A Comparison of Five Conducting Media for Length Determination of Electronic Apex Locator Using a Simulation Model

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Abstract

The aim of this study was to compare five conducting media for length determination of electronic apex locator using a simulation model. Fifty plastic teeth were performed the access opening and mounted in simulation models. Simulation models were constructed with a clear acrylic tube (8 mm. in diameter) filled with conducting media in a clear acrylic box (50x50x30 mm). They were randomly allocated into 5 groups (n=10) according to the conducting media used which were 0.9% sodium chloride (NaCl), 2.5% sodium hypochlorite (NaOCl), 2% chlorhexidine (CHX), 17% ethylenediamine tetraacetic acid (EDTA), and cell culture medium (Minimum Essential Medium, MEM). The working length of each tooth was recorded visually (actual working length, AWL) and measured by an electronic apex locator at 0.5 bar (electronic working length, EWL). The mean differences between AWL and EWL were calculated and statistically compared among groups with one-way ANOVA, followed by Tukey's HSD test (p<0.05). Results showed that the mean differences in the 0.9% NaCl and MEM groups were significantly lower than the 2.5% NaOCl, 2% CHX and 17% EDTA groups. Under the limitations of this study, 0.9% NaCl and MEM were suitable conducting media for length determination of electronic apex locator using a simulation model.

Keywords: *Conducting media/ Electronic apex locator/ Tooth length determination/ Simulation model*

Received: *April 01, 2020*
Revised: *January 12, 2021*
Accepted: *January 25, 2021*

Introduction

Length determination of root canals during root canal treatment can be performed by electronic apex locators (EAL). The EAL is a very useful and reliable tool for obtaining root canal length.[1] Therefore, the use of EAL has been generally included in endodontic courses in the D.D.S curriculum.

The end point of root canal preparation should be located at the apical constriction (AC).[2] In the classic study by Kuttler, it was discovered that AC was located at a distance of 0.5-0.75 mm short of the apex.[3] The new generation of EAL determines the position of AC by estimating the changes in impedance values between the tip of the file and the periodontal tissue around the root apex.[1] Numeric reading of the "0.5" bar on the EAL display screen was claimed by manufacturers to indicate the position of the file tip at the AC.[1]

EAL in simulation model has been widely used in endodontic laboratories for dental students. Most of the simulation models were constructed with extracted or artificial teeth. The teeth were mounted in a container or dental model with conducting media.[4-15] These conducting media acting as periodontal tissue. The electric circuit is completed when the endodontic file contacts the medium through the apical foramen. Several media and materials have been used, such as alginate,[4-5, 8-10] silicone,[11] gelatin,[5,12-13] agar,[10,14] and 0.9% sodium chloride (NaCl).[5-6,10,15] Among these media, alginate was the most frequently used, and showed promising results.[4-5,8-10] However, alginate exhibits shrinkage and becomes more rigid after setting due to dehydration. A study by Alshwaimi and Narayanraopeta showed that the accuracy of EAL depended on the moisture content in alginate, therefore it can only be used within a limited timeframe.[8]

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Simulation models which constructed with transparent material can aid students in understanding the relation between EAL readings and the position of endodontic file in root canal. Thus, the purpose of this study was to compare the accuracy of 5 transparent conducting media for length determination of EAL using clear simulation models.

Materials and Methods

Fifty simulation models were constructed with clear mandibular first premolar (Nissin dental product, Japan) mounted in a clear acrylic model. Before mounting, the access cavity was prepared by a tapered diamond bur to allow straight line access. Canal was dried with paper point. Tooth length was determined by the insertion of a #15 K-file (Maillefer, Switzerland) in the root canal until the tip of the file was visible at the apical foramen. The rubber stop was gently moved towards the reference point at the buccal cusp. The distance between rubber stop and the file tip was visually gauged using a Vernier caliper, which measures to the two decimal places. This length was minus with 0.5 mm, then the "actual working length (AWL)" was recorded. Measurement of AWL was conducted 3 times by the same operator, who was trained how to use the EAL.

Once all the measurements of AWL were recorded, plastic teeth were randomly allocated into 5 groups (n=10). Each plastic tooth was mounted in a clear acrylic model. A model constructed with a clear acrylic tube with a diameter of 8 mm and a height of 20 mm, fixed in the middle of clear acrylic box with the dimensions of 50x50x30 mm (Figure 1). Clear acrylic box was designed to stabilize the model. While the tube was filled with conducting media according to the following groups: Group 1: 0.9% NaCl, Group 2: 2.5% sodium hypochlorite (NaOCl), Group 3: 2% chlorhexidine (CHX), Group 4: 17% ethylenediamine tetraacetic acid (EDTA), and Group 5: cell culture medium (Minimum Essential Medium, MEM, Gibco BRL, England). A stainless-steel wire was then immersed in the conducting media and secured with sticky wax. A lip clip was hooked to the outer end of the stainless-steel wire in order to transfer an electric current to EAL. The file clip was connected with a #15 K-file which was slowly inserted into the canal. Electronic length measurement was performed using RootZX (J. Morita, Japan).

The electronic working length (EWL) was taken when the signal on the display screen reached the "0.5" bar. At this point, the rubber stop was gently moved to the reference point at the buccal cusp. The file length was measured with a Vernier caliper (Figure 2). Measurement of EWL in each plastic tooth was conducted 3 times by the same operator.

Differences between the EWL and AWL were calculated in each tooth. Statistical comparisons of mean differences between groups were performed using one-way ANOVA, followed by Tukey's HSD test ($p<0.05$).

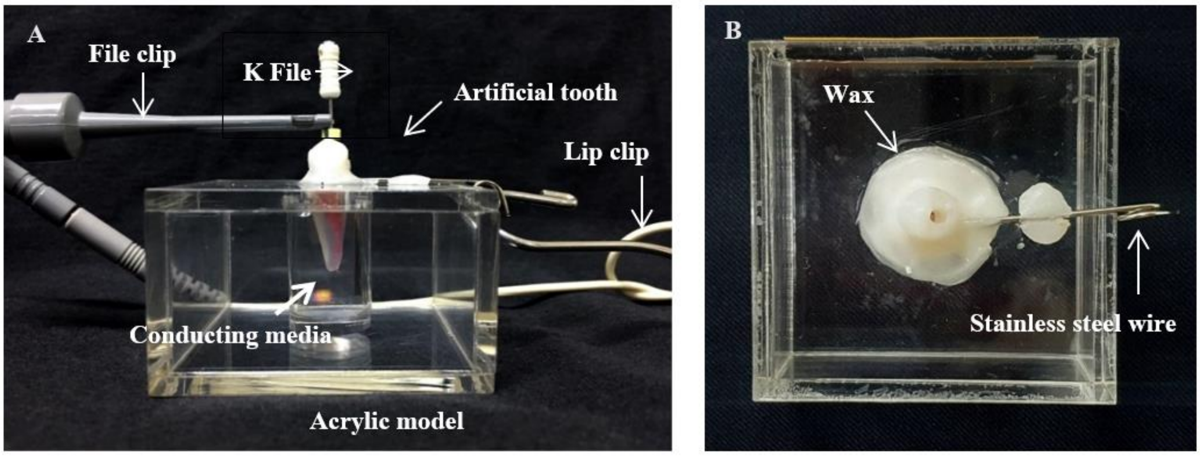

Figure 1 The simulation model constructed with artificial tooth and clear acrylic box. (A) side view, (B) top view

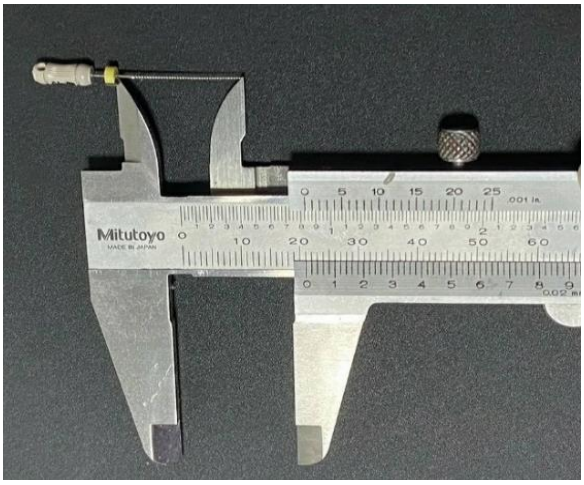

Figure 2 Measurement of K-file using a Vernier caliper

Results

Data of mean differences between AWL and EWL, standard deviation, and minimum and maximum differences are shown in table 1 and figure 3.

All conducting media showed promising results. The maximum difference of each group was within ±0.5 mm from AWL. MEM demonstrated the lowest mean difference, followed by 0.9% NaCl, 2% CHX, 17% EDTA and 2.5% NaOCl, respectively. Comparison by one-way ANOVA followed by Tukey's HSD test showed that the mean differences were significantly lower in MEM and 0.9% NaCl groups ($p<0.05$). There was neither a significant difference between the MEM and 0.9% NaCl groups nor the 2.5% NaOCl, 2% CHX and 17% EDTA groups.

The distribution of frequency of differences between EWL and AWL according to the conducting media can be seen in table 2. All samples in the 2.5% NaOCl and 17% EDTA groups distributed in range of -0.50 to 0.00 mm, indicated that EWLs were consistently short of AWLs. On the other hand, all samples in 2% CHX groups distributed between 0.00 to 0.50 mm, indicated that EWLs were consistently longer than AWLs. Samples in the 0.9% NaCl and MEM groups were distributed in both positive and negative values.

Table 1 The mean differences and the range of minimum to maximum differences between EWL and AWL in each group

Groups	Mean differences ± SD (mm)	Range (mm)
0.9% NaCl	0.14±0.08	0.00-0.30
2.5% NaOCl	0.322±0.07	0.20-0.46
2% CHX	0.29±0.08	0.15-0.46
17% EDTA	0.303±0.05	0.24-0.40
MEM	0.104±0.07	0.06-0.14

Table 2 The distribution of frequency of distance between EAL and AWL according to conducting media

	0.9% NaCl	2.5% NaOCl	2% CHX	17% EDTA	MEM
-0.25 to -0.50 mm	1	9	0	8	1
0.00 to -0.25 mm	3	1	0	2	2
0.00 to 0.25 mm	6	0	5	0	7
0.25 to 0.50 mm	0	0	5	0	0

Negative value indicated reading short of apex

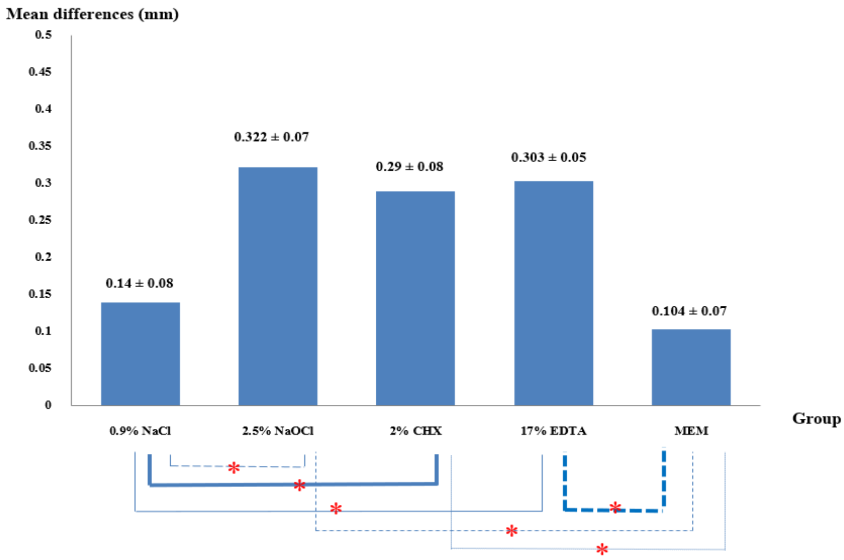

Figure 3 Bar graph representing mean differences between EAL and AWL, and significant differences between groups (*Statistically significant difference of p<0.05)

Discussion

In this study, a new simulation model was developed for EAL training. Clear plastic teeth were used in order to control size of root canal and diameter of apical foramen which could be influenced on accuracy of the EAL. Moreover, plastic root canal is not easily enlarged which practitioners can use this model several times.[11] Many studies successfully used plastic teeth for length determination.[11,14-15] All clear components in this model provide the opportunity for dental students to investigate the relationship between EAL reading on screen and file position in root canal. However, because of the clear container of this simulation model, conducting media could not be obscured during EAL measurement. The EAL used in this study was Root ZX, as this device is widely used and provides a reliable reading index.[1, 7,12,16] Nevertheless, the accuracy may be more precise if the measurements of AWL and EWL were determined under microscope.

The conducting media were of considerable importance for length determination of EAL using simulation model. Materials that can be used as conducting media in simulation models should have electrical conductivity. Electrical conductivity of solution creates by ions that carry the electricity through the liquid, and it represents substance's ability to conduct electrical currents. The more ions present, the more current can be carried.[1]

The results of this study showed that mean differences in the MEM and 0.9% NaCl groups were statistically lower than the mean differences in the 2.5% NaOCl, 17% EDTA, and 2% CHX groups. MEM is a clear pink-colored chemical-based synthetic media which supports cell survival and proliferation, as well as cellular functions for cell culture technology.[17] MEM contains several amino acids, vitamins, glucose and other salts such as calcium chloride, potassium chloride, magnesium sulfate, and sodium chloride. Amino acid levels of MEM are similar to the protein content of mammalian cells.[18] This is, however, the first time that MEM has been used as a conducting media for length determination of EAL using a simulation model. While data from the MEM group proved accurate, MEM is more expensive than other conducting media used in this study. Furthermore, MEM requires preparation before use, and it can deteriorate when stored at room temperature.

0.9% NaCl is a mixture of sodium chloride in water. It has a number of uses in medicine, such as fluid replacement, cleansing of wounds, and nasal lavage. The mean difference of the 0.9% NaCl group was statistically equal to the MEM group. Sauerheber and Heinz showed that 0.9% NaCl has a good electroconductive property and ionic composition similar to blood plasma and biological tissue.[19] Leonardo et al (2008) showed that 0.9% NaCl used as a conducting media in a simulation model displays a high accuracy for length determination even though it was used for primary teeth.[20] In this study, both MEM and 0.9% NaCl groups showed high accuracy as the maximum difference between EWL and AWL were only 0.14 and 0.30 mm respectively.

Turning to the data in 2.5% NaOCl, 17% EDTA, and 2% CHX groups, this is the first time for these common root canal irrigants that have been used as conducting media in simulation models for length determination of EAL. These irrigants were selected because they are transparent and available in clinic. Moreover, literatures showed that they have electrical conductivity,[21,22] which considered the most important properties of conducting media for length determination of EAL in simulation model. However, mean differences in 2.5% NaOCl, 17% EDTA, and 2% CHX groups showed significantly higher than MEM and 0.9% NaCl groups.

Electrical conductivity may be the key factor for the accuracy of EAL simulations models. The electrical conductivity of some root canal irrigants, culture mediums, body fluids, and blood have undergone testing. In 1976, Culkins reported electrical conductivity of 0.9% NaCl 16,000 µS/cm.[23] While Mazzoleni et al (1986) reported 15,400 µS/cm for 0.9% NaCl and 13,800 µS/cm for MEM.[21] Shin et al (2012) reported 2,160 and 172,420 µS/cm for 2% CHX and 1% NaOCl respectively.[22] Compared to electrical conductivity of body fluid reported at 15,000 and 7,000 for blood,[24] it seems that the closer the electrical conductivity of conducting media is to human body fluid, the higher the accuracy of length determination of EAL used in simulation models. The electrical conductivity of MEM and 0.9% NaCl are close to that of the electrical conductivity of body fluid. This confirmed the results of our study that MEM and 0.9% NaCl enhanced the accuracy of EAL in simulation models. Whereas NaOCl which has very high electrical conductivity, the results showed that the EWLs were always short of AWLs. On the other hand, the 2% CHX group, with low electrical conductivity, reached 0.5 bar EAL only when K-file went through AWL. As precise working length determination is required for root canal treatment, an erroneous working length, either short or long, can compromise the outcome. A short working length leaves uncleaned and unfilled root canal space in apical regions, while a long working length will lead to over-instrumentation and overextended obturation, causing significant postoperative discomfort and failure.

The simulation model used in this experiment was effective, inexpensive, and easy to assemble. The model provided a better understanding of the relation between the file position within the canal and the EAL reading. Conducting media in simulation model imitate condition in periapical area, because they also have electrical conductivity in the same way that body fluid has. The solute compositions of body fluid are classified into electrolytes (inorganic salts, acids, bases and some proteins) and nonelectrolytes (glucose, and lipids). Sodium is the major cation, and chloride is the major anion.[25] MEM and NaCl, which have similar compositions and electrical conductivity to body fluid, demonstrated the highest accuracy of EAL reading among other conducting media. However, 0.9% NaCl is considered the best conducting medium, due to the fact that it is inexpensive, colorless, and transparent, has a long shelf life, gives accurate length determination, and is widely available for laboratory settings.

Conclusion

Both 0.9% NaCl and MEM can be used as conducting media in simulation model for determining the working lengths using EAL. *Electrical conductivity* of conducting media may be the key factor for the accuracy of EAL using simulations models.

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การเปรียบเทียบผลการใช้สารตัวนำห้าชนิดในการวัดความยาวคลองรากฟันด้วยเครื่องหยั่งปลายรากฟันไฟฟ้าในแบบจำลอง

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บทคัดย่อ

วัตถุประสงค์ของการทดลองนี้เพื่อเปรียบเทียบผลของสารตัวนำ 5 ชนิดที่ใช้ในการวัดความยาวคลองรากฟันด้วยเครื่องหยั่งปลายรากฟันไฟฟ้าเมื่อใช้ในแบบจำลอง โดยฟันพลาสติกจำนวน 50 ซี่ ถูกนำมาเปิดทางเข้าสู่โพรงเนื้อเยื่อในและนำไปยึดติดกับแบบจำลอง ซึ่งแบบจำลองประกอบจากท่ออะคริลิกใส (เส้นผ่านศูนย์กลาง 8 มิลลิเมตร) ที่เติมไว้ด้วยสารตัวนำ ฝังอยู่ในกล่องอะคริลิกใส (50X50X30 มิลลิเมตร) แบ่งฟันแบบสุ่มออกเป็น 5 กลุ่ม (กลุ่มละ 10 ซี่) ตามชนิดของสารตัวนำ ได้แก่ สารละลายโซเดียมคลอไรด์ความเข้มข้นร้อยละ 0.9 สารละลายโซเดียมไฮโปคลอไรต์ความเข้มข้นร้อยละ 2.5 สารละลายคลอร์เฮ็กซิดีนความเข้มข้นร้อยละ 2 เอทิลีนไดอะมีนเตตระอะซิติกแอซิดความเข้มข้นร้อยละ 17 และอาหารเลี้ยงเซลล์ชนิดมินิมัมเอสเซ็นเชียลมีเดีย ฟันแต่ละซี่ถูกบันทึกความยาวทำงาน โดยการวัดด้วยตาเปล่า (ความยาวทำงานจริง, AWL) และโดยการวัดด้วยเครื่องหยั่งปลายรากฟันไฟฟ้าที่ระดับขีด 0.5 (ความยาวทำงานจากเครื่องมือไฟฟ้า, EWL) ค่าเฉลี่ยผลต่างระหว่างความยาวทำงานจริงและความยาวทำงานจากเครื่องมือไฟฟ้าถูกนำมาคำนวณและเปรียบเทียบทางสถิติด้วยวิธีความแปรปรวนแบบทางเดียว ตามด้วยการทดสอบตูร์กีเอชเอสดี ($p<0.05$) ผลการทดลองแสดงให้เห็นว่าค่าเฉลี่ยความแตกต่างระหว่างความยาวทำงานจริงกับความยาวทำงานจากเครื่องมือไฟฟ้าในกลุ่มโซเดียมคลอไรด์ความเข้มข้นร้อยละ 0.9 และกลุ่มอาหารเลี้ยงเซลล์ชนิดมินิมัมเอสเซ็นเชียลมีเดียมีค่าน้อยกว่ากลุ่มสารละลายโซเดียมไฮโปคลอไรต์ความเข้มข้นร้อยละ 2.5 กลุ่มสารละลายคลอร์เฮ็กซิดีนความเข้มข้นร้อยละ 2 และกลุ่มเอทิลีนไดอะมีนเตตระอะซิติกแอซิดความเข้มข้นร้อยละ 17 อย่างมีนัยสำคัญ ภายใต้ข้อจำกัดจากการทดลองนี้สรุปได้ว่าโซเดียมคลอไรด์ความเข้มข้นร้อยละ 0.9 และอาหารเลี้ยงเซลล์ชนิดมินิมัมเอสเซ็นเชียลมีเดียมีความเหมาะสมที่จะใช้เป็นสารตัวนำสำหรับวัดความยาวคลองรากฟันด้วยเครื่องหยั่งปลายรากฟันไฟฟ้าในแบบจำลอง

คำไขรหัส: *สารตัวนำ/ เครื่องหยั่งปลายรากฟันไฟฟ้า/ การวัดความยาวฟัน/ แบบจำลอง*

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