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ABSTRACT

Vibration characteristics of endodontic motors with different motion: reciprocation and conventional rotation

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Objectives: By introduced reciprocation motion file in dentistry, dentists benefit simple canal shaping procedure and time-saving. But, reciprocation motion generates uncomfortable vibration to doctors and patients. Because there was no study about this consideration, this study compared vibration pattern and power generated from reciprocation motion motor and conventional rotary motor. Materials & Methods: One conventional rotary motor; X-Smart (Dentsply Maillefer, Ballaigues, Switzerland); and two reciprocating motors; WaveOne Motor (Dentsply Maillefer, Ballaigues, Switzerland) and X-SMART PLUS (Dentsply Maillefer, Ballaigues, Switzerland); were used in this study. Triaxial ICP® Accelerometer (Model 356A12, PCB piezotronics, New York, USA) was attached on motor's handpiece head, and was measured tri-axial vibratory acceleration with NI Sound and Vibration Assistant 2009 software (National Instruments, Texas, USA). Mean vibratory acceleration and maximum vibratory acceleration was measured on fixed position and handed position. The results of vibratory acceleration were statistically analyzed using ANOVA and multiple comparisons are made using Turkey's test at $p<0.05$ level. Results: Reciprocating motors showed higher mean vibratory acceleration and maximum vibratory acceleration than conventional rotary motor ($p<0.05$). Between reciprocating motors, X-SMART PLUS had lower mean vibratory acceleration and maximum vibratory acceleration than WaveOne Motor ($p<0.05$). Conclusion: Reciprocating motors generate more vibration than conventional rotary motor. Further study about effect of vibration to dentist and patient is needed. And it seems to be necessary to make a standard about vibration level in endodontic motors.

Key words : Endodontic motor vibration; Reciprocation; Triaxial accelerometer; WaveOne; Reciproc; X-Smart; WaveOne Motor; X-SMART PLUS

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Ⅰ. Introduction

Recently, single-file endodontic systems, which use reciprocation motion, have been introduced, such as WaveOne(Dentsply Maillefer, Ballaigues, Switzerland) and Reciproc(VDW, Munich, Germany)[1]. Because these file systems do not use conventional rotary motion, but reciprocation motion[2], they must be used by special automated endodontic motors, such as WaveOne Motor(Dentsply Maillefer, Ballaigues, Switzerland), VDW.SILVER motor(VDW, Munich, Germany), and X-SMART PLUS(Dentsply Maillefer, Ballaigues, Switzerland).

WaveOne and Reciproc single-file instruments are advanced in the canal and engaged dentin to cut it when the endodontic motors rotated in a counterclockwise movement, which will disengage when the endodontic motors are rotated in clockwise. Disengaging reduces a screw-in effect in instruments and risk of instrument fracture[2]. Because the root canal shaping procedure is completed using a single-instrument, the root canal treatment procedure is simplified, and the treatment time is reduced[3~6]. The risk of cyclic fatigue fracture is also reduced[2, 7, 8].

However, the reciprocation motion generates vibrations in the endodontic motor when the rotation direction is changed. It is highly likely to lead to patient discomfort[9, 10]. It can also reduce the controllability of nickel-titanium instruments, badly affecting the dentist's body. Although previous studies have analyzed the torque generated from endodontic motors[11], there has been no research into the vibrations of endodontic motors. Because there was no study about this consideration, this study compared vibration pattern and power generated from reciprocation motion motor and conventional rotary motor.

In this study, the vibration characteristics of three endodontic motors(X-Smart, WaveOne Motor, and X-SMART PLUS) are compared and evaluated.

Ⅱ. Materials and methods

1. Materials

This study used three endodontic motors: X-Smart(Dentsply Maillefer, Ballaigues, Switzerland), WaveOne Motor(Dentsply Maillefer, Ballaigues, Switzerland), and X-SMART PLUS(Dentsply Maillefer, Ballaigues, Switzerland). the X-Smart can be used for conventional rotary motion only, while the WaveOne Motor and the X-SMART PLUS can be used for both conventional rotary motion and reciprocation motion. All endodontic motors are rarely used in clinical purpose.

To measure the vibration generated from the endodontic motors' handpiece, a Triaxial ICP® accelerometer(Model 356A12, PCB piezotronics, NY, USA), measuring the vibratory acceleration tri-axially, was attached to the head of the endodontic motors' handpiece. Vibratory acceleration was analyzed using NI Sound and Vibration Assistant 2009 software(National Instruments, Austin, TX, USA).

2. Methods

Because the X-Smart could not be used for reciprocation motion, the vibratory acceleration measurement of the X-Smart was performed in relation to conventional rotary motion only, the WaveOne Motor and the X-SMART PLUS were performed in relation to both a conventional rotary motion and a reciprocation motion. The endodontic motor settings of the conventional rotary motion were 300 rpm, 2.0Ncm, and those of the WaveOne file were "WAVEONE ALL" mode, while those of the Reciproc file were "RECIPROC ALL" mode. Two kinds of vibratory acceleration were measured: holding the handpiece with a pen grasp(handed position) and placing a handpiece on a handpiece stand(fixed position).

The accelerometer was attached to each of the three endodontic motor heads with paraffin wax, and vibratory acceleration was measured on three axises of the handpiece: X-axis, Y-axis, and Z-axis (Fig. 1). The X-axis was at a direction parallel to the handpiece's long-axis; the Y-axis was at a direction perpendicular to the handpiece's long-axis; and the Z-axis was at a direction perpendicular to the endodontic motor head surface. These vibratory accelerations were sent to computer by DAQ Board and Wi-Fi carrier,

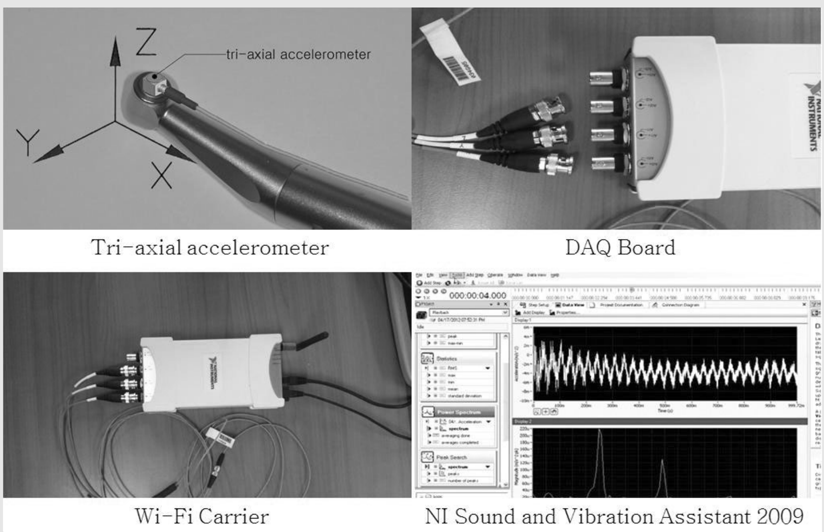

Fig. 1. Representative photograph of vibration test

and measured by NI Sound and Vibration Assistant 2009 software in real-time. The acceleration data consisted of 76800 values for three seconds. 76800 values were divided by one cycle. One cycle was defined as one rotation for conventional rotary motion, and defined as being from the start point of counterclockwise rotation to the end point of clockwise rotation for the reciprocation motion. For the conventional rotary motion, the WaveOne file and the Reciproc file each consisted of each 15 cycles, 30 cycles, and 26 cycles. The mean value and the maximum value of all cycles were calculated.

3. Statistical analysis

The mean values and maximum values were statistically analyzed using one-way ANOVA and multiple comparisons were made using Tukey's test, with statistical significance at the level of 95%.

Ⅲ. Results

The mean values and the maximum values of the vibratory accelerations are shown in Table 1 and Table 2.

The mean values and maximum values of the reciprocation motion(WaveOne Motor, X-SMART PLUS) were higher than that of the conventional rotary motion(X-Smart, WaveOne Motor, X-SMART PLUS) ($p < 0.05$). In the reciprocation motion, the mean values and maximum values of the vibratory acceleration of the WaveOne Motor were higher than those of the X-

Table 1. Mean values and standard deviations of vibratory acceleration (g; gravity)

	Rotary motion		Reciprocation motion (WaveOne)		Reciprocation motion (Reciproc)	
	Handed	Fixed	Handed	Fixed	Handed	Fixed
X-Smart	0.27±0.01[a]	0.24±0.01[a]				
WaveOne Motor	0.25±0.01[b]	0.24±0.01[b]	0.85±0.04[a]	0.64±0.04[a]	0.61±0.03[a]	0.45±0.03[a]
X-SMART PLUS	0.14±0.01[c]	0.13±0.00[c]	0.30±0.02[b]	0.32±0.02[b]	0.23±0.02[b]	0.26±0.02[b]

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Table 2. Maximum values and standard deviations of vibratory acceleration (g; gravity)

	Rotary motion		Reciprocation motion (WaveOne)		Reciprocation motion (Reciproc)	
	Handed	Fixed	Handed	Fixed	Handed	Fixed
X-Smart	1.62±0.21[a]	1.30±0.11[a]				
WaveOne Motor	4.35±0.46[b]	4.03±0.52[b]	12.36±2.65[a]	12.09±1.60[a]	13.71±2.51[a]	10.74±1.37[a]
X-SMART PLUS	1.00±0.18[a]	1.00±0.18[a]	5.62±0.92[b]	5.30±0.79[b]	4.31±0.69[b]	4.40±0.81[b]

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SMART PLUS($p < 0.05$). In the conventional rotary motion, the mean values of vibratory acceleration were in the order of X-Smart > WaveOne Motor > X-SMART PLUS($p < 0.05$), but the difference was very slight clinically. The maximum values of vibra tory acceleration were the highest in the WaveOne Motor($p < 0.05$), while the X-Smart and X-SMART PLUS showed lower similar values than the WaveOne Motor($p > 0.05$).

Graph characteristics of the X-axis, Y-axis, and Z-axis in relation to vibratory acceleration, show consistent values in the conventional rotary motion, but revealed two rapid peaks per cycle in the reciprocation motion(Fig. 3, 4). The rapid peak was considered to be a moment of rotation change. The rapid peak was shown in a fixed position(Fig. 4).

Ⅳ. Discussion

The endodontic motor, for conventional rotary motion, is designed to work at a constant speed without rapid acceleration change. However, because the endodontic motor for the reciprocation motion has a rotation change, it has vibration impact. Due to the fact that the rotation direction has to be changed in a moment, vibration impact is unavoidable. The WaveOne Motor, the first endodontic motor for reciprocation motion, generated the highest vibration, but the X-SMART PLUS, the next series of X-Smart, had a lower vibration than the WaveOne Motor. Handpiece blueprints are needed to analyze the reason. It is possible that the high vibration of reciprocation motion negatively affects dentist/patient comfort.

From the patient's perspective, because vibration from the endodontic motor is delivered under high stress conditions of endodontic treatment[12], it is possible that vibration impact is regarded as highly stressful factor. Consequently, vibration stress may affect treatment satisfaction. Vibratory acceleration values were high enough to cause discomfort, but further study is needed to show how this can be efficiently conveyed to a patient. Further studies must consist of an experimental model, a reproduced oral environment, and a questionnaire about the link between vibration and treatment satisfaction.

From the dentist's perspective, vibration of the endodontic motor may influence tactile sense of torque. When nickel-titanium endodontic file is bound excessively to root canal, the response of the backward movement may be delayed. Other studies have reported that the torque of reciprocation was higher than that of the conventional rotary motion.

When the rotation direction of the reciprocation motion is changed, rapid peaks of vibratory acceleration are generated. Using these peaks, it is possible

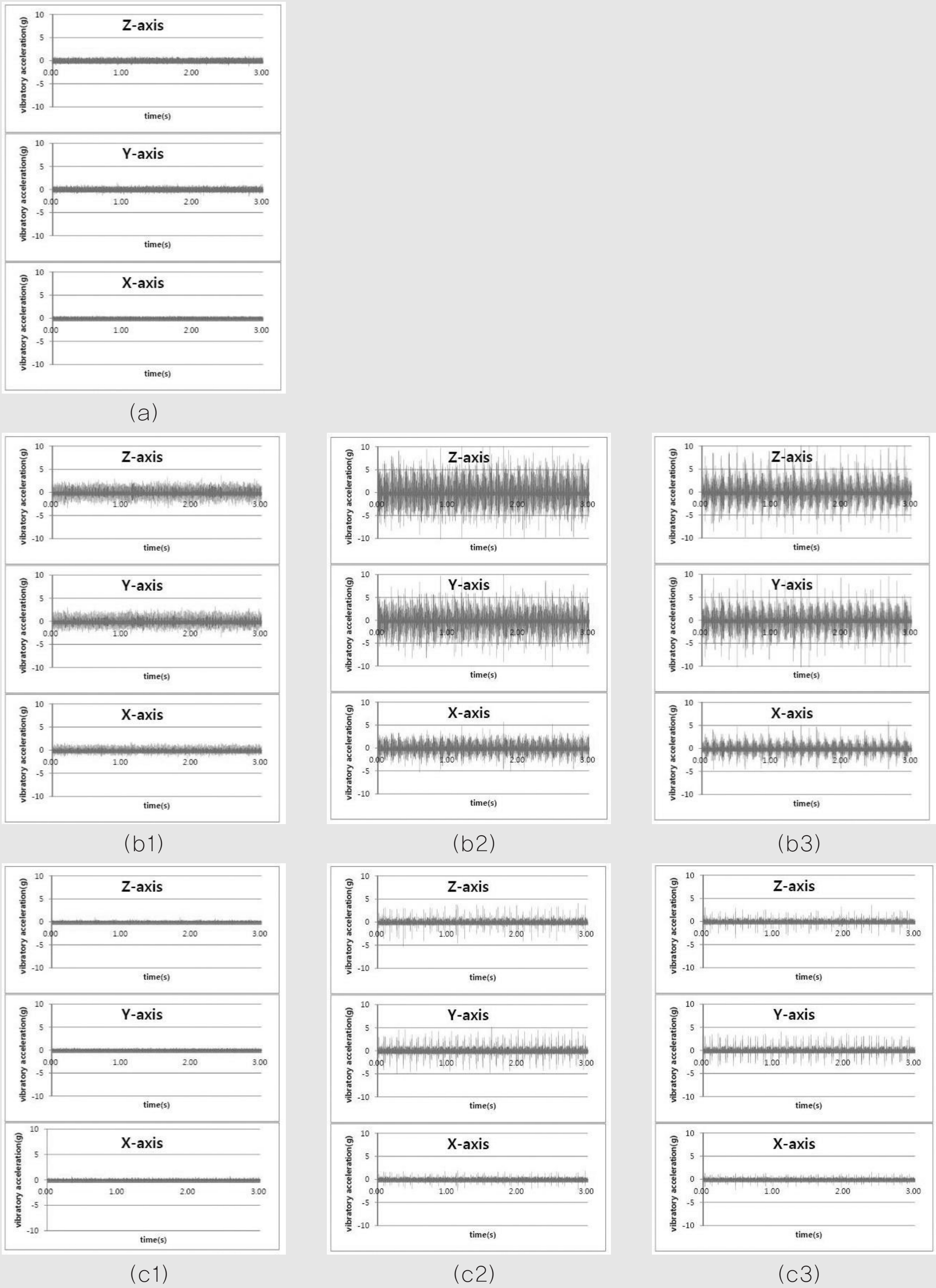

Fig. 3. Comparison of vibration graph in handed position. (a) rotary motion, X-Smart. (b1) rotary motion, WaveOne Motor. (b2) Reciprocation motion, WaveOne, WaveOne Motor. (b3) Reciprocation motion, Reciproc, WaveOne Motor. (c1) rotary motion, X-SMART PLUS. (c2) Reciprocation motion, WaveOne, X-SMART PLUS. (c3) Reciprocation motion, Reciproc, X-SMART PLUS.

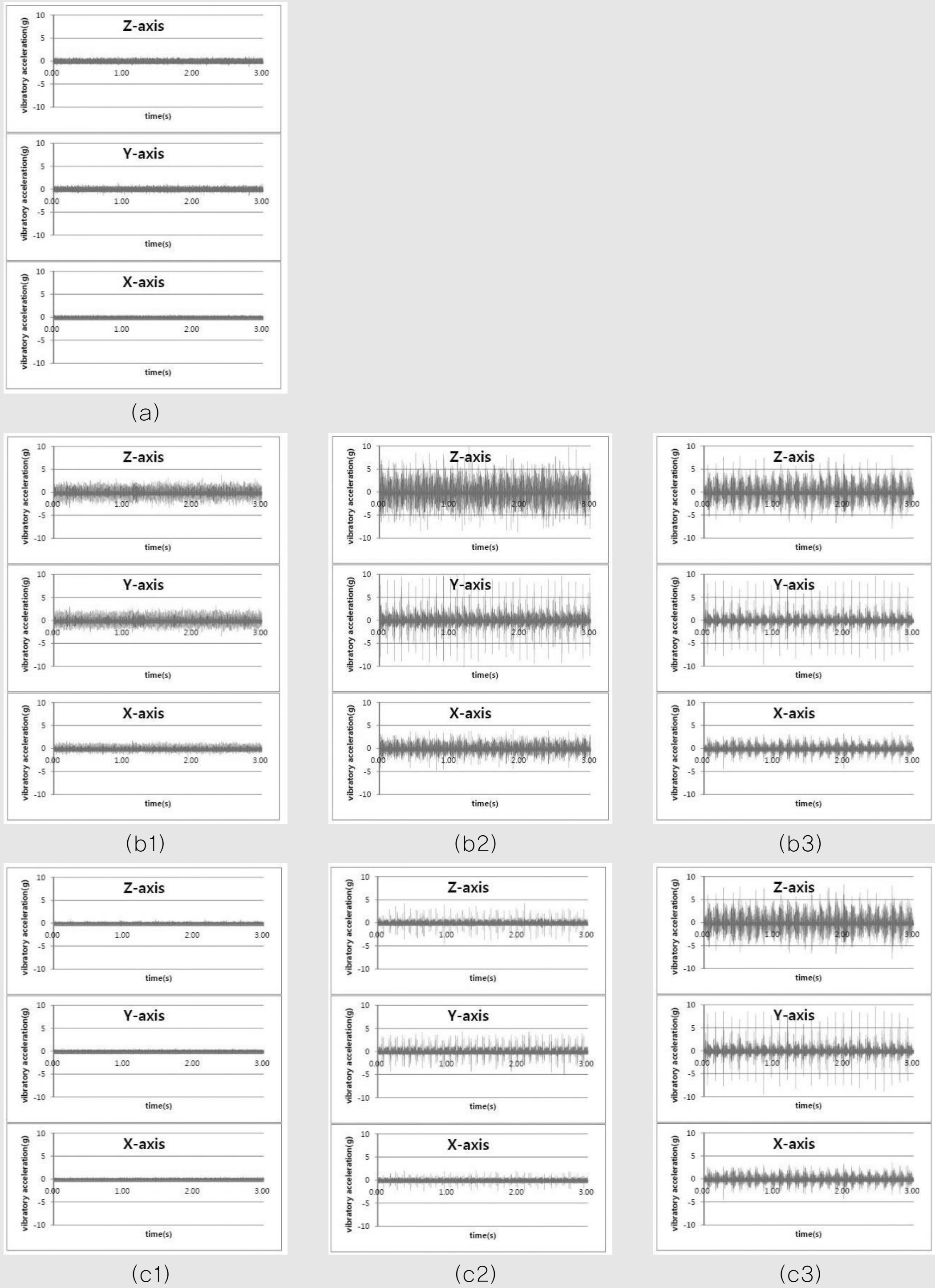

Fig. 4. Comparison of vibration graph in fixed position. (a) rotary motion, X-Smart. (b1) rotary motion, WaveOne Motor. (b2) Reciprocation motion, WaveOne, WaveOne Motor. (b3) Reciprocation motion, Reciproc, WaveOne Motor. (c1) rotary motion, X-SMART PLUS. (c2) Reciprocation motion, WaveOne, X-SMART PLUS. (c3) Reciprocation motion, Reciproc, X-SMART PLUS.

to determine one cycle time. Seeing the best features of vibratory acceleration graph(fixed, Y-axis), WaveOne takes 0.099 seconds per cycle, and Reciproc takes 0.115 seconds per cycle(Fig. 2). When calculating cycles per second based on this, WaveOne has 10.08 cycles/second, while Reciproc has 8.74 cycles/second.

Assuming that the counterclockwise and clockwise rotation speed is constant, and using a ratio of rotating degree(according to manufacturer, counterclockwise 170° and clockwise 50° for WaveOne, countercloc kwise 150° and clockwise 30° for Reciproc), it is expected that the rotating change time can be calculated. This time corresponds with the rapid peak in the graph, so the rapid peak is regarded as the moment of rotational change. When the rotational direction changes from clockwise to counterclockwise, the WaveOne Motor shows the highest vibratory acceleration peak value; however, X-SMART PLUS shows similar peak values regardless of rotational direction. This difference is regarded as a main cause of the vibratory acceleration difference between the two endodontic motors.

It is also possible to calculate the revolutions per minute(rpm) of the endodon tic motors. In the case of WaveOne, it is rotated to 220° (counterclockwise 170°, clockwise 50°) per one cycle(0.099 second), and rotated to 133333° per minute, corresponding to 370.37 rpm. In the case of Reciproc, it is rotated to 180°(counterclock wise 150°, clockwise 30°) per one cycle (0.115 second), and rotated to 93913° per minute, 260.87 rpm. The rpm count mentioned by the manufacturers(WaveOne

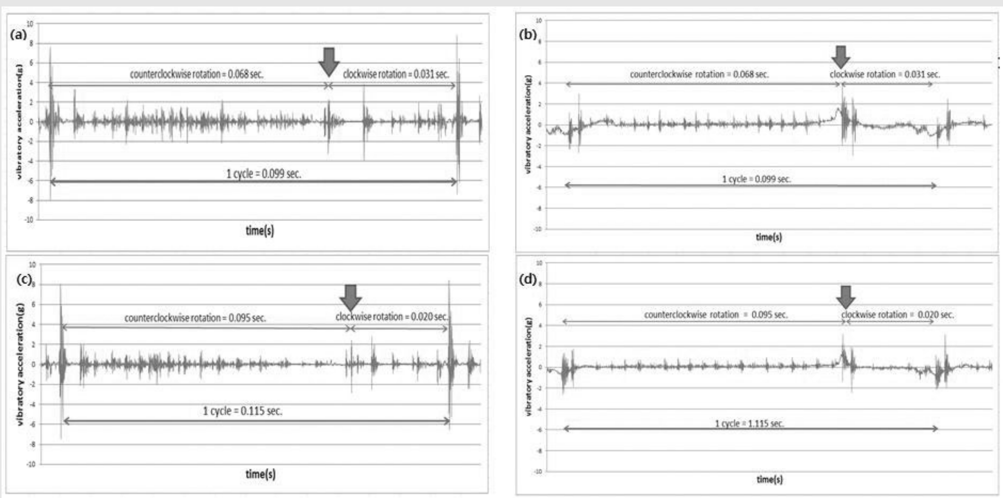

Fig. 2. One cycle vibration graph of reciprocation motion. (a) WaveOne, WaveOne Motor, fixed position. (b) Reciproc, WaveOne Motor, fixed position. (c) WaveOne, X-SMART PLUS, fixed position. (d) Reciproc, X-SMART PLUS, fixed position.

350 rpm, Reciproc 300 rpm) differs from the count found in this study.

In this study, an accelerometer was attached to the head of the endodontic motors' handpiece head. This method faced a problem because the mass and attached method of the accelerometer may affect vibratory acceleration values. Therefore Laser Doppler vibrometers using non-contact techniques are a suitable alternative method to traditional vibration sensors such as accelerometers[13].

This study is designed to focus on two grip positions(handed position, fixed position). The vibratory acceleration of the handed position was shown to be higher than that of the fixed position in the WaveOne, and showed similar values between the two positions in the Reciproc. How hard a dentist grips a handpiece affects the amount of vibrational energy entering the hands; therefore, hand-grip force is another important factor in the exposure assessment[14). A study design analyzing an endodontic motor vibration has not yet been established. Further study is necessary to establish a typical study design for analyzing an endodontic motor vibration.

Ⅴ. Conclusion

Reciprocating motors generate more vibration than conventional rotary motors ($p < 0.05$). Thus, further study about the effects of vibration on dentists and patients is needed. Specifically, it seems to be necessary to establish a standard regarding vibration level in endodontic motors.

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