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Original Article

Force and vibration correlation analysis in the self-adjusting file during root canal shaping: An in-vitro study

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KEYWORDS
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Abstract *Background/purpose:* The focus of this study was to find a correlation between the forces and vibrations during root canal shaping. This can be used to predict the fracture of the self-adjusting file (SAF) in root canal shaping.
Materials and methods: Forty J-shaped resin blocks were used in this study. Simulated root canals of resin blocks were prepared with the SAF. Force and vibration during root canal shaping were measured by dynamometer and accelerometer respectively. The recorded time domain signal of force and vibration were transformed to frequency domain signals. Frequency domain signals had been used for correlation study between force and vibration amplitude. The root mean square (RMS) value of force and vibration signature for new file and file just before failure were statistically compared using t-test at 95% confidence interval (CI).
Results: Vibrations generated during root canal shaping exhibited positive linear correlation ($r = 0.9173$) with force exerted by the SAF on the root canal. It means vibration has strong correlation with force. The RMS values of force and vibration increase significantly ($P < 0.05$) just before the fracture.
Conclusion: From force and vibration analysis of SAF it was concluded that the vibration is well associated with force applied by the SAF on root canal. Therefore, the trend of force variation was reflected in the vibration signature. The sudden increment in vibration was the symptom of bulge formation and the end of useful life of the SAF.

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Introduction

First root canal instrument was reported in 1838; Edwin Maynard prepared the root canal using a watch spring as shaping file.[1] On the basis of that method, different endodontic instruments were designed, fabricated and used in clinical practice. Dentists have been using nickel-titanium (NiTi) rotary files since 1988.[2] NiTi instruments are more flexible than stainless steel alloy and they are able to go through curved root canal. In order to enhance its performance, the design fabrication and heat treatment process[3] of the endodontic instrument are continuously transforming over the time. Each of new design brings new features and protocols to improve clinical practice. But more or less some typical issues like screwing in, canal deviation and apical transportation are still there with endodontic instruments. To evade the issues related to rotary instruments, the reciprocating instrument was used. However, reciprocation instruments were not able to adequately shape flat root canals.[4] ReDent-Nova (Ra'Anana, Israel) addressed issues such as screw-in effect and shaping of flat root canals in the designing of the self-adjusting file (SAF). The SAF has adjustable, adaptable, thin-walled, hollow pointed cylinder lattice like structure.[4–7] The motion of the SAF is different from other existing instrumentation techniques. The SAF performs in and out oscillatory motion in root canal at the speed of 50 Hz—83.33 Hz instead of continuous angular motion.[4] Root canals with complicated geometry, oval or flat shape cross sections can easily be shaped using the SAF without affecting the original shape and canal integrity, because it does not cut the canal wall.[8]

Apart from its shaping ability, the literature reveals that the SAF loses its filing capability with working time and on further use, the SAF becomes distorted followed by fracture. Different experimental and clinical studies carried out to know about the working and sustainability of the SAF.[9] Reciprocating motion of the SAF generates vibration during root canal shaping. Few studies carried out on these vibrations and comfort[10] condition of patients.[11] This study attempts to investigate vibrations and force generated during root canal shaping using the SAF. Results are shown as time and frequency response. The study shows that frequencies of force and vibration responses are strongly correlated, measured vibrations can be used to predict forces generated during root canal shaping and fracture of endodontic file. This study has clinical relevance to prevent separation of files in the root canal system due to forces exerted on the file, during instrumentation procedures in routine endodontic practice. This may be useful to develop smart endodontic instruments by sensing the amplitude and trend of vibration signature.

Materials and methods

In the present study, forty square pillars, J-shape endodontic training blocks (Endo Training Bloc-J, Dentsply Maillefer, Ballaigues, Switzerland) have been used for force and vibration analysis of the SAF file. Each block was held in a vice to provide a rigid support during experimentation and prevents displacement of the block from its home position. This vice has been mounted on a Kistler dynamometer (Kistler Group, Winterthur, Switzerland) for force measurement. An accelerometer Dytran 3093B (Dytron Corp., Fraser, USA) is used for sensing vibration signals. The accelerometer is mounted on the vice at nearest point to endodontic block, as shown in Fig. 1. Data acquisition frequency for dynamometer and accelerometer are set at 7142 Hz and 51,200 Hz respectively. Sensors are directly connected with data acquisition system, which converts current and voltage signals into respective values of force and acceleration with respect to time. Both data acquisition systems are connected to a computer for online signal monitoring (visualization) and acquisition. Further, force and vibration signals are processed in MATLAB® software developed by MathWorks®, Natick, USA.

The simulated root canals have been prepared by an endodontist having experience of more than five years. Glide path of each endodontic block is verified or established using #15 K file (Dentsply Maillefer, Ballaigues, Switzerland). Each canal is prepared using the SAF file operating at the speed of 5000 oscillations (ω_f = 83.33 Hz) per minute and 0.4 mm amplitude with continuous irrigation of water.The SAF file is used with WaveOne motor (WOM, Dentsply Maillefer, Ballaigues, Switzerland) along with a vibrating hand-piece head (RDT3: ReDent-Nova Reanana, Israel). During canal preparation endodontist manually perform up and down motion (pecking) of the hand-piece.

For real-time monitoring of the SAF during root canal shaping, the separate endodontic file has been used to prepare each root canal. Total forty (n = 40) SAF have been used in this study. The peak amplitude of vibrations and forces correspond to oscillation frequency (ω_f = 83.33 Hz) of the SAF. Responses have been analyzed in frequency domain (FFT of signals) to find correlation between force and vibration. The correlation coefficient between force and vibration amplitude (f and v) is calculated from the following equation.[12]

$$r=\frac{\sum_{i=1}^{n}\left(f_i-\overline{f}\right)(v_i-\overline{v})}{\sqrt{\sum_{i=1}^{n}\left(f_i-\overline{f}\right)^2}\sqrt{\sum_{i=1}^{n}(v_i-\overline{v})^2}} \quad (1)$$

For statistical comparison, root mean square (RMS) values of force and vibration signature for normal running

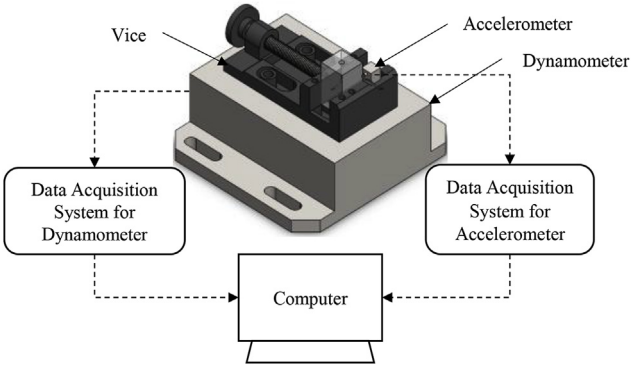

Fig. 1 Schematic diagram of experimental setup.

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