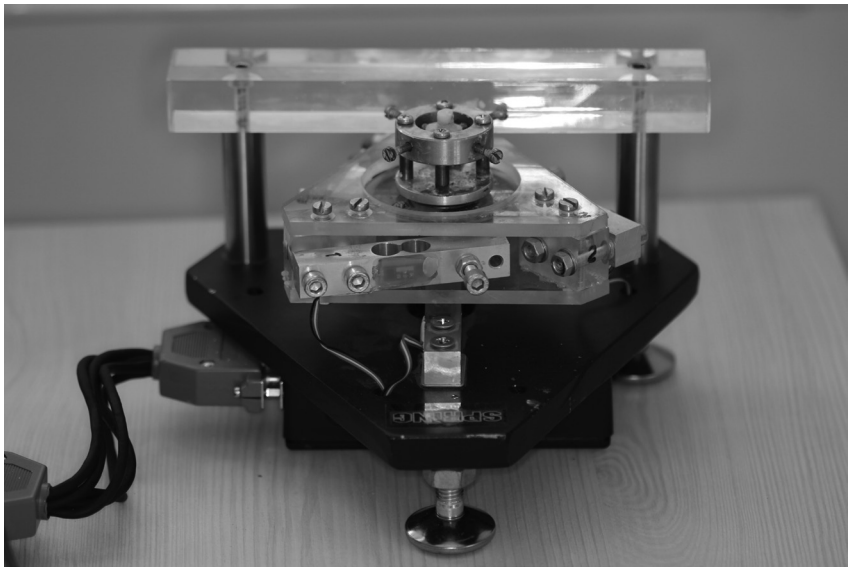


Figure 1
Tooth immersed into auto acrylate mold and placed into the measuring device.

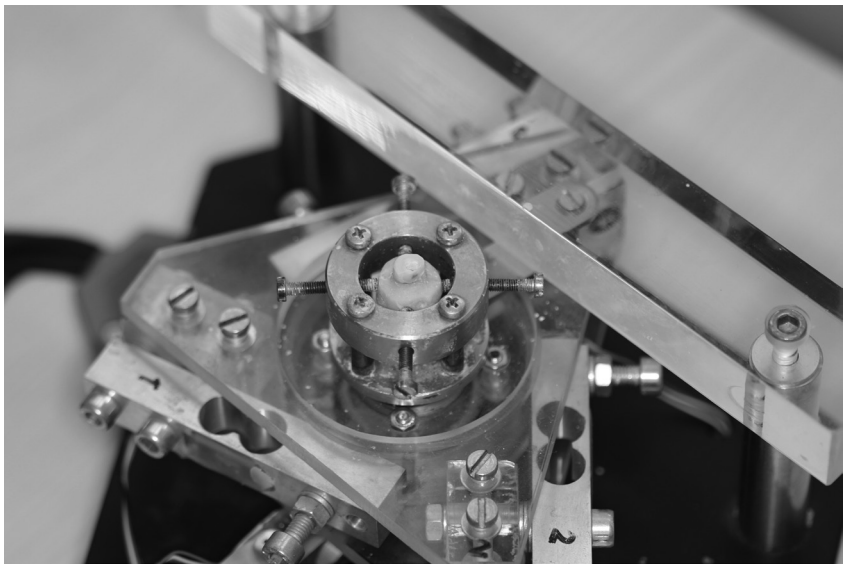


Figure 2
Vertical force measuring device.

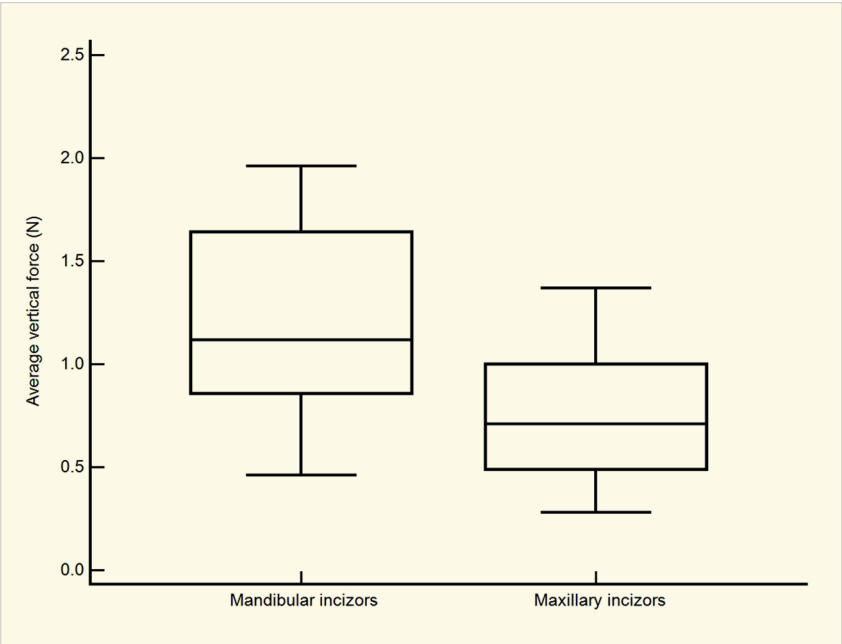
was prepared by a postgraduate student training in endodontology. Group 3 was prepared by an experienced operator, an endodontic specialist with more than 10 years of experience. None of the operators had previous experience using Neoniti rotary files. They had only theoretical knowledge about the system.

Vertical force measuring device

The constructed device had a platform for tooth placement, which was wedged using a vertical shaft into a membrane sensor with eight gauges (1-Ly11-10/120, Hottinger, Baldwin, Messtechnik, GmbH, Darmstadt, Germany) to measure vertical forces (Figure 2). The construction allowed free passage and rotation of the vertical shaft in a radial bearing while being wedged into the membrane sensor trough axial-radial bearing.

Prior to instrumentation, device calibration was performed using 50 g and 100 g standardized weights. Measured data were recorded with a two-channel oscilloscope (ADC-216, Pico Technology Limited, St Neots, UK) every 0.1 s. They were presented in a form of diagrams and tables on the computer monitor and entered into Microsoft. Excel data sheet. The recorded variables were expressed in newton (N) units for vertical force variable. The measuring device was described in a previously published paper (15).

Figure 3
Difference in vertical force regarding tooth type.



Statistical analysis

Statistical analysis was performed using the commercial software MedCalc 14.8.1 (MedCalc Software bvba, Belgium) at level of statistical significance $P<0.05$. Kolmogorov-Smirnov test was used to test data for normal distribution. Since distribution of the data was not normal, as a measure of central tendency and dispersion, a median and interquartile range values were used. Testing the differences between the groups was accomplished using Mann-Whitney U test and Kruskal-Wallis test. Given the large number of tests Bonferroni correction concerning statistical significance was applied in the post hoc analysis. To explore relationship between number of shaped root canals and vertical force a Spearman's rank correlation was used.

Results

The median vertical force measured during instrumentation was 1.12 N (0.86-1.64) in mandibular incisors and 0.71 N (0.49-1.00) in maxillary incisors. The amount of vertical force was significantly higher in mandibular incisors ($P=0.001$, Figure 3). Significant differences in vertical forces developed by three operators were found

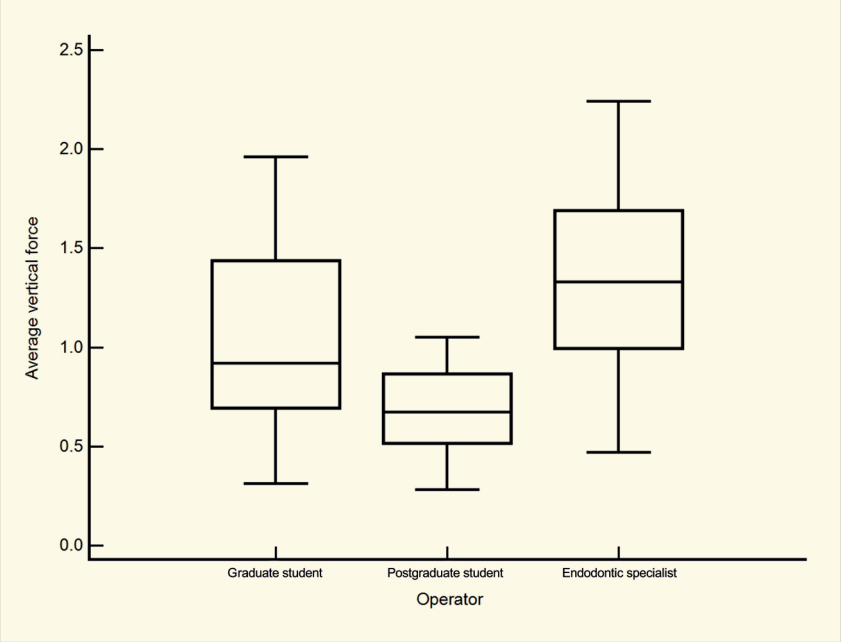
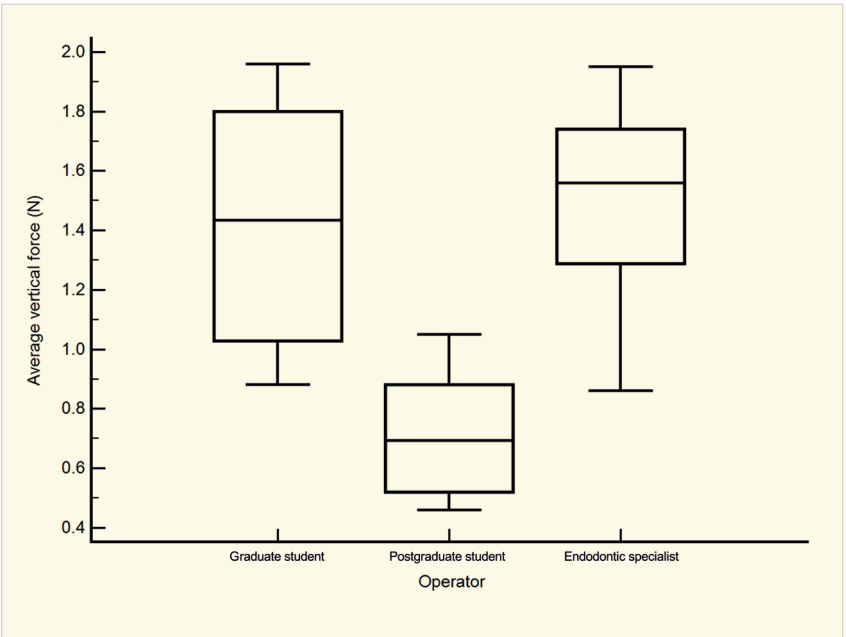


Figure 4
Difference in vertical force in all teeth regarding operator's experience.

(*P*<0.001). Average vertical force developed by postgraduate student was 0.68 (0.52-0.87) N while graduate student and endodontic specialist developed 0.92 N (0.70-1.44) and 1.33 N (1.00-1.69) , respectively (Figure 4). Post hoc analysis revealed that median vertical force developed by postgraduate student was significantly lower than in other two operators (both *P*<0.01). The figures 5 and 6 show median, minimal and maximal values as well as interquartile range of vertical force applied by three operators during instrumentation of mandibular and maxillary incisors. Significant differences in amount of vertical force during instrumentation between different operators were observed in both mandibular and maxillary incisors. (*P*<0.001 and *P*=0.008, respectively). In mandibular incisors, the average amount of vertical forces developed by graduate student and endodontic specialist were 1.44 N (1.03-1.80) and 1.56 N (1.29-1.74), respectively. Force developed by postgraduate student was on average 0.70 N (0.52-0.88). Post hoc test revealed that force developed by postgraduate student was significantly lower than in other two operators (*P*<0.01, Figure 5).

Figure 5
Difference in vertical force in mandibular incisors regarding operator's experience.



Significant differences in amount of vertical force during instrumentation of maxillary incisors between operators were also observed (*P*=0.008). The average amount of vertical force developed by endodontic specialist was 1.05 N (0.89-1.37), and it was significantly higher than average forces developed by graduate and postgraduate student (*P*<0.01, Figure 6). A significant positive correlation between number of shaped root canals and vertical force was demonstrated for postgraduate student (ρ=0.490, *P*=0.003). The amount of vertical force increased with the number of shaped root canals. A negative correlation was found for graduate student (ρ=-0.143, *P*=0.548) and endodontic specialist (ρ=-0.340, *P*=0.143), however it was not statistically significant.

Discussion

Only a few studies evaluated the influence of operator's experience on the shaping of the root canals (11, 16, 17). While some of them used simulated root canals in resin blocks, others used natural extracted teeth. In the present study extracted teeth were used as samples. There are several disadvantages when resin blocks are used. First, the physical properties such as texture, hardness, and cross section of simulated root canals differ from natural teeth. Second, heat generated during instrumentation of simulated root canals, may soften the resin material and lead to binding of

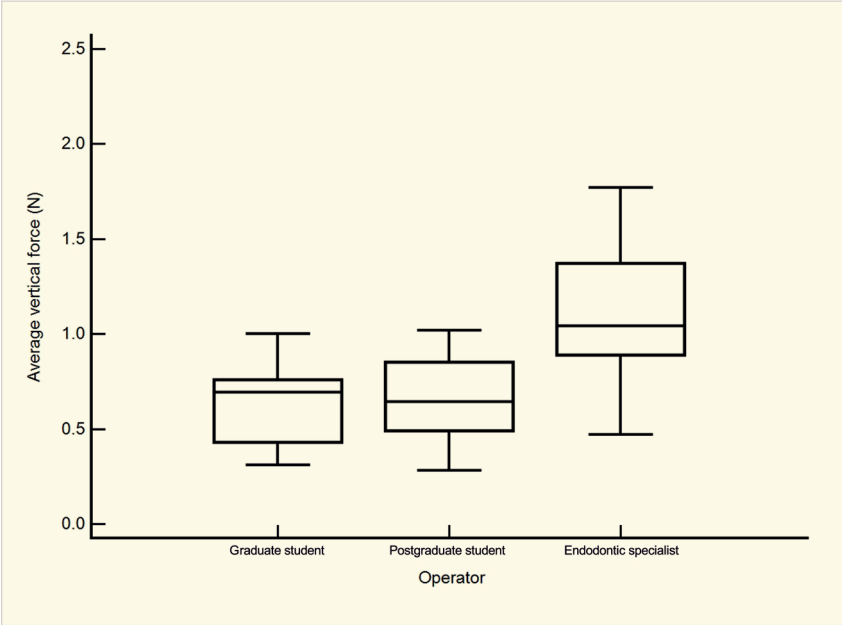


Figure 6
Difference in vertical force in maxillary incisors regarding operator's experience

cutting blades (16). However, it can eliminate morphological variations of root canal as a source of measurement variations (18, 19). Although the skills required for preparation of plastic block canals and canals in natural teeth are not identical (16), the experience and tactile skills of operator remain important issues of investigation. The results of this study demonstrated significant differences in vertical force developed by operators with different levels of experience. An operator with extensive experience in rotary instrumentation (endodontic specialist) had on average highest vertical force values between the operators, but this difference was significant only in the model of wide root canals. On the other hand, the postgraduate with limited experience in rotary instrumentation had on average lowest values of vertical force as opposed to other two operators. Statistical analysis revealed that this was significant in total sample and in the model of narrow root canals. This finding can be attributed to the "learning curve" of the less experienced operator. Blum et al (20) compared vertical forces developed by a group of students and a group of endodontists during root canal instrumentation utilizing an endograph. The results of their study showed that the vertical forces of students were lower than those of the endodontists in the beginning of the experiment. However, with the progression of the study, the amount of forces increased in the group of students and became similar to the values of experienced operators. This could indicate their advancement in correct manipulation of the rotary instruments (20). This trend can be observed in the present study as well and confirms the positive correlation between progression of operator's experience and an increase in instrumentation force. Our results demonstrated that the vertical force values of the postgraduate student increased with the number of shaped root canals, possibly reflecting an increase in experience and tactile skills of the operator.

Instrument separation is an unpleasant complication, which can often be prevented through correct instrument manipulation. Care is advised especially during instrumentation of the narrow root canals. Previous study performed by Peters et al confirmed a correlation of vertical force to preoperative canal volume (21). It was observed that the apically directed force increased during preparation of narrow root canals. Torsional fractures and "taper lock" effect were induced through forced manipulation of the rotary file into the apical portion of the narrow root canal (21, 22). Similar finding was observed in this study. Regardless of the operator experience, the average amount of vertical force was significantly higher in the model of narrow root canals.

Regardless of the recorded vertical force values, no instrument separation was recorded in any of the operator groups. This could be attributed to the single use of rotary files, maintenance of the glide path and manual enlargement of the root canals prior to rotary instrumentation. During the last two decades, NiTi instruments have gained popularity and are widely used by both general practitioners and endodontic specialists (23, 24).

A study performed on general dentist and endodontists in Tehran revealed that the most common procedural fault associated with NiTi instruments was file separation due to over-use and application of exces-

sive pressure (25). Aside from instrument separation, increased instrumentation force is associated with formation of dentinal defects on the canal walls. These structural defects can increase the risk of root fracture and lead to tooth loss (22). One of the major shortcomings of many comparative studies conducted in ex vivo conditions, including the present study, is a lack of anatomical matching of teeth prior experiment (26).

In the present study, after applying the exclusion criteria and standardization of the root length and apical diameter, teeth were randomly divided to create experimental groups. Although several previously conducted studies created experimental groups by randomization (14, 27), there are concerns that the results may reflect the root canal anatomy rather than the variable of interest (26). To overcome this problem several studies measured buccolingual and mesiodistal root canal diameter at 5 mm from the apex and calculated long: short cross-section diameter ratio to discern oval from round root canals (28-30).

Recently, a study by De-Deus et al (26) proposed a micro-computed tomographic (micro-CT) technology as a method to remove variations in root canal anatomy as a confounding variable in experiments with pair-matched design.

Other limitations of the present research include a relatively small sample of teeth analyzed in each operator group. Instrumentations were performed by only one representative of the operators. A more generalized representation of each operator group would have been achieved through multiple operators in each experience group. Finally, we cannot exclude the possibility that differences in vertical force may be rather attributable to individual operator characteristics than operator's experience. Several investigations have demonstrated that utilizing machine-driven Ni-Ti instruments by inexperienced users results in more confidence and an improved sense of security in performing endodontic treatment (31, 32). Therefore, it seems rational to introduce the use of machine-driven Ni-Ti files into their pre-clinical curriculum.

Conclusions

Under the present experimental conditions, the postgraduate with limited experience in rotary instrumentation had on average lowest values of vertical force as opposed to other two operators. However, these values increased with the number of shaped root canals.

Clinical Relevance

The present study emphasized the importance of preclinical training to acquire experience and tactile skills for correct manipulation of the rotary endodontic instruments.

Conflict of Interest

None.

Acknowledgements

We thank Neolix for the donation of nickel-titanium files. Mr. Domagoj Galin is acknowledged for electronic images preparation.
This work was supported by projects "Interdisciplinary research on fluid flow in macro and micro systems using supercomputer simulations" and "Influence of general health on oral health", funded by University of Rijeka, Croatia.

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