

Effect of Blue Heat Treatment on Vertical Force Induced with Endodontic Files

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ABSTRACT

Objective: To evaluate the vertical forces induced with Reciproc (R) and Reciproc Blue (RB) systems during canal shaping.

Methods: Maxillary premolar teeth with two separate straight and constricted canals were chosen (n=26). After access cavity preparation, each tooth was fixed in a standing position on a stage connected to a force analyzing device (M5-20 Advanced Digital Force Gauge; Mark-10 Corporation, NY, USA). The glide path was prepared manually until K file sizes #15. Then, canals in all the groups were completely shaped with an R25/RB25 file (size 25, .08 taper). The canal shaping was done with a steady and gentle pressure on the file to give a slow “in-and-out” movement of 2 mm amplitude. The file was inserted three times until it reached the WL successfully. After each insertion, the canal was recapitulated and irrigated with a 1% sodium hypochlorite solution. The shaping time was analyzed by Student’s t-test. The inward and upward peak forces were used for analysis by using the Mann-Whitney test. All statistical analyses were performed using SPSS software at a 95% confidence level.

Results: Each root canal was shaped successfully with a single file inserted three times until the WL was reached. Within each group, the overall real-time force increased with the successive insertions of the file. The inward peak forces in both groups ranged from 1.71 to 8.38 N and the R group showed minimal peak forces than the RB group in the three insertions (P<0.05). The upward peak forces ranged from 1.50 to 3.26 N wherein both groups showed comparable peak forces at each insertion (P>0.05). The R and RB systems required average times of 22.01±3.08 and 23.93±4.15 s, respectively, to shape the canals completely (P>0.05). In this experiment, no file fracture took place during canal shaping.

Conclusion: The blue heat treatment influenced the forces developed during canal shaping. RB file was associated with higher inward peak forces than R file.

Keywords: Endodontics, root canal preparation, shaping time, vertical force

HIGHLIGHTS

- This study investigated the vertical forces induced during the shaping of constricted canals with Reciproc Blue and Reciproc systems.
- The blue heat treatment influenced the forces developed during canal shaping
- The results indicated that Reciproc Blue file induced greater inward-directed forces during shaping constricted canals, compared to Reciproc file.

INTRODUCTION

Endodontic files made of nickel-titanium (NiTi) alloy are extensively used in clinical practice for root canal shaping. Recent advances in their design (1, 2), motion kinematics (3, 4), and alloy metallurgy (5, 6) have shown superior performance with greater flexibility, improved cutting ability, reduced canal transportation, and quicker and centered canal shaping compared to stainless steel files (7, 8).

Reciprocating movement is considered as a progress of the balanced force technique in canal shaping. It consists of a counterclockwise and a clockwise motion where the angle of the counterclockwise motion is greater than the angle of the clockwise motion. This movement was found to be able to maintain the original axis of curved canals during preparation, reduce the risk of defects on the canal walls and increase the lifespan of the file (9-11). Moreover, it makes canal shaping with a single file possible which, in turn, reduces the shaping time, cost, and cross-contamination risks (12). Previous studies showed that canal shaping with single file systems under different kinematics is as effective as that with the traditional multi-file systems (6, 13).

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Reciproc (R) (VDW, Munich, Germany) is a single-file system used in a reciprocating motion and is made of a martensitic NiTi wire (14). It has three file sizes with an "S" cross-section and two cutting edges, namely, R25 (0.25/.08v), R40 (0.40/.06v) and R50 (0.50/.05v). In 2016, an updated version with an identical cross-sectional design and geometry but different NiTi alloy has been proposed; namely, Reciproc Blue (RB). The RB is manufactured using a blue heat treatment which subjects the file to heating-cooling proprietary treatment (15). This treatment provides a titanium oxide layer on the surface of the file and improves the cyclic fatigue resistance and flexibility (16); however, it reduces the surface micro-hardness (15) which may negatively affect cutting efficiency (17, 18). Nevertheless, Belladonna et al. (19) concluded that R and RB files created similar shaping outcomes.

During canal shaping, intracanal stresses are generated which adversely affect the fatigue resistance of the file resulting in intra-canal file fracture (20, 21). It is reported that shaping stresses are greatly affected by the contact area between the file and the canal walls, file geometry and design, preoperative canal volume, and file's motion kinematics (4, 21-25). So, investigating the forces required to shape a root canal is important and can contribute to successful treatment. The effect of blue heat treatment on the shaping force has not been adequately addressed. Therefore, this study aimed to evaluate the vertical forces induced with R and RB systems during canal shaping. The null hypothesis tested was that the tested endodontic files developed the same shaping forces.

MATERIALS AND METHODS

Sample size calculation

Based on a pilot study, the sample size was calculated using a 5% significance level and 80% power to detect a 0.24 N force difference between the R and RB systems. The standard deviation within a group was set as 0.20 N. This calculation reported that at least twelve root canals should be included. Thus, thirteen root canals were considered in each group.

Extracted teeth selection

Maxillary premolar teeth with intact crowns and fully formed roots with two separate and distinct canals from the pulp to the apex were chosen from a pool of extracted human teeth that were kept in distilled water with an exempt protocol accepted by the Institutional Review Board (RC17-008-R). The extraction reasons and the age of patients were not available.

2D radiographs in the proximal view using a Planmeca ProX™ (Planmeca®, Helsinki, Finland) were taken to choose straight root canals (<10 degrees curvature) (26). Access cavity preparation was performed and the root canals were checked to be patent and constricted to a level that a #15 K file (Dentsply Sirona, Ballaigues, Switzerland) can be placed no less than 3 mm away from the apex. If these criteria were not achieved, the tooth was excluded.

Force analyzing device

Each tooth was fixed on a stage connected to the force analyzing device (M5-20 Advanced Digital Force Gauge; Mark-10 Corporation, NY, USA) in a way that put the root canals in a parallel direc-

tion with the device (23,24). This allowed the device to monitor the vertical force and show its instantaneous values using the MESUR™ Lite software (Mark-10 Corporation, NY, USA) in both the inward and upward directions (Fig. 1). The inward force represents the positive force needed to advance the file into the canal while the upward force represents the negative force developed when the file was pulled out from the canal. The device was zeroed before each use and the vertical force values were expressed in Newton (N). The gauge device measured data every 0.1 s.

Canal shaping

The apical part of the tooth was covered with utility wax and the whole tooth was embedded in a mixed pattern resin (DuraLay, Reliance Dental Mfg. Co., Worth, IL, USA) that enclosed the root surface and the wax. The distance between the reference point and the file's tip at the major foramen minus 0.5 mm was defined as the working length (WL) for each canal. Based on the WL, the root canals were assigned to two similar groups of 13 root canals ($P=0.95$).

The glide path was prepared manually with K file sizes #10 and #15. Then, canals in all the groups were completely shaped with an R25/RB25 file (0.25/.08v) using the 'RECIRPROC ALL' mode under their dedicated reciprocating motion at a speed of 300 rpm.

A stand was made beside the force analyzing device where the clinician's working hand was placed to be at a level higher than the tooth during canal shaping. Consequently, the shaping was done with a steady and gentle pressure on the file to give a slow "in-and-out" movement of 2 mm amplitude. The file was inserted three times until it reached the WL successfully. After each insertion, the canal was irrigated with a 1% NaOCl at room temperature and recapitulated with a #10 K file, and the file's flutes were cleaned and inspected under magnification. Each file was used in 4 canals or until there was a fracture or any evidence of deformation (23-25). The canal shaping procedure was performed by a single experienced clinician at room temperature. The shaping time, which included the total active shaping, was documented.

Data analysis

The shaping time was analyzed by an independent t-test since its distribution was normal (Shapiro-Wilk test; $P>0.05$). Differences between the mean inward and upward peak forces of the three shaping insertions for both groups were tested for statistical significance using Mann-Whitney U-test since the data were not normally distributed (Shapiro-Wilk test; $P<0.05$). All statistical analyses were performed by using SPSS software version 22 (SPSS Inc, Chicago, IL) at a 95% confidence level.

RESULTS

Table 1 summarizes the vertical peak force values of the upward forces and inward forces for each file insertion in the tested systems.

Each root canal was shaped successfully with a single file inserted three times until the WL was reached. The real-time forces induced during canal shaping with each file were studied. Figure 2 shows the mean and standard deviation values of inward and upward peak forces for each file system. Within each group, the overall real-time force increased with the successive insertions

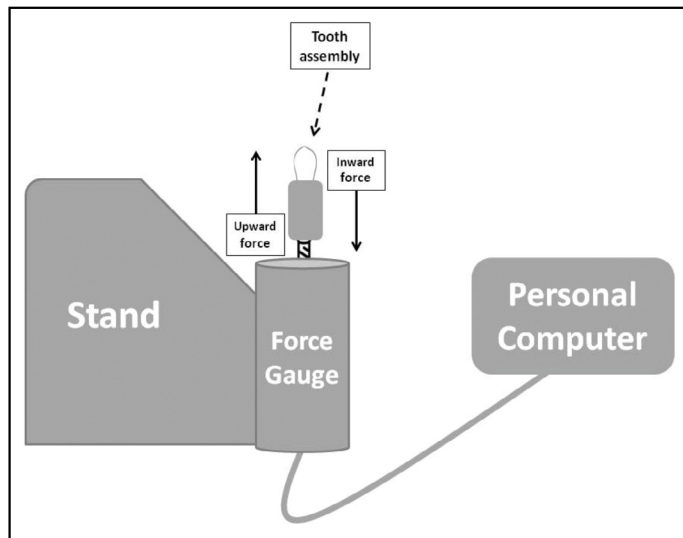


Figure 1. Schematic drawing of the experimental set-up. The force analyzing device was used for recording vertical forces in both directions and the received data are presented on a PC using MESUR Lite software (Mark-10 Corporation). The device was fixed to a stand at where the operator’s hand was placed to be slightly above the level of the tooth crown during canal shaping

PC: Personal computer

of the file. The inward peak forces in both groups ranged from 1.71 to 8.38 N and the R group showed minimal peak forces than the RB group in the three insertions ($P < 0.05$). The upward peak forces ranged from 1.50 to 3.26 N wherein both groups showed comparable peak forces at each insertion ($P > 0.05$).

The R and RB systems required average times of 22.01 ± 3.08 and 23.93 ± 4.15 s, respectively, to shape the canals completely ($P > 0.05$). In this experiment, no file fracture took place during canal shaping.

DISCUSSION

The present study was designed to purely investigate the effect of metallurgical properties in shaping forces using R and RB systems. Both systems have the same design, size, and motion kinematics but are made from different alloy treatments. This study was intended to provide information on the vertical forces induced during the shaping of constricted and straight canals. The instantaneous vertical force appeared to increase with the successive file insertions until the file reached the full WL. Advancing the file deep in the canal is reported to require larger force (24). Although a previous study showed that the tested systems are similar in design, geometry, size, reciprocation movement and percentage of prepared canal surface (27), they had differences in the instantaneous shaping forces. In the three insertions, RB generated higher inward-directed peak forces than R, whilst they had comparable upward-directed peak forces (Fig. 2). These differences might be attributed to the special metallurgical treatment (15) of the RB file that resulted in higher flexibility, softness, and ductility caused by the martensitic state of RB File compared to the austenitic-based R file (15, 27). It was reported that the more flexible the file, the less rigid and lower is its buckling resistance (28). Clinically, buckling resistance and stiffness are needed during the canal shaping to enable the file

TABLE 1. The vertical peak force values of the upward forces and inward forces for each file insertion in the tested systems

System	Vertical force (N)											
	First insertion				Second insertion				Third insertion			
	Inward force		Upward force		Inward force		Upward force		Inward force		Upward force	
Reciproc (n=13)	Mean±SD	Median (25 th -75 th percentile)	Mean±SD	Median (25 th -75 th percentile)	Mean±SD	Median (25 th -75 th percentile)	Mean±SD	Median (25 th -75 th percentile)	Mean±SD	Median (25 th -75 th percentile)	Mean±SD	Median (25 th -75 th percentile)
Reciproc Blue (n=13)	0.17±0.07	0.15 (0.13-0.21)	0.17±0.06	0.16 (0.13-0.21)	0.30±0.15	0.26 (0.21-0.39)	0.24±0.91	0.23 (0.18-0.29)	0.63±0.31	0.50 (0.43-0.83)	0.33±0.10	0.32 (0.26-0.39)
P	0.34±0.14	0.33 (0.26-0.43)	0.15±0.53	0.14 (0.12-0.18)	0.50±0.27	0.39 (0.32-0.67)	0.21±0.66	0.19 (0.17-0.25)	0.84±0.27	0.75 (0.67-1.00)	0.23±0.04	0.24 (0.2-0.26)
	<0.01		0.38		0.04		0.378		0.04		<0.01	

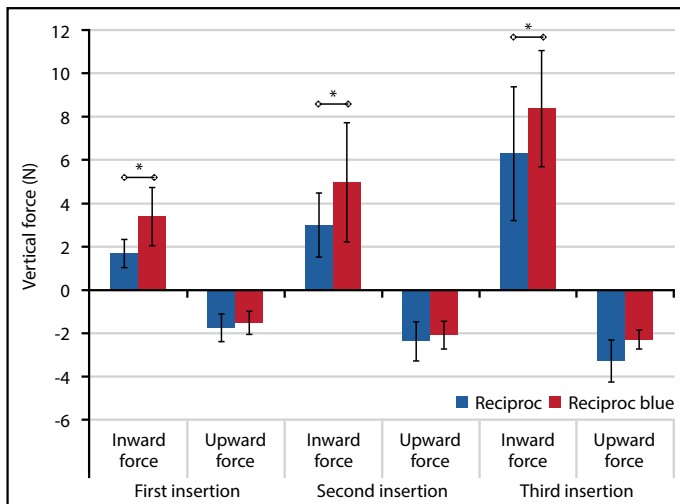


Figure 2. The vertical peak force values of the upward forces and inward forces for each file insertion in the tested systems. Each column represents a mean of 13 peak force values and the asterisk means there is statistical significance

to negotiate the canal and advance in the apical direction. Collectively, the alloy treatment may play an important role in the efficiency of the RB in shaping force development.

Canal shaping is required to provide adequate space for chemical debridement. However, this step creates internal stresses and accumulates root canal strain that could lead to dentinal defects mainly at or near the file tip (29). As evident in previous studies, the reciprocating movement could reduce the force magnitude generated on the canal wall and prevent occurrence of root cracking (6, 30, 31). However, our results show that the tested systems generated high vertical forces. This could be attributed to the fact that canal shaping was made using a single file without prior shaping with smaller shaping files. This would develop a great contact surface with the canal walls, leading to increased stress on the canal walls and the file (6). This is obvious in the results where the generated peak forces exceeded 8 N. In a previous study, the multi-file systems did not generate more than 6.4 N peak force (23). Based on this finding, shaping the canal with smaller shaping files contributed to lower peak forces generated by the last shaping file. This puts the gentle shaping with single-file systems at question that has been mostly proposed based on simplicity and experience (6). Nonetheless, despite the higher forces detected with the tested file, no fracture and/or deformation was found. Premolar teeth with two separate and distinct canals from the pulp to the apex were chosen to ensure the presence of constricted canals. Each of the tested files was able to shape four constricted and straight canals. Based on this, it can be recommended that the reciprocating single-file systems are fracture-resistant and can be used to shape at least four canals (13, 32).

Minimal intervention dentistry was introduced to keep the tooth functioning providing that the case is managed effectively. This is applicable in endodontics wherein a clinical setting safe and effective mechanical debridement of the root canal system is partly dependent on the magnitude of forces exerted by endodontic files (32). The use of efficient files that

advance easily until reaching the WL would reduce the frictional forces (33). It has been reported that the resultant torque is proportional to the applied vertical force, wherein the shaping force would exert stresses on the canal walls and increase the torque (34). Therefore, the shaping force could affect the lifespan of the file, which might lead to file fracture (20, 24, 35).

The inward-directed force was investigated to study the screwing-in effect of files which is defined as a feeling that the file is being pulled into the canal during removal, especially when applied to the constricted canal (36). This phenomenon is potentially risky since it may lead to uncontrolled over-shaping of the canal beyond the canal foramen and possible file fracture (1, 36). The maximum upward forces attained with R and RB are similar to WaveOne and WaveOne Gold systems (24) but are considered higher than XP-Shaper and OneCurve systems (23). This might be due to the file design. On the hand, the current results were higher than Twisted File Adaptive, Twisted File, ProTaper Universal and ProTaper Next systems (25) which can be attributed to the use of a single file in this study without pre-shaping the canal successively with smaller files.

It is evident that temperature induces austenitic-martensitic transformation leading to different file's mechanical behaviour (37, 38). However, the current experiment was conducted at room temperature considering that the shaping time did not exceed 34 seconds in the three insertions. Clinically, this short time required to shape a canal in the presence of an endodontic irrigant at room temperature along with insulating dentin would not rise the temperature of the file.

In this study, there are limitations that should not be overlooked. The present work did not investigate the exerted torque because the tested files utilize the reciprocating-movement approach. Despite the variations in the morphology of natural teeth, attempts were made in the present study to ensure comparability of the experimental groups. Constricted canals were selected in this study and verified to provide additional challenges for the canal shaping, and straight canals were included to eliminate the effect of the inclination of force vectors which may affect the accuracy of the measurements (39). To ensure comparability in this study, efforts were made to allocate the root canals in one of the 2 groups. A balance between the groups concerning the WL was confirmed statistically. Furthermore, although the pressure applied during canal shaping might not be controlled and could present inaccurate values generated. Thus, the canals were shaped steadily and gently with a single clinician who has more than 8 years of experience with the reciprocating systems. Another limitation was that this study tested one aspect in the file behavior. Involving other research methods could provide a comprehensive picture about the tested systems. Therefore, a multimethod approach is required in future studies in order to improve the research internal validation and give an accurate translation of *in-vitro* findings to guide the clinical use (27, 40). Furthermore, the effect of the measured forces on file fatigue, deformation, and breakage, as well as on the root canal structure should be investigated.

CONCLUSION

Within the parameters of this study, the blue heat treatment influenced the forces developed during canal shaping as shown with the greater inward-directed forces induced with RB file during shaping constricted canals, compared to its counterpart.

Disclosures

Conflict of interest: The authors deny any conflict of interest.

Ethics Committee Approval: This study was approved by The King Abdullah International Medical Research Center Ethics Committee (Date: 07/02/2017, Number: RC17-008-R).

Peer-review: Externally peer-reviewed.

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