The use of micro-computed tomography to determine the accuracy of electronic working length with two apex locators

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Abstract

Purpose: This study evaluated the precision of electronic working length by microcomputed tomography using two electronic apex locators (EALs).

Methods: Twenty single-rooted permanent teeth without caries or restorations were selected as the subject teeth. The positions of the minor apical constriction (AC) and major apical foramen (AF) were measured by electronic root canal length, and microcomputed tomography was performed with the file inserted and fixed in the root canal. All teeth were measured individually and independently by two operators. The Mann-Whitney U-test was used to statistically test the AC and AF values using two EALs; P < 0.05 was defined as statistically significant.

Results: This was 65.0% within 1.5 mm in the case of two EALs on AC. This was more than 90.0% within 1.0 mm in the case of two EALs on AF. Comparison of the differences between the respective AC and AF of the measurements obtained using the two EALs revealed no significant difference.

Conclusion: The two EALs are devices that can greatly improve the accuracy of WL control.

Keywords; cementodental junction, electronic apex locator, microcomputed tomography, working length

Introduction

Removal of all pulp tissue, necrotic matter, and microorganisms from the root canal is essential for successful endodontic therapy [1]. It is generally accepted that endodontic therapy should be limited to the root canal system [2]. To realize this goal, working length (WL) must not only be accurately detected during root canal treatment, but it must also be maintained. Accurate WL determination is a prerequisite for successful root canal treatment, reducing the likelihood of inadequate root canal irrigation or damage to the tissue surrounding the apex from excessive instrumentation. Appropriately determining WL is one of the most important factors in the success of endodontic treatment. Conventional methods of establishing WL consist of (a) finger sensation, (b) use of radiographic images, and (c) information using anatomical mean values. While the fingers are useful in determining WL, this method has many limitations. Radiography for measurement of WL has been used for many years. Radiographs are an important and regarding the apex on the meter screen, the major AF was displayed. Instructions, the meter screen of both EALs for WL indicated minor AC, as shown in Fig. 2b, the radiographic apices were designated as anatomical structure is complex [5-7]. Anatomical changes in AC site, size, tooth type, and age cause WL assessments to be unreliable [5-7]. It is well known that the AF is not always at the radiographic apex of the root, which is often located on the lingual/buccal or mesial/distal side [2]. At present, while many radiographs are taken, electronic apex locators (EALs) are also widely used. The development of EALs, used with appropriate radiographs [8-12], has enabled the assessment of WL to be more accurate and predictable, and has made EALs more accurate and reliable in determining WL [8-12]. As a result, many devices have been developed as clinical aids for determining apex location. Osada Electric Co., Ltd (Tokyo, Japan) and other companies have developed and improved electronic root canal measuring devices based on basic research on root canal length [1,13-15]. In recent years, qualitative evaluation based on microcomputed tomography (CT) has attracted considerable attention in the field of histomorphological research [16-18]. At present, microcomputed tomography (micro-CT) imaging is the most accurate imaging method for assessing the internal structure of the root canal system [18]. Furthermore, micro-CT images are nondestructive research tools that can effectively identify, evaluate, and measure the root canal system in 3D [19,20]. The purpose of this study was to compare the accuracy of two EALs using micro-CT imaging and determine anatomical variations that may affect their accuracy.

Material and Methods

The EALs used in this study consisted of Apit 7 (Osada Electric Co, Ltd, Tokyo, Japan) and Apit 15 (Osada Electric Co., Ltd) (Fig.1a, b). Written consent was obtained from each patient according to the stipulations of the institutional review board of Nihon University Faculty of Dentistry (EP16D012). Twenty single-rooted permanent teeth without caries or restorations were selected as the study specimens. Roots with root resorption, tooth fracture, open apex, or root canals not radiographically visible were excluded from the study. After extraction, the teeth were placed in 5.25% sodium hypochlorite solution to remove residual tissue from the external root surface. The cusps were flattened with a diamond bur using a high-speed handpiece. Opening of the root canal was performed using a Gates-Glidden drill. After locating the root canal orifice, the specimens were cleansed with 1% sodium hypochlorite to wash away root canal debris and subsequently perforated with a No.15 K-file. Root canal enlargement was not performed. An in vitro model was developed in which the teeth, root canals included, were fitted in a plastic case while being immersed in a 0.9% saline solution. The present study compared the accuracy of two EALs on the same tooth in combination with No. 20K-file. Figure 2a shows the idealized anatomy of the apex. In accordance with the manufacturer’s instructions, the meter screen of both EALs for WL indicated minor AC, and regarding the apex on the meter screen, the major AF was displayed. Herein, the K-file was inserted until the meter screen showed that it had reached the AC and the AF, with the EALs used in random order. After inserting the file into the root canal and performing fixation, micro-CT imaging was performed immediately. The imaging conditions of micro-CT (R. mCT; Rigaku Corp., Tokyo, Japan) were imaging magnification: 6.7× (voxel size: 30 × 30 × 30 μm), tube voltage: 90 kV, tube current: 120 μA, and filming duration: 17 s. The imaging data were observed by i-View-R (Rigaku Corp., Tokyo, Japan) and qualitatively evaluated. In the evaluation method, as shown in Fig. 2b, the radiographic apices were designated as...
A and B, and lines were drawn at those locations. With the center of the drawn line set as C, this study measured the distance (D) from C to the file tip. In performing the measurement, the mesiodistal and buccolingual sides were measured three times each, and the mean value of the two was used for the value. All teeth were measured individually and independently by two operators.

**Statistical analysis**

The Mann-Whitney U-test (SPSS version 16.0, Chicago, IL, USA) was used to statistically test the AC and AF values using two EALs; \( P < 0.05 \) was defined as statistically significant.

**Results**

Accuracy was calculated only with stable measurements.

Figure 3 shows the micro-CT images of AC and AF of Apit 7 and AC and AF of Apit 15 on the mesiodistal and buccolingual sides. Figure 4 shows the Box-plot illustrating the AC and AF of the two EALs. Median AC was 1.119 mm (first quartile: 0.806 mm, third quartile: 1.629 mm) by Apit 7 and 1.319 mm (first quartile: 1.062 mm, third quartile: 1.541 mm) by Apit 15. Median AF was 0.586 mm (first quartile: 0.423 mm, third quartile: 0.768 mm) by Apit 7 and 0.634 mm (first quartile: 0.478 mm, third quartile: 0.7745 mm) by Apit 15. Comparison of the respective differences between AC and AF of the measurements obtained using the two EALs revealed no significant differences. Table 1 shows the number and percentage of cases of AC by Apit 7 and Apit 15. This was 65.0% within 1.5 mm in the case of Apit 7 and 65.0% within 1.5 mm in the case of Apit 15. Table 2 shows the number and percentage of cases of AF by Apit 7 and Apit 15. This was 95.0% within 1.0 mm in the case of Apit 7 and 90.0% within 1.0 mm in the case of Apit 15. In all studies, there were no data concerning protrusion from the apex.

**Discussion**

EALs are currently considered to be accurate devices for determining WL [1]. Recent studies have reported that the use of an electronic apex locator...
generally reduces the number of radiographs that need to be taken. It has also been demonstrated that even higher accuracy can be realized by using a combination of both these techniques [1]. An important consideration in root canal treatment is apex anatomy [5-7]. In terms of conventional therapies, it has been established that root canal treatment and subsequent root canal filling should end at the site of AC, the narrowest diameter of the root canal [21,22]. This point appears to be consistent with the CDJ and is based on data from histological sections and specimens [22]. However, the location and anatomy of the CDJ differs considerably for each tooth, root, and root canal wall [22]. Furthermore, the CDJ cannot be accurately placed on the radiograph. For this reason, the shortening of the radiographic apex by 0.5 to 1.5 mm has been proposed [23,24]. The concept of apical anatomy is based on three anatomical and histological landmarks: AC, CDJ, and AF. Kutter’s description of the apical anatomy shows that the root canal tapers into the AC from the root canal opening, typically 0.5 to 1.5 mm toward the crown [5]. The AC is generally considered the narrowest portion of the root canal. It is also most often used by clinicians as the apical terminus and the reference point for expansion, shaping, cleaning, disinfection, and filling [5]. To improve the likelihood of long-term success, injuries in this area due to devices or filling material should be avoided. Microcomputed tomography was used in this study. Previous studies have utilized visual inspection, scanning electron microscopy, or root sectioning to determine EAL accuracy [25-27]. When using these methods, the apex is partially destroyed during examination, making it likely that an error will occur during measurement [25-27]. However, microcomputed tomography (micro-CT) imaging is a nondestructive research tool that enables 3D identification, evaluation, and measurement of the root canal system [19,20]. The 3D reconstruction of scanned teeth was extremely useful for measuring AC and AF. In addition, it allowed visualization and accurate measurement of anatomical details of the apical one-third [19,20]. To date, no studies have used micro-CT imaging to study the EAL. The results of this study confirmed that the two EALs could accurately determine the root canal length within 1.5 mm from the site of AC in the case of AC and within 1.0 mm from the site of AC in the case of AF, as shown above. The obtained measurements revealed that EALs can measure root canal length with a high degree of accuracy. None of the subjects in the present study exhibited crossing of the AF. Epidemiological studies report optimal root prognosis when the root canal filling is within 2 mm of the radiological apex [23,24]. Thus, it was demonstrated that the use of these two EALs reduces the risk of instruments’ crossing the AF. Therefore, the EAL is an instrument that uses appropriate radiographs and is a device that can greatly improve the accuracy of WL control.

Conflict of interest
None.

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