Application of Using Standard Equipment for Dental Scaler Tip Testing according to ISO 18397

Chompoonoot Hirunyapruk and Tassanai Sanponpute

Mechanical Metrology Department, National Institute of Metrology (Thailand), Pathumthani 12120, Thailand

Abstract: The objective of this work was to study the use of standard equipment in amplitude and frequency tests of dental scaler tip according to ISO 18397. Four types of standard equipment: a laser displacement sensor, a microscope, a tachometer, and an ultrasonic frequency meter, were experimentally investigated to test a tip. The standard laser displacement sensor and the standard microscope were used to test the unloaded amplitude of the scaler tip. It was found that two types of standard equipment were able to measure the unloaded amplitude of the tip. The standard microscope was also employed for the loaded amplitude test. This test was performed by pressing the scaler tip with a load of 1 N, which was measured by a load cell set. The peak-to-peak amplitude found from the test was 116.7 μm . The frequency test of the scaler tip was conducted using the standard laser displacement sensor, the tachometer and the ultrasonic frequency meter. All three types of standard equipment were found to be able to test the frequency of the tip without cooling liquid. Nevertheless, only the standard tachometer was capable of measuring the frequency of the tip with cooling liquid applied.

Key words: Dental scaler tip, ISO 18397, testing, standard equipment.

1. Introduction

A dental scaler is a hand-held device used widely in dentistry. The device needs to be designed so that its performance conforms to international standards such as ISO 18397 [1]. One of the requirements of performance tests specified in ISO 18397 is the vibration characteristic of scaler tip. There have been several studies on the tip performance assessment [2-8]. Lea et al. [2] assessed vibration characteristics of ultrasonic scalers using a scanning laser vibrometer. The assessments were performed in various conditions such as the various water flow rate and power setting of the device in an unloaded condition. The displacement amplitudes were found in the order of nanometers. The authors [3] continued their study to assess the oscillatory characteristics of various ultrasonic generators and various scaler tips. The effect of loading on the scaler tip amplitudes was later investigated in the work of Lea et al. [4]. The investigations were also conducted using the scanning

laser vibrometer. The insert tips were applied with loads of 0.25, 0.5 and 1.0 N under various power settings. The displacement amplitudes were found increasing with applied power and affected by the applied loads. The correlation of vibrometry and cleaning effects in ultrasonic dental instrument was studied by Tiong et al. [5] by using sonochemical method. Although assessment of scaler tip vibration characteristics has been proposed, the standard equipment used, i.e. scanning laser vibrometer, is too expensive for using in dental industry. This paper presents an alternative cheaper equipment to test dental scaler tip. Four types of standard equipment were experimentally investigated. The standard laser displacement sensor and the standard microscope were studied for the unloaded amplitude test of the scaler tip, while the standard microscope with the load cell set was used for the loaded amplitude test. Three types of standard equipment: the standard laser displacement sensor, the standard tachometer and the standard ultrasonic frequency meter were studied for the frequency test.

Corresponding author: Chompoonoot Hirunyapruk, Ph.D., research field: mechanical metrology.

2. Unloaded Vibration Amplitude Test

Dental scaler tips are required to be tested according to ISO 18397. Three tests considered in this paper are unloaded amplitude test, loaded amplitude test and frequency test. The dental scaler tips, which conform to ISO 18397, should be tested by the standard equipment having the accuracy within $\pm 10\%$ of the measured value.

The unloaded vibration amplitude test aims to measure a peak-to-peak distance of the unconstrained scaler tip when operating with or without cooling water. It is required in ISO 18397 that the standard equipment for unloaded amplitude test should be a non-contacting length measurement device. According to this requirement, two types of equipment were selected for this experiment. Those were a standard laser and a standard microscope. The accuracy of both laser displacement sensor and microscope was assessed by the calibrations presented in Ref. [6]. In this section, both types of standard equipment were used to test the unloaded vibration amplitude of a dental scaler tip model A-DENT Slim La-Ong 25K 1710 working together with an ultrasonic scaler generator model Mega II.

2.1 Standard Laser Displacement Sensor for Unloaded Vibration Amplitude

The standard laser used was a Keyence laser displacement sensor model LK-H022 with a controller model LK-G5001V. This standard laser was selected by considering three specifications, a beam diameter, speed, and accuracy. The beam diameter must be small enough to measure the vibration amplitude at the small end of the tip. As the tip diameter is approximately $184\ \mu\text{m}$, the laser beam selected should be three times smaller than this diameter. The beam diameter of the laser chosen is $25\ \mu\text{m}$. The sampling frequency of the laser displacement sensor needs to be fast enough to measure very high operating frequency of the scaler tip. The scaler tip of interest in this work operates at frequency about $24\ \text{kHz}$. The laser selected

measure displacement discretely. Its sampling cycle is $2.55\ \mu\text{s}$ or $392\ \text{kHz}$ approximately. The maximum accuracy of the laser displacement sensor in the working range between 40 and $230\ \mu\text{m}$ found from its calibration is 5.7% of reading [6].

The set-up of the unloaded amplitude measurement by the laser displacement sensor is shown in Fig. 1. The laser head model LK-H022 was located $2\ \text{cm} \pm 3\ \text{mm}$ far from the end of scaler tip and its beam was pointed to the tip as shown in Fig. 2. This aimed to determine the position of the tip by measuring the reflected light from the tip. This reflected light was reflected onto a CMOS detector inside the laser head. The detector then sent a signal to a laser controller model LK-G5001V and PC for analysis. The peak-to-peak amplitude was recorded after operating the tip without cooling water at least $1\ \text{min}$. In the experiment, the laser beam was pointed at 3 positions which are, at the free end of the tip and at $1\ \text{mm}$ and $2\ \text{mm}$ from the end of the tip. This aimed to investigate the vibration characteristic of the tip.

Fig. 1 Experimental set-up to measure unloaded amplitude using standard laser sensor.

Fig. 2 Distance between laser head and the unconstrained end of the scaler tip.

2.2 Standard Microscope for Unloaded Vibration Amplitude

The standard microscope used was a microscope model FZR350PC2 having maximum magnification of $\times 100$. The maximum accuracy of the microscope found from its calibration is 1.3% of reading in the working range 50 to 400 μm [6]. The set-up of the unloaded amplitude measurement by the microscope is shown in Fig. 3. The scaler tip was placed under the microscope. The light underneath the tip was set so that the output photo was clearly shown on computer screen. The tip was operated at least 1 min before the photo of the moving tip was recorded by the microscope as shown in Fig. 4. The peak-to-peak amplitude was then measured from the captured photo using a Measure PRO-EX software in computer.

2.3 Experimental Results for Unloaded Vibration Amplitude Test

The results of unloaded vibration amplitude test measured by the standard laser and the standard microscope are illustrated in Fig. 5. The vertical values shown in the figure is peak-to-peak amplitude averaged from four repeated measurements. The horizontal axis is measured positions presented in terms of the distance of the laser beam from the end of the scaler tip. It can be seen from the laser results ($\ominus$) shown in Fig. 5 that the peak-to-peak vibration amplitude decreases as the distance from the end of the tip increases. The maximum amplitude that occurred at the end of the tip was 88.7 μm with standard deviation of 5.8 μm . Fig. 5 ($\bullet$) shows the unloaded amplitude measured at the end of the tip by using the standard microscope. The measured amplitude obtained from standard microscope was 93.1 μm and its standard deviation was 7.6 μm . The result from the microscope was slightly higher than that from the standard laser at the end of the tip.

Although both types of standard equipment seem to be able to perform the unloaded vibration amplitude test, the results from the standard microscope may not conform to specifications in ISO 18397. As the standard ISO 18397 requires the unloaded amplitude

Fig. 3 Experimental set-up to measure unloaded scaler tip amplitude using standard microscope.

Fig. 4 Photo of scaler tip amplitude measurement by using microscope.

Fig. 5 Peak-to-peak unloaded vibration amplitude measured by: $\ominus$ using standard laser and $\bullet$ using standard microscope.

to be continuously measured for a certain period, the microscope can only measure the amplitude instantaneously. Its results are better to be used for verifying the standard laser.

3. Loaded Vibration Amplitude Test

The loaded vibration amplitude of the scaler tip was tested using a non-contacting measurement device, which was the microscope model FZR350PC2. The set-up for testing scaler tip under loaded condition is

Fig. 6 Experimental set-up to press the scaler tip with a load of 1 N.

Fig. 7 The set-up for loaded amplitude measurement using microscope.

shown in Fig. 6. The test was done by pressing the scaler tip laterally with a load of 1 N on the painted glass surface. The load of 1 N was measured by a load cell set that the glass was attached to. Only the end of the tip may touch the glass surface. The glass under the tip was moved in the direction perpendicular to the vibration direction so that the track of the tip occurred on the glass. The vibration tracks were recorded with and without power on and then the tracks were measured using the calibrated microscope as shown in Fig. 7. The loaded amplitude was calculated from the peak-to-peak amplitude obtained operating with power supply minus without power supply. The testing procedure was repeated three times. The average peak-to-peak amplitude obtained was 116.7 μm and the standard deviation of the result was 6.5 μm .

4. Oscillation Frequency Test

The oscillation frequency test aims to measure the frequency of the scaler tip at the operating area when the scaler tip is operated at the maximum liquid flow rate and maximum power. For this test, the non-contacting frequency measurement device with an accuracy of $\pm 10\%$ of the measured value is required

[1]. According to this requirement, three types of equipment were selected for experiment. Those were a standard laser displacement sensor, a standard tachometer, and an ultrasonic frequency meter. In this section, all three types of standard equipment were used to test the frequency of a dental scaler tip model A-DENT Slim La-Ong 25K 1710 working together with an ultrasonic scaler generator model Mega II.

4.1 Standard Laser for Frequency Test

Standard laser used for the frequency test was the Keyence laser displacement sensor which was the same laser used for unloaded amplitude test. The standard laser was employed to test the scaler tip under two conditions, with and without cooling water. The set-up for frequency measurement without cooling water is shown in Figs. 1 and 2. When operating scaler tip with water supplied, a thin plastic was placed between the standard laser and the tip under test to prevent damage to the laser. During the test, the scaler tip was operated for at least 1 min without any applied load and then the frequency was measured and recorded. The measured result from the standard laser without cooling water shows the sinusoidal movement. The measured frequency was obtained by performing curve fit to a sinusoidal function. However, the laser sensor was unable to measure the frequency of the tip with cooling water supplied. The reason might be that the spray from the tip causes the difficulty in receiving the reflect light from the tip.

4.2 Standard Tachometer and Ultrasonic Frequency Meter for Frequency Test

Two types of standard equipment that have been studied in this section were a TurboTester high speed tachometer model TT50k and a SonicSniffer ultrasonic frequency meter model SSNF80k-Plus. The tachometer has a neodymium magnet inside and aims to measure the change of magnetic flux caused by the magnetized scaler handpiece. The ultrasonic

frequency meter has a high frequency sensor inside. The positions of sensors inside the tachometer and the ultrasonic frequency meter are shown in Fig. 8a.

In this section, the influences of two parameters, i.e. the installed direction and the distance of the standard tachometer and frequency meter from the scaler tip under test, were examined experimentally. This study aimed to investigate the optimized installed position and direction of the standard equipment. The experiments on the tachometer and the ultrasonic frequency meter were conducted using the set-up shown in Fig. 8. The standard tachometer and ultrasonic frequency meter were installed in two directions. The sensors of both standard instruments were firstly pointed towards the scaler tip as shown in Fig. 8a for the first installed direction and pointed to the direction parallel to the tip as shown in Fig. 8b for the second installed direction. In the experiments, the distance between the standard equipment and the scaler tip was varied from 1 to 12 cm. The distance increased in increment of 1 cm. The frequency measurements by standard tachometer and ultrasonic frequency meter were performed simultaneously. The experiments were conducted both with and without cooling water. The measurements for each setting condition were taken twice so that the average of measured frequency could be calculated. Fig. 9 shows the average of measured frequencies in terms of the distance between the standard tachometer and the tip under test.

It can be seen from Fig. 9 that the measured frequencies of the tip without water taken by the tachometer installed in the direction towards the tip (-■-) show unstable results, which were found that they varied from 24.64 to 47.96 kHz. The measured frequencies obtained from the tachometer installed in direction parallel to the scaler tip were approximately 24.7 kHz both with and without cooling water. The frequencies measured by tachometer installed in direction towards the tip with water supplied were

Fig. 8 Experimental set-up to measure oscillation frequency using tachometer and ultrasonic frequency meter in two directions: (a) sensor direction towards the scaler tip, and (b) sensor direction parallel to the scaler tip.

also found to be about 24.7 kHz.

Fig. 10 illustrates the average of measured frequencies in terms of the distance between the standard ultrasonic frequency meter and the tip under test. The frequencies of the tip with cooling water measured by the ultrasonic frequency meter installed in both directions (-□-, -△-) were found to be much lower than the specification of the tip, which is 24 kHz. The measured frequencies (- -△- -) of the tip without cooling water measured by the frequency meter installed in the direction parallel to the tip were found to be about 24 kHz at the installed distance between 1 cm and 8 cm. However, they started to be slightly lower than 24 kHz at the installed distance greater than 8 cm. In the condition without cooling water, the frequency meter installed in the direction towards the tip provided the result of 24.6 kHz approximately for the whole range of installed positions. Experimental results demonstrated that the ultrasonic frequency meter was able to measure the frequency of scaler tip operated without cooling water only. The optimized installed direction of the frequency meter was the direction towards the tip. The tachometer installed in direction towards the tip faced problem when measuring the frequency of the tip without water only.

The experiments were also taken to investigate the effect of cooling water on the measured frequency of the tip. Fig. 11 shows the measured frequency in terms

of operating time of the scaler tip. The frequencies were measured every 10 s when operating the scaler tip with and without cooling liquid. It can be seen that when measuring frequency without cooling water, the measured frequency decreases as operating time increases. However, when measuring frequency with cooling water, the measured frequency was almost the same for the whole range of operating time studied.

4.3 Comparison Results among Three Types of Standard Equipment for Frequency Test

The frequency of a dental scaler tip model A-DENT Slim La-Ong 25K 1710 was measured by using three types of standard equipment. Those are a laser

displacement sensor, a TurboTester high speed tachometer, and a SonicSniffer ultrasonic frequency meter. The laser beam of the laser displacement sensor was pointed to the end of the scaler tip. The sensor of the tachometer and the ultrasonic frequency meter was pointed in the direction perpendicular to the tip and towards the tip respectively. The tachometer was installed 10 mm from the tip, while the ultrasonic frequency meter was installed 1 mm from the tip. The measurement was performed without cooling water supplied and the tip was operated at maximum power 1 min before the frequency measurement was performed. The set-up of all standard equipment is shown in Fig. 12.

Fig. 9 Averaged frequencies measured by the standard tachometer at various positions and two installed directions: ■ tachometer installed in the direction towards scaler tip; ▲ tachometer installed parallel to scaler tip.

Fig. 10 Average frequencies measured by the standard ultrasonic frequency meter at various installed distances and two installed directions: □ frequency meter installed in the direction towards scaler tip; △ frequency meter installed parallel to scaler tip.

Fig. 11 Averaged frequencies measured at various operating time of scaler tip by: □ frequency meter installed in the direction towards scaler tip; ■ tachometer installed in the direction towards scaler tip; ▲ tachometer installed parallel to scaler tip.

Fig. 12 Set-up to measure frequency without water by using tachometer, ultrasonic frequency meter and laser displacement sensor.

Fig. 13 Measured frequencies by tachometer, ultrasonic frequency meter, and laser displacement sensor.

Fig. 13 shows the measured frequencies by using tachometer, ultrasonic frequency meter and laser displacement sensor. The vertical axis is the average measured frequency from two measurements. It can be seen that the measured frequency from the tachometer and the ultrasonic frequency meter was 24.6 kHz

approximately. The measured frequency obtained from the laser displacement sensor was 24.57 kHz, which was slightly lower than from the others.

5. Conclusions

Four types of standard equipment were experimentally investigated in this paper. Those were the standard laser displacement sensor, the standard microscope, the standard tachometer, and the standard ultrasonic frequency meter. They were used to test the unloaded vibration amplitude, the loaded vibration amplitude and the frequency of the dental scaler tip according to ISO 18397. The laser displacement sensor and the microscope were able to test the unloaded vibration amplitude of the tip. However, the standard microscope was used for verifying the standard laser displacement sensor only because it was able to measure the instantaneous amplitude only. The standard microscope with a load cell set was able to test the loaded amplitude of the tip. The load cell set was used to measure the load of 1 N pressing on the tip. The tests of frequency were performed by the standard laser displacement sensor, the standard tachometer, and the standard ultrasonic frequency meter. It was found that only the standard tachometer was able to test the frequency of the tip with cooling water supplied.

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