Effect of Water Ratio in Alginate-mounted Endodontic Models on Electronically Determined Working Length of Root Canals

Ya-Ping Pan[1], Jen-Gwo Liu[1], Wei-Cheng Hwang[1], Cheng-Wen Lin[2], Trong-Neng Wu[2], Ming-Gene Tu[1,3,4], Chi-Cheng Tsai[4]

[1]School of Dentistry, College of Medicine, [2]Teaching Excellence Project, [3]Department of Dentistry, China Medical University Hospital, China Medical University, Taichung, Taiwan. [4]Faculty of Dentistry, Kaohsiung Medical University, Kaohsiung, Taiwan.

Background/Purpose. To evaluate whether the water content in alginate endodontic models affects the accuracy of the Root ZX apex locator in determining the working length of root canals.

Methods. Twenty-nine extracted single-rooted teeth were embedded in alginate models and divided into two groups. Group A (15 teeth) was stored in a completely sealed box and placed in an incubator so that the humidity level would reach 100%. Group B (14 teeth) was stored in a box without a cover to simulate natural humidity. Models in both groups were stored in a 27°C incubator for up to 120 hours. The percentage of water content in alginate was measured by weighing the invested models at different measuring time points. The distance from the incisor edge or cusp tip to the major foramen of the root apex indicated the actual tooth length (AL).The electronically determined length (EDL) was measured by a K file advanced into the root canal to just beyond the major foramen, and then withdrawn counter-clockwise until a flashing bar appeared at the "APEX" of the Root ZX. The measurements were performed at different time intervals. The subtraction difference (SD) between AL and EDL was recorded for each tooth in each group. The SD values at five different measuring time points in each group were then compared by a Student's *t*-test.

Results. No significant difference in SD was observed in either group when the water content of alginate remained within the range of 73% to 62.5%. An average constant subtraction difference of 0.30 mm was found in group B.

Conclusion. The Root ZX apex locator provided accurate and stable working length measurements when the water content in the alginate invested models remained within the range of 73% to 62.5%. **(Mid Taiwan J Med 2008;13:12-8)**

Key words

actual tooth length, alginate, electronic apex locator, electronically determined length, Root ZX, working length determination

INTRODUCTION

Accurate determination of root canal length is a crucial factor that influences the outcome of root canal treatment [1, 2]. The cemento-dentinal junction (CDJ), where the pulp tissue changes into the apical tissue, is the ideal physiologic apical limit of the working length. This also is referred to as the minor diameter or the apical constricture. Since the anatomical apical constricture of the root canal is easy to clean and

Received : 1 October 2007. Revised : 26 October 2007.
Accepted : 5 December 2007.

Address reprint requests to : Ming-Gene Tu, School of Dentistry, College of Medicine, China Medical University, 91 Hsueh-Shih Road, Taichung 404, Taiwan

shape or obturate by endoodnitc procedures, many researchers have recommended setting the apical constricture as the apical limit of the working length [3, 4]. Traditionally, the point of termination for endodontic instrumentation and obturation has been determined by taking radiographs. The development of the electronic apex locator (EAL) has helped to make the assessment of working length more accurate and predictable [5].

The first electronic apex locator was introduced by Custer [6] in 1918 and improved by Sunada [7] in 1962. There are currently many Apex locators on the market; however, many studies have shown that the Root ZX (Root ZX, Morita Co., Tokyo, Japan) is the most reproducible and reliable for determining working length of root canals in vitro [8-14].

Alginate is used as an invested material for electronical working length demonstration and research models in vitro [2,17-20]. Tinaz et al [18] stated that alginate models could provide accurate electronical working length for demonstration purposes for up to 45 hours. However, the models used in vitro in endodontic laboratory classes are used for more than 2 or 3 days at a time; furthermore, alginate models for students' use are usually stored in natural humidity and at room temperature on the laboratory bench for more than 3 days.

We hypothesize that dehydration of alginate affects the accuracy of determining the working length using an apex locator; therefore, the purpose of this study is to evaluate the accuracy of the Root ZX in determining working length in alginate models with various water content.

MATERIALS AND METHODS

Measurement of actual tooth length (AL)

The actual tooth length (AL) of each tooth was measured from the incisor edge to the major foramen of the apex using a K file. A No.10 K file was used to tease through the major foramen of the root apex and the corresponding length was adjusted and recorded in a flat glass mixing slab (Fig. 1). The length of the file was measured with a caliper (MITUTOYO Co, Japan). The corresponding length of each measurement was recorded as AL.

Specimen preparation and water content measurement at 5 measuring points

Twenty-nine extracted single-rooted human anterior teeth and premolars were used in the study. Access to each canal was established and preflared, and the contents of the canal were removed. The roots were embedded in alginate (Jeltrate-Regular set, Dentsply Caulk, USA) up to the cemento-enamel junction (CEJ) of the tooth, then fixed in 4-cm tall plastic tubes until the alginate set. The ratio of powder to liquid in alginate was 19 mL to 7 g, according the manufacture's instructions. A paper clip was inserted into the alginate to establish an electric circuit (Fig. 2).

All teeth were randomly divided into two groups according to the apical diameter. Both groups were stored in a 27℃ incubator. Group A (15 teeth) was stored in a completely sealed box and placed in an incubator so that the humidity level would reach 100%. Group B (14 teeth) was stored in a box without a cover to simulate natural humidity. In both groups, a thermometer (KOKA, KT-169, Taiwan) was used to monitor the humidity (Fig. 3).

Mixed alginate has a tendency to become dehydrated over time when stored at room temperature. The amount of water lost in the

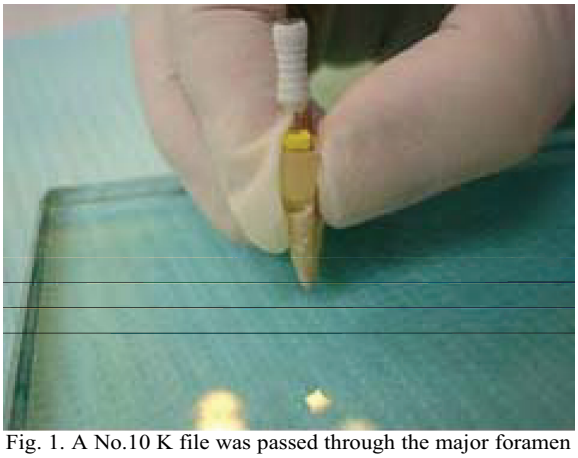

Fig. 1. A No.10 K file was passed through the major foramen of the root apex and adjusted in a flat glass mixing slab.

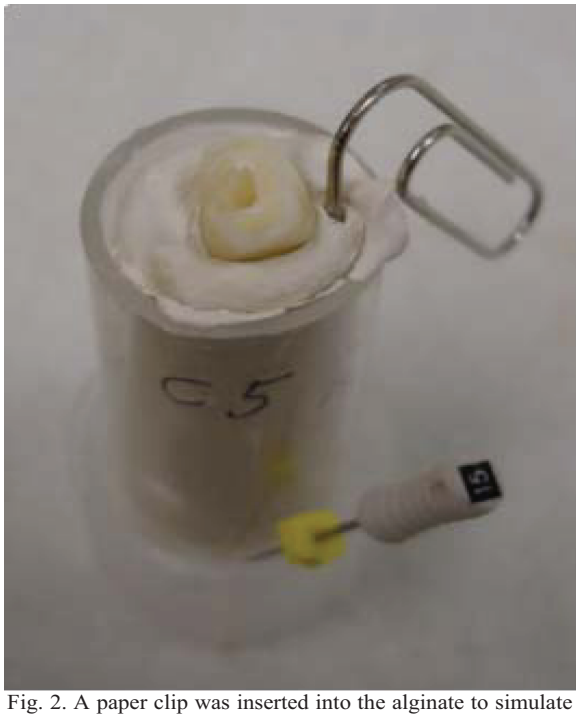

Fig. 2. A paper clip was inserted into the alginate to simulate an electric circuit in the oral cavity.

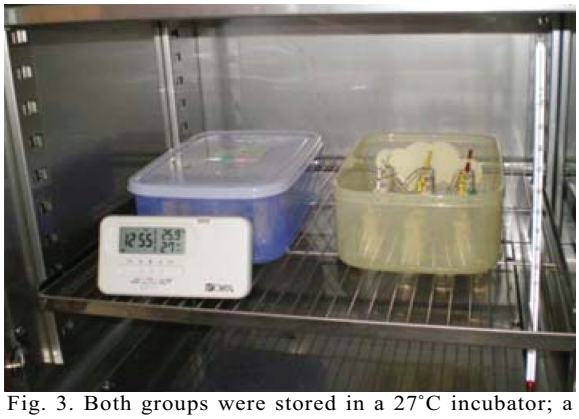
Fig. 3. Both groups were stored in a 27˚C incubator; a thermometer (KOKA, KT-169, Taiwan) was used to monitor humidity.

tooth-embedded alginate models can be calculated by weighing all specimens at 5 separate measuring points. All prepared specimens were weighed on an electronic scale (Sartorius AG, Gottingen, Germany) at the beginning, 24, 48, 96 and 120 hours of the experiment. The percentage of water lost was calculated as follows: (weight of specimen at beginning)-(weight of specimen at the a given time point)/weight of specimen at the beginning.

Measurement of electronically determined length (EDL)

The electronically determined length (EDL) was measured by a K file and the Root ZX apex locator at the beginning, and at 24, 48, 96, and 120 hours in sequence. During the measurement process, a lip clip from the Root ZX machine was connected to the paper clip that had been inserted into the alginate model. A file holder connected to the Root ZX machine was attached to the file to simulate a circuit between the oral mucosa and the periodontium of the tooth (Fig. 4A). The entrance to the canals was irrigated with distilled water and excess liquid was dried by aspiration using a syringe with a No. 27 gauge needle. A pre-adjusted K file that fit snugly to the canal of each tooth was advanced into the root canal to just beyond the major foramen. The file was then withdrawn counter-clockwise until a flashing bar appeared at the "APEX" and an audible signal indicated that the anatomical foramen had been reached. The length of the file from the incisor edge or cusp tip to the anatomical foramen was recorded as EDL.

All measurements were calculated using a caliper with a precision of 0.01 mm under a magnifying view box. The prepared specimens were double-checked by digital radiography (Gendex, Dentsply, USA) using a Rinn XCP cone indicator (Dentsply, Elgin, Illinois, USA) (Figs. 4B, 4C).

Data collection and statistical analysis

The weight of each specimen at different time intervals was recorded. The water content was calculated by measuring the weight loss of all the specimens at each particular measuring point. Each electronically determined distance (EDL) was compared with the actual tooth length (AL) and the subtraction difference (SD) equaled AL-EDL. All data were statistically analyzed by a Student's *t* test.

RESULTS

The water content of alginate was 73% at the beginning of the experiment. In the B group (natural humidity), the water content decreased to 62.5% at 120 hours. There was a 2% linear

decrease of water every 24 hours up to 120 hours in group B (Fig. 5): In group A (100% humidity), the water content increased at 24 hours (75%); however, from 24 hours to 120 hours, there was a linear decrease in water content (Fig. 5). The SD in both groups is shown in Figure 6 and Table 1. The average values of the subtraction difference (SD) from AL-EDL at each measuring point were collected. In the present study, a constant 0.31 ±0.25 mm SD value was observed when the water content ranged from 73% to 62.5% in the alginate invested model. A statistically significant difference in SD ($p < 0.01$) was found at the 24 hour point between both groups (Table 1).

DISCUSSION

In this study, we evaluated whether the water content of alginate affects the accuracy of electronic length determination using the Root

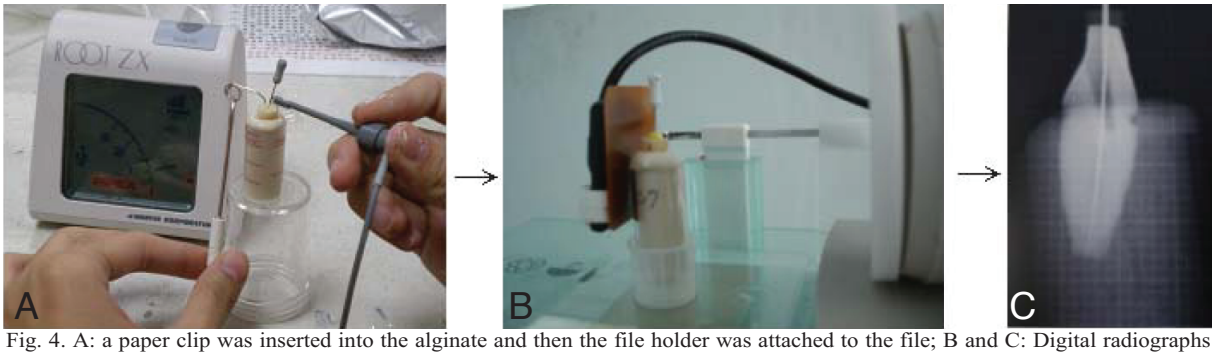

Fig. 4. A: a paper clip was inserted into the alginate and then the file holder was attached to the file; B and C: Digital radiographs of the prepared specimens were examined to double check the file posilion.

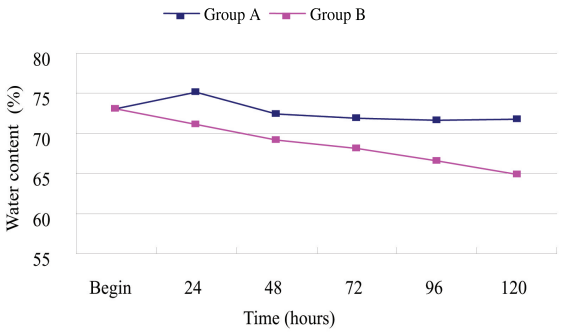

Fig. 5. Changes in water content in alginate over time. Group A = alginate model stored in 100% humidity. Group B = alginate model stored in a natural humidity condition.

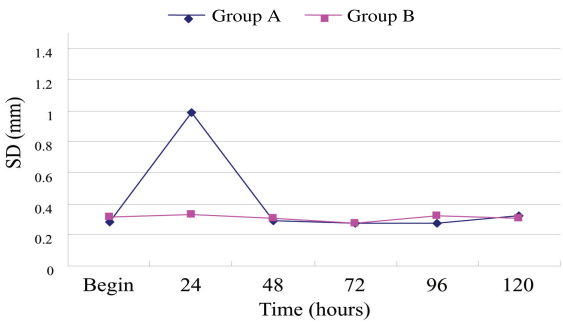

Fig. 6. Changes in subtraction difference (SD) in both groups by time. Group A = alginate model stored in a 100% humidity condition. Group B = alginate model stored in a natural humidity condition.

Table 1. Comparison of subtraction difference (SD) of AL-EDL between the two groups at different intervals

Time	SD (mm)				*p*-value
	Group A		Group B		
	n	Mean ±SD	n	Mean ±SD	
Beginning	13	0.28 ±0.19	12	0.31 ±0.19	0.63
24 hours	14	0.99 ±0.80	12	0.33 ±0.29	0.01*
48 hours	14	0.29 ±0.22	13	0.31 ±0.32	0.86
72 hours	14	0.28 ±0.19	13	0.27 ±0.18	0.96
96 hours	14	0.27 ±0.18	13	0.33 ±0.26	0.56
120 hours	14	0.32 ±0.19	12	0.31 ±0.16	0.82

Group A: 100% humidity; Group B: nature humidity. * significant difference, $p < 0.05$

ZX. We found that a water content of alginate ranging from 73% to 62.5% provided accurate working length determination when the model was stored in an open container at 27°C to simulate natural humidity. The Root ZX apex locator provided reliable length determination in the initial invested alginate model and in the models stored for 120 hours (73% to 62.5% water content). A constant subtraction difference of 0.30 mm was found at five different measuring time points in the natural humidity condition when distilled water were used as an irrigant.

The Root ZX was used in this study because this device has a high reliability index in readings [9,13,14]. Jenkins et al [15] reported that the Root ZX electronic apex locator could reliably measure canal lengths to within 0.31 mm, and that there was virtually no difference in the length determination as a function of the various irrigants used (2% lidocine, 5.25% sodium hypochlorite, RC Prep, liquid EDTA, 3% hydrogen peroxide, and Peridex). Although distilled water was used as an irrigant in the present study to provide a conduction medium between the K file and the alginate in the endodontic alginate invested model during electronic measurement of root canal working length, the average SD value of 0.30 mm obtained in Group B was in agreement with Jenkins et al. Lee et al [21] suggested that the major foramen [15] was more reproducible than the CDJ for measuring the working length using EAL. In the present study, we used the major foramen for the measurement of AL and EDL.

Various materials have been used for endodontic in vitro models, including isotonic normal saline [21], agar combined with different percentages of normal saline [22-24], gelatin (Jell-O) combined with normal saline [9,25,26], and refrigerated gelatin made with 0.9% sodium chloride instead of water [27]. The problem with the invested materials above is that, although suitable for research, they are not practical for use as endodontic teaching models. The alginate invested model is the most commonly used tool for teaching students how to measure working lengths using EALs [17-20]. Tinaz et al stated that the alginate model could be used accurately for demonstration purposes for periods of up to 45 hours provided that it was kept moist [18]. According to the present study, the alginate invested models, when stored in a natural humidity environment, can provide accurate working length determination using the Root ZX for up to 120 hours, and that 0.30 mm should be added to the EDL to reach the real tooth length (AL).

Kumar et al [20] reported that the working length determined by EAL would be a little shorter after the alginate model had been immersed in water for 24 hours. This 0.99 ± 0.80 mm reduction in working length determination using the Root ZX was reproduced in group A, which was stored in 100% humidity and showed a significant increase in water content (75%) at 24 hours (Fig. 5); thus the SD value was significantly larger than other samples at different measuring points (Table 1, Fig. 6). The reason for this variation might be that the water drops aggregated in the over-saturated alginate model and back-flushed from the apical foramen into the root canals. The EDL reading will be shorter when too much conducting medium (water) exists inside the root canal.

In the present study, we found that the Root ZX provided accurate working length measurements when the file tip was at the major foramen of the root apex of teeth stored in alginate models with a water content ranging from 73% to 62.5%. On average, an additional 0.30 mm should be added to the working length value of the EDL determined by the Root ZX in an alginate invested model in order to get the real tooth length (AL) for each tooth.

Students can store their endodontic alginate models on the laboratory bench at room temperature and can practice determining the working length using the Root ZX Apex locator with accuracy using alginate models within a period of 5 days.

ACKNOWLEDGMENT

This research was supported by a student grant from The National Science Council of

Taiwan (NSC 95-2815-C-039-001-S) and CMU Teaching Excellence Project P3-4: Research-based learning group, Ministry of Education, Taiwan.

REFERENCES

1. Staffen H, Splieth CH, Behr K. Comparison of measurements obtained with hand files or the Canal Leader attached of electronic apex locators: an in vitro study. *Int Endod J* 1999;32:103-7.
2. Kaufman AY, Keila, Yoshpe M. Accuracy of a new apex locator: an in vitro study. *Int Endod J* 2002; 35:186-92.
3. Hasselgren G. Where shall the root filling end? *NY state Dent J* 1994;34-5.
4. Ricucci D. Apical limit of root canal instrumentation and obturation, part I. Literature review. *Int Endod J* 1998;31:384-93.
5. Fouad AF, Reid LC. Effect of using electronic apex locators on selected endodontic treatment parameters. *J Endod* 2000;26:364-7.
6. Custer C. Exact methods for locating the apical foramen. *J Natnl Dent Assoc* 1918;5:815-9.
7. Sunada I. New method for measuring the length of the root canal. *J Dent Res* 1962;41:375-87.
8. Kobayashi C, Suda H. New electronic canal measuring device based on the ratio method. *J Endod* 1994;20: 111-4.
9. Czerw RJ, Fulkerson MS, Donnelly JC. Walmann JO. In vitro evaluation of the accuracy of several electronic apex locators. *J Endod* 1995;21:572-5.
10. McGinty DT, Fabre DD. Miller DA, Lautenschlager EP. Do irrigants affect the precision of apex locators? (abstract). *J Endod* 1996;22:195.
11. Weiger R, john C, Geigle H, Lost C. An in vitro comparison of the modern apex locators. *J Endod* 1999;25:765-8.
12. Ounsi HF, Naaman A. In vitro evaluation of the reliability of the root ZX electronic apex locator. *Int Endod J* 1999;32:120-3.
13. Elayouti A, Weiger R, Lost C. The ability of Root ZX apex locator to reduce the frequency of overestimated radiographic working length. *J Endod* 2002;28:116-9.
14. Vajrabhaya L, Tepmongkol P. Accuracy of apex locator. *Endod dent traumatol* 1997;13:180-2.
15. Jenkins JA, Walker WA 3rd, Schindler WG, Flores CM. An in vitro evaluation of the accuracy of the Root ZX in the presence of various irrigants. *J Endod* 2001;27:209-11.
16. Meares WA. Steiman HR. The influence of sodium hypochlorite irrigation on the accuracy of the Root ZX electronic root apex locator. *J Endod* 2002;287:595-8.
17. Katz A, Kaufman AY, Szajikis S. An in vitro model for testing the accuracy of apex locators. *Revue Francaise D'endodontie* 1992;11:67. (abstract).
18. Tinaz AC, Alacam T, Topuz O. A simple model to demonstrate the electronic apex locator. *Int Endod J* 2002;35:940-5.
19. Tinaz AC, Gorgul G, Turkoz EG. The effects of Sodium Hypochlorite concentrations on the accuracy of an apex locating device. *J Endod* 2002;28:160-2.
20. Kumar SS, Chacko Y, Lakshminarayanan L. A simple model to demonstrate the working of electronic apex locators. *Endodontology* 2004;16:50-3.
21. Lee SJ, Nam C, Kim YJ, Kim DW. Clinical accuracy of a new apex locator with an automatic compensation circuit. *J Endod* 2002;26:706-9.
22. Felippe MC, Soares IJ. In vitro evaluation of an audiometric device in locating the apical foramen of teeth. *Endod Dent Traumatol* 1994;10:220-2.
23. Aurelio JA, Nahmias Y, Gerstein H. A model for demonstrating an electronic canal length measuring device. *J Endod* 1983;9:568-9.
24. Kobayashi C, Okiji T, Kaqwashma N, Suda H, Sunada I. A basic study on the electronic root canal length measurement: Part 3. New designed electronic root canal length measuring device using division method. *Jap J Cons Dent* 1991;34:1442-8.
25. Donnelly JC. A simplified model to demonstrate the operation of electronic root-canal measuring devices. *J Endod* 1983;19:579-80.
26. Czerw RJ, Fulkerson MS, Donnelly JC. An in vitro test of a simplified model to demonstrate the operation of electronic root canal measuring devices. *J Endod* 1994;20:605-6.
27. Turkoz EG. The effects of Sodium hypochlorite concentrations on the accuracy of an apex locating device. *J Endod* 2002;28:160-2.

不同含水比例之藻膠包埋牙齒模型對電子式根管長度測定器之影響

潘雅萍[1] 劉正國[1] 黃偉政[1] 林振文[2] 吳聰能[2] 涂明君[1,3,4] 蔡吉政[4]

中國醫藥大學 牙醫學系[1] 教學卓越計畫辦公室[2]

中國醫藥大學附設醫院 牙醫部[3]

高雄醫學大學 牙醫學系[4]

背景/目的 探討根管治療藻膠包埋模型其含水量對電子式根管長度測定器準確度之影響。

方法 組A(15顆牙)爲100%飽和溼度，組B(14顆牙)爲自然濕度組保存於27℃恆溫箱，每隔24小時記錄藻膠重量及Root ZX測量之牙齒長度至120小時；得出兩組實際牙齒長度(AL)減去測量長度(EDL)之差值(SD)，評估藻膠失水量與SD值之變化以學生的*t*-test統計分析。

結果 組A在24小時含水量異常增高後與組B同樣按時間增長呈線性失水，在24小時組A的SD值有顯著差異。本實驗得出兩組SD差值維持在0.3 mm。

結論 根管治療實習藻膠模型以Root ZX量測，建議維持在含水量73%到62.5%環境才可提供準確的工作長度測量。（中台灣醫誌 2008;13:12-8）

關鍵詞

藻膠印膜材，電子長度測量，Root ZX，電子根管長度測定器，牙齒長度，長度差值

聯絡作者：涂明君

地 址：404台中市北區學士路91號

中國醫藥大學 牙醫學系

收文日期：2007年10月1日 修改日期：2007年10月26日

接受日期：2007年12月5日