

# An In Vivo Evaluation of Root ZX Electronic Apex Locator

Shahrokh Shabahang, DDS, William W. Y. Goon, DDS, and Alan H. Gluskin, DDS

**The Root ZX has been introduced recently as a device capable of performing accurately in the presence of sodium hypochlorite, blood, water, local anesthetic, and pulpal tissues. The Root ZX was used to locate the apical foramen in 26 root canals of vital teeth. After extraction of the teeth, a stereomicroscope was used to confirm visually the relationship of the tip of the endodontic file to the apical foramen. The Root ZX located exactly the apical foramen in 17 canals (65.4%), was short in 1 canal (3.8%), and was overextended in 8 canals (30.8%). When a potential error of  $\pm 0.5$  mm from the foramen is accepted as a tolerable range for the clinical application of an electronic apex locator, the Root ZX was able to locate the foramen within this range in 25 teeth for a clinical accuracy rate of 96.2%.**

Numerous electronic apex locating devices have been introduced since the 1960's. They operate under different electronic principles and circuitry. In 1962, Sunada (1) demonstrated that the electrical resistance between the periodontal ligament and oral mucosa has a constant value that can be measured. As a result, a number of devices were developed for use as clinical aids in apex location. However, many devices often performed unpredictably from patient to patient.

Wet contaminants in the canal were recognized as factors adverse to reliable performance (2, 3). Consequently, one manufacturer placed plastic insulation over the electronic probe to prevent electrical conductance through moist canal contents. However, the thickness of the insulating material prevented entry of the probe into tight and tortuous canals, especially at midroot and the apical level (3).

Several manufacturers have introduced devices that use more advanced technology that measures the ratio of two electrical impedances emitted from the probing instrument. The Root ZX instrument (J. Morita Corp., Tustin, CA) is one such device.

The promotional material for the Root ZX states that it can perform with high accuracy in the presence of sodium hypochlorite solution, blood, water, local anesthetic, and pulpal tissues (4). The manufacturer further states that fine endodontic files can be used

without the need to precalibrate the circuitry before locating the apical foramen.

The purpose of this in vivo study was to determine the ability of the Root ZX to locate the apical foramen in unprepared root canals of vital teeth.

## MATERIALS AND METHODS

Seven healthy patients with a total of 26 teeth treatment planned for extraction participated in this study. An informed written consent meeting the criteria of the Institutional Review Board of the University of the Pacific School of Dentistry and the California Pacific Medical Center was obtained from each patient before treatment was initiated. The teeth were tested to confirm vitality of the pulp, and all demonstrated intact periapical tissues on radiographic examination.

Two clinicians from the Department of Endodontics, School of Dentistry, University of the Pacific, participated in the clinical trial of this device.

Under local anesthesia, each tooth was accessed with a high-speed handpiece. The contents of each canal were not removed. The apical foramen was located with the Root ZX device by advancing a fine endodontic file toward the apex. File insertion was stopped when the meter flashed and an audible signal indicated that the foramen had been reached. For this particular device, the 0.5 marking just before the "apex" was selected for termination. Self-curing glass-ionomer material (Ketac-Silver, ESP-Premier, Norristown, PA) was mixed to the manufacturer's direction, injected into the access cavity to surround the shaft of the file, and allowed to set completely. Locked in place, the file handle and exposed shaft were separated using a high-speed handpiece. The Root ZX electrode was again placed against the residual shaft of the file to verify that the meter reading had not changed. The tooth was then extracted and stored in 10% formalin.

The teeth were soaked in 5.25% sodium hypochlorite for 24 h. The teeth were then subjected to decalcification in 5% nitric acid for 3 days, with daily changes of the solution. After a short rinse in tap water, the teeth were dehydrated by immersing them in 80% ethyl alcohol for 24 h, followed by a 90% and 100% alcohol immersion for 1-h periods. A final immersion in methyl salicylate (Sigma Chemical Co., St. Louis, MO) for 4 h rendered the teeth transparent.

The apex of each tooth was inspected independently by three examiners under an Olympus SZ-STB1 stereomicroscope. The

**TABLE 1. Frequency of observed file tip location in relation to the apical foramen**

Short of Foramen	At Minor Diameter	At Major Diameter	Beyond the Foramen
Spec. 26	Spec. 1	Spec. 2	Spec. 3
	Spec. 4	Spec. 6	Spec. 5
	Spec. 8	Spec. 9	Spec. 7
	Spec. 10	Spec. 11	Spec. 12
	Spec. 13	Spec. 15	Spec. 14
	Spec. 17	Spec. 16	Spec. 18
	Spec. 21	Spec. 19	Spec. 22
	Spec. 24	Spec. 20	Spec. 23
		Spec. 25	
<i>n</i> = 1	<i>n</i> = 8	<i>n</i> = 9	<i>n</i> = 8

position of the file tip relative to the apical foramen was recorded and photographed. Location of the file tip was classified into one of three categories: (a) at the anatomic apical foramen, (b) protruding beyond the apical foramen, and (c) short of the apical foramen. Measurements were then reconfirmed by removing the teeth from the methyl salicylate solution to allow them to opacify. Each apex was reinspected to verify the actual position of the file. There was general agreement among the investigators in determining the category of a particular specimen.

## RESULTS

The results are shown in Table 1. In a moist canal environment, the Root ZX device located the apical foramen precisely in 17 roots. The endodontic file tip protruded beyond the foramen in eight roots and did not reach the foramen in one root.

Table 2 lists the macroscopically observed distances of the tip of the endodontic file relative to the apical foramen. Among the roots with a protruding file tip, the mean distance of the overextension was 0.269 mm. The majority of overextended specimens were observed to be <0.5 mm beyond the major diameter. In the root with the endodontic file short of the foramen, the observed distance was 3.0 mm from the major diameter. Examination of the root did not reveal a reason, such as multiple portals of exit that were coronal to the apex (3) or a large foraminal opening (5, 6), for this result.

The observation of apical root resorption in several specimens was a notable finding, despite the fact that all of the selected teeth were clinically vital and demonstrated no periapical pathosis on radiographic examination. Even so, the Root ZX device was able to locate the root end consistently within the resorptive lacuna. In one resorbed root, the endodontic file had protruded by 0.5 mm outside of the root surface, but followed a path that kept the instrument in close proximity to the dentin interface of the resorbed root surface and periodontal ligament space.

## DISCUSSION

The performance of electronic apex locators have traditionally been afforded some latitude of acceptable error in locating the apex. Thus, radiographic positions within the  $\pm 0.5$  mm range to the apex are considered by some as the strictest acceptable range (7, 8). Measurements attained within this tolerance are considered highly accurate. Other studies rely on a more lax clinical range of

$\pm 1.0$  mm to the foramen (9). One reason cited for accepting a  $\pm 1.0$  mm margin of error is the wide range seen in the shape of the apical zone. Root canals do not always end with an apical constriction, a well-delineated minor or major apical diameter, or an apical foramen within the base of the cemental cone (10). Lacking such demarcations, an error tolerance of  $\pm 1.0$  mm is deemed clinically acceptable.

In this study, when the strictest clinical tolerances are applied, the Root ZX device located the apical foramen within  $\pm 0.5$  mm in 25 teeth for a clinical accuracy rate of 96.2%. This result is slightly higher than the range (89.64%) reported for a similar type of electronic apex locator (11). Our findings suggest that measurements attained within this clinical range would require an adjustment of the probing instrument to ensure that the file tip is well within the canal space. The length of adjustment is subject to radiographic corroboration. For the file tip located exactly at the foramen, a withdrawal of 0.5 mm or more would position the instrument within the apical constriction. Nine or 34.6% of our samples would require this type of adjustment. For the file tip located just beyond the foramen, a withdrawal of 1.0 mm or more may be necessary to avoid the overpreparation and potential destruction of the delicate constricture. Eight specimens or 30.7% of our samples would require this degree of adjustment. The finding that two thirds of the measurements were past the minor diameter were similar to the results of Mayeda et al. (12).

A further point of interest concerns the reliability of radiographs. The accuracy of electronic apex locators has traditionally been corroborated by radiographs (2, 3, 7-12). Nearly all of the root canals exited in orientations perpendicular to the path of the central X-ray beam and at acute angles. Visualization of curvature in the third dimension on radiographs is a challenge, at best. This makes radiographic confirmation of electronically positioned endodontic instruments difficult as a sole arbiter of canal length. In one study that determined instruments to be short of the radiographic apex, the investigators were surprised to find that >43% of the files were actually overextended beyond the foramen (13). We believe that an eccentric foramen and complex canal curvature that are hidden from conventional radiographic angles together caused this phenomenon.

The effects of an eccentric foramen and complex canal curvature hidden in the plane of the radiograph were clearly seen in many of the roots. In most instances, the Root ZX was able to position the file tip to the root surface, as seen with the stereomicroscope. Observations from several radiographic vantages, however, place the file some distance short of the radiographic apex. Correction of the file position based on these radiographic projections would invariably lead to overextension. The potential for overextension using unreliable radiographic images correlates with the clinical experiences of others (10).

The dilemma facing the clinician, who is using an electronic apex locator, is whether to believe the electronic signals or the radiographic position of the endodontic file. Using a device that measures electrical resistance of periapical tissues, Hembrough et al. (14) found a higher accuracy rate for measurements that are radiographically determined (88.5%), compared with measurements electronically determined (73.1%). Because of the inferior performance of their apex locator, Hembrough et al. (14) felt that radiographs remain indispensable for calculating canal lengths. Based on the present study, it was clear that the Root ZX located the apical foramen in a high majority of instances. However, the radiograph of an eccentric foramen and a canal with hidden curvature may show that the file is short of the apex. This conflicting

TABLE 2 Observed distances in millimeters from file tip to major diameter

Short of Foramen (mm)	At Minor Diameter $\leq$ CDJ/Constriction	At Major Diameter $\geq$ CDJ/Foramen	Beyond the Foramen $>$ Major Diameter (mm)
3.0	Behind lacuna		0.25
			0.50
			0.25
			0.25
			0.25
			0.20
			0.20
	Within lacuna		0.25
			0.20
Mean = 3.0 mm	Accepted as 0 mm	Accepted as 0 mm	Mean = 0.269 mm

CDJ, cementodentinal junction.

radiographic data can easily raise doubt in the mind of the operator. Thus, the clinician is forced to choose between the electronic signals or radiographic images, risking overpreparation of the canal.

When corroboration between electronic signal and radiographic image is inconclusive, tactile sensing may offer yet another determinant of the anatomical apical foramen (10, 15, 16). Leeb (17) found that tactile acuity in probing for the apical constriction could be enhanced by enlargement of the coronal level of the canal space. When the orifice and coronal portions of the canal were initially instrumented, that is preflared, Stabholz et al. (16) were able to probe to within 1.0 mm of the radiographic apex with a 75% accuracy rate, compared with an accuracy rate of 32% in unprepared canals. Thus, preflaring may offer the clinician an intuitive sense to go with either the electronic indication or radiographic data.

Lastly, we found the device easy to use. Patient acceptance was good. Intact teeth with patent canals presented no difficulty in the performance of the device. However, metallic restorations interfered with electrical conductivity. In this situation, the Root ZX performed inconsistently, requiring a larger access cavity first be made before attempting to locate the apical foramen. Furthermore, in a heavily calcified canal, patency needed to be established before determining the electronic signal of the apical foramen. With canal patency established, the device performed well in the canal, even under heavy lubrication with a nonconductor such as RC Prep (Premier Dental Products Co., Norristown, PA).

The study was supported in part by the J. Morita Corporation, Tustin, CA; the Pacific Dental Research Foundation, School of Dentistry, University of the Pacific, San Francisco, CA; and by the Eberhart Teacher-Scholar Award, University of the Pacific, Stockton, CA.

Dr. Shabahang was adjunct clinical instructor (and is currently a postgraduate endodontic resident at Loma Linda University, Loma Linda, CA), Dr. Goon is professor, and Dr. Gluskin is chairman, Department of Endodontics, School of Dentistry, University of the Pacific, San Francisco, CA. Address requests for reprints to Dr. William W. Y. Goon, Department of Endodontics,

School of Dentistry, University of the Pacific, 2155 Webster Street, San Francisco, CA 94115-2333.

#### References

1. Sunada I. New method for measuring the length of the root canal. *J Dent Res* 1962;41:375-87.
2. Trope M, Rabie G, Tronstad L. Accuracy of an electronic apex locator under controlled clinical conditions. *Endod Dent Traumatol* 1985;1:142-5.
3. McDonald, Hovland EJ. An evaluation of the apex locator, endocater. *J Endodon* 1990;16:5-8.
4. J. Morita Corporation. Root ZX—full automatic apex locator, operator's manual. Tustin, CA: J. Morita Corporation.
5. Hulsmann M, Pieper K. Use of an electronic apex locator in the treatment of teeth with incomplete root formation. *Endod Dent Traumatol* 1989; 5:238-41.
6. Stein TJ, Corcoran JF, Zillich RM. The influence of the major and minor foramen diameters on apical electronic probe measurements. *J Endodon* 1990;16:520-2.
7. Fouad AF, Krell KV, McKendry DJ, Koobusch GF, Olson RA. A clinical evaluation of five electronic root canal length measuring instruments. *J Endodon* 1990;16:446-9.
8. Ricard O, Roux D, Bourdeau L, Woda A. Clinical evaluation of the accuracy of the Evident RCM Mark II apex locator. *J Endodon* 1991;17:567-9.
9. Keller ME, Brown CE, Newton CW. A clinical evaluation of the endocater—an electronic apex locator. *J Endodon* 1991;17:272-4.
10. Gutmann JL, Leonard JE. Problem solving in endodontic working-length determinations. *Compend Cont Educ Dent* 1995;16:288-304.
11. Frank AI, Torabinejad M. An in vivo evaluation of Endex electronic apex locator. *J Endodon* 1993;19:177-9.
12. Mayeda DL, Simon JHS, Aymar DF, Finley K. In vivo measurement accuracy in vital and necrotic canals with the Endex apex locator. *J Endodon* 1993;19:545-8.
13. Chunn CB, Zardiackas LD, Menke RA. In vivo root canal length determination using the Foramer. *J Endodon* 1981;7:515-20.
14. Hembrough JH, Weine FS, Pisano JV, Eskoz N. Accuracy of an electronic apex locator: a clinical evaluation in maxillary molars. *J Endodon* 1993;19:242-6.
15. Seidberg BH, Alibrandi BV, Fine H, Longne B. Clinical investigation of measuring working lengths of root canals with an electronic device and with digital-tactile sense. *J Am Dent Assoc* 1975;90:379-87.
16. Stabholz A, Rotstein I, Torabinejad M. Effect of preflaring on tactile detection of the apical constriction. *J Endodon* 1995;21:92-4.
17. Leeb J. Canal orifice enlargement as related to biomechanical preparation. *J Endodon* 1983;9:463-70.