Dynamic Torque and Vertical Force Analysis during Nickel-titanium Rotary Root Canal Preparation with Different Modes of Reciprocal Rotation

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Abstract

Introduction: The purpose of the present study was to compare 2 modes of reciprocal movement (torque-sensitive and time-dependent reciprocal rotation) with continuous rotation in terms of torque and apical force generation during nickel-titanium rotary root canal instrumentation. **Methods:** A custom-made automated root canal instrumentation and torque/force analyzing device was used to prepare simulated canals in resin blocks and monitor the torque and apical force generated in the blocks during preparation. Experimental groups (n = 7, each) consisted of (1) torque-sensitive reciprocal rotation with torque-sensitive vertical movement (group TqR), (2) time-dependent reciprocal rotation with time-dependent vertical movement (group TmR), and (3) continuous rotation with time-dependent vertical movement (group CR). The canals were instrumented with TF Adaptive SM1 and SM2 rotary files (SybronEndo, Orange, CA), and the torque and apical force were measured during instrumentation with SM2. The mean and maximum torque and apical force values were statistically analyzed using 1-way analysis of variance and the Tukey test (α = 0.05). **Results:** The recordings showed intermittent increases of upward apical force and clockwise torque, indicating the generation and release of screw-in forces. The maximum upward apical force values in group TmR were significantly smaller than those in group CR (P < .05). The maximum torque values in clockwise and counterclockwise directions in groups TqR and TmR were significantly smaller than those in group CR (P < .05). **Conclusions:** Under the present experimental conditions using TF Adaptive instruments, both torque-sensitive and time-dependent reciprocal rotation generated significantly lower maximum torque and may have advantages in reducing stress generation caused by screw-in forces when compared with continuous rotation. *(J Endod 2017;■:1–5)*

Key Words

Fracture, nickel-titanium rotary instrument, reciprocating, reciprocation, screw-in force, torsional fatigue

Significance

Torque-sensitive and time-dependent reciprocal rotation generated significantly lower maximum torque values when compared with continuous rotation, suggesting that the 2 modes of reciprocal rotation have advantages in reducing torsional fatigue that lead to instrument separation.

Reciprocal rotation has been introduced in nickel-titanium (NiTi) rotary root canal preparation with the claim that this type of movement enables the preparation of root canals with only a single NiTi rotary instrument (1, 2). It has also been demonstrated that reciprocal rotation increases the resistance to failure when compared with continuous rotation because it relieves stress on the instrument and reduces the risk of cyclic fatigue caused by tension and compression (3–5). Based on these findings, single-file systems such as WaveOne (Dentsply Maillefer, Ballaigues, Switzerland) and Reciproc (VDW, Munich, Germany) have been developed. The movement adopted in these systems is a repeated counterclockwise and clockwise rotation regardless of the torque during shaping, which is defined as time-dependent reciprocal rotation.

Recently, progressive torque reverse mechanisms with reciprocal rotation have been developed and marketed as the Root ZX II Optimum Torque Reverse Module (J. Morita, Kyoto, Japan) and the TF Adaptive system (SybronEndo, Orange, CA) (6). Both motors rotate in the cutting direction continuously, and when a predetermined torque is detected, the apparatus automatically reverses the direction of rotation and again rotates to the cutting direction without detecting torque. This type of reciprocal rotation is defined as torque-sensitive reciprocal rotation.

The tendency to bind into the root canal is a known disadvantage of NiTi rotary instruments. This "screw-in" effect is caused by an apical driving force that is generated by the binding of the instrument blades in the root dentin because of the instrument's spiral configuration (7–9). This screw-in force gives the sensation of the rotating file being pulled into the canal in an apical direction. The binding force may also increase torsional fatigue and lead to locking and separation of the instrument (8–10). Reciprocal rotation may reduce such instrument binding because the momentary rotation in the noncutting direction releases torsional stresses (10); however, the

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generation of dynamic apical driving forces during NiTi rotary preparation using reciprocal rotation systems has not yet been fully investigated.

The purpose of the present study was to compare 2 modes of reciprocal movement (torque-sensitive and time-dependent reciprocal rotation) with continuous rotation in terms of torque and apical force generation during NiTi rotary root canal instrumentation. To achieve this purpose, a customized device for automated root canal instrumentation and torque/force analysis was developed. Our hypothesis was that torque-sensitive and time-dependent reciprocal rotation generate significantly smaller torque/force values when compared with continuous rotation during NiTi root canal instrumentation.

Materials and Methods

Automated Root Canal Instrumentation and Torque/ Force Analyzing Device

The device consisted of a prototype motor for automated root canal instrumentation (J Morita, Kyoto, Japan), a motorized test stand (MX2-500N; Imada, Aichi, Japan), and a torque/force measuring unit (Fig. 1*A*). The handpiece of the motor was attached to the moving stage of the test stand using a custom-made holder. The insert angle between the root canal axis and the axial plane was adjusted to 90° using a digital inclinometer (Bevel Box BB-180; Niigata Seiki, Niigata, Japan).

The automated root canal shaping motor was programmed to rotate with the following 3 different rotation modes. In the torque-sensitive reciprocal rotation mode (group TqR), the motor was programmed to detect torque values every 180° during rotation (300 rpm), and when the predetermined torque value (0.4 Ncm) was detected, the motor reversed its rotation 90° to the noncutting direction and then 180° to the cutting direction without torque control. In the time-dependent reciprocal rotation mode (group TmR), the motor repeatedly rotated 90° to the noncutting direction and 180° to the cutting rotation at 300 rpm regardless of torque. In the continuous rotation mode (group CR), the device was set to rotate continuously at 300 rpm.

The moving handpiece was programmed to move in the up or down direction at 10 mm/min regardless of the stress applied. In the torque-sensitive movement, the handpiece moved down for 2 seconds and up for 1 second when the torque was below the predetermined value, simulating the pecking motion. When the predetermined torque was detected, the handpiece moved down for 0.25 seconds (simulating the time lag between the torque detection and instrument withdrawal) and then up for 3 seconds (simulating instrument withdrawal). In the time-dependent movement, the handpiece moved down for 2 seconds and up for 1 second regardless of torque values.

The torque/force measuring unit consisted of a torque sensor (LUX-B-ID; Kyowa Electronic Instruments, Tokyo, Japan) for measuring apical force and strain gauges (KFG-2-120-D31-11, Kyowa Electronic Instruments) for measuring torque (Fig. 1*A*). A metal stage on which a canal model was fixed was connected to the torque sensor with a round metal rod that had a flattened portion in its center. The strain gauges were adhered to the flattened portion. The correlation coefficient of 2.609 for the conversion of distortion values (measured by the strain gauges) to torque values was determined by applying known torques (to the clockwise and counterclockwise direction) to the metal rod by hanging weights with a string of known length (Fig. 1*B* and *C*). Apically directed and opposite forces on the root canal model were defined as positive and negative forces, respectively. Cutting (clockwise) and noncutting (counterclockwise) directions were defined as positive and negative, respectively, in torque values.

Root Canal Instrumentation

A total of 21 simulated resin canal models with a straight canal (END3L001; Nissin Dental Products, Kyoto, Japan; 0.2-mm apical

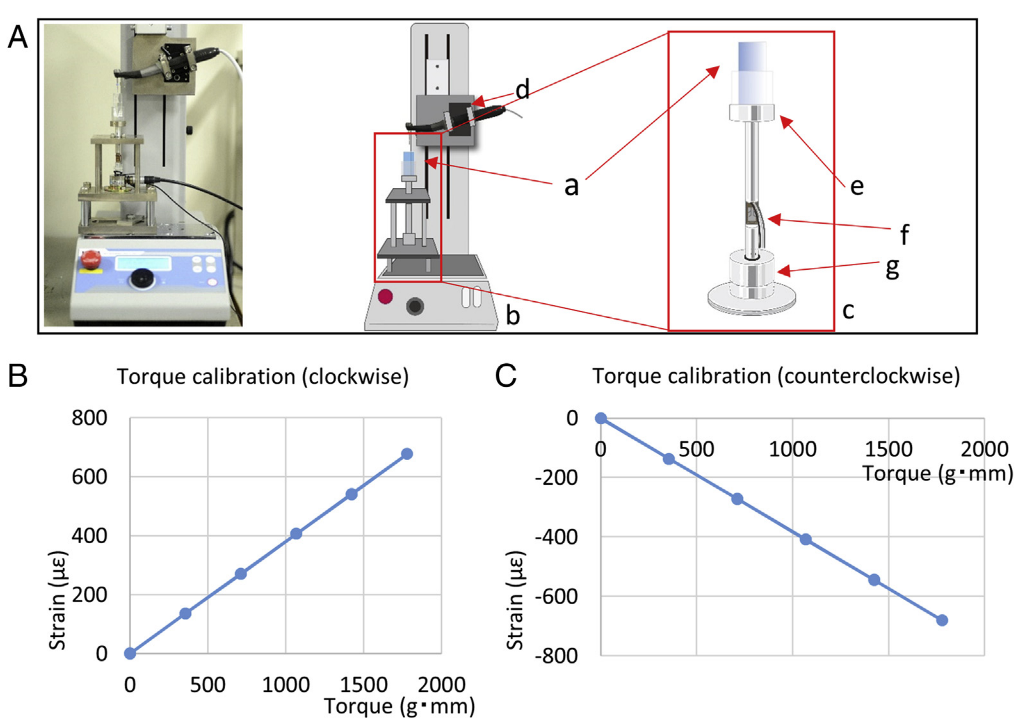

Figure 1. (*A*) The root canal instrumentation and torque/force analyzing device used in this study. a, root canal model; b, motorized test stand; c, torque/force measuring unit; d, custom-made handpiece holder; e, metal stage with an acrylic tube; f, strain gauge; g, torque sensor. (*B* and *C*) Calibration graphs for torque in the positive domain (clockwise, *B*) and negative domain (counter clockwise, *C*).