Evaluating the paper point technique for locating the apical foramen after canal preparation

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Objective. Despite not having been formally evaluated in the endodontic literature, claims have been made regarding the acceptability of the paper point technique (PPT) in estimating the location of the apical foramen (AF). Our aim was to investigate the repeatability and accuracy of PPT in estimating AF location in a cohort of dental patients.
Study design. Root canals with ≤10° of curvature (n = 71) in unsalvageable anterior and premolar teeth were measured using PPT as described in the literature. An endodontic file was cemented in each canal to the position indicated by PPT. Teeth were extracted and microscopic computerized tomography scanned.
Results. The PPT was 0.5 mm short to 0.5 mm long of AF in 87% of the canals. Repeated measurements in a given canal were within 0.19 mm of each other 95% of the time.
Conclusion. For relatively straight root canals, PPT appears to be similar to current clinically acceptable techniques in estimating AF location. **(Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2009;108:e101-e105)**

In memory of Dr. Dave Rosenberg, 1956-2009.

Working length (WL) is the distance from a coronal reference point to the point at which canal preparation and filling should terminate.[1] In the short term, accurate WL determination may prevent flare-ups,[2] and in the long term it allows for successful treatment outcome by contributing to prevention of periapical foreign body reactions,[3] sealing of root canal apices,[4] and microbial control.[5] Intraoperatively, WL typically is measured before and after straight-line access to the apical third of the canal ("initial-WL" and "final-WL," respectively). Because instrumentation shortens the canal,[6,7] measuring final-WL allows for a higher degree of length control during final apical instrumentation and root canal filling.

Available techniques to determine WL are: periodontal sensitivity,[8] tactile,[8-10] radiographic,[10-12] and electronic.[10,13,14] Periodontal sensitivity and tactile methods have been abandoned owing to poor accuracy. Neither radiographic nor electronic should be the only methods for WL determination, owing to their limitations.[13,15,16]

The paper point technique (PPT) uses conventional absorbent paper points to determine WL, assuming the canal is dried after its contents are removed, and the environment outside the root canal is hydrated. The maximum length a paper point can be placed into the canal and remain dry is recorded as the length of the canal.[17] The PPT is for final-WL determination because it can be used only after the canal is instrumented to an initial-WL obtained by another technique.

Although Siqueira[16] finds using paper points for WL determination to be empirical and fraught with limitations, Rosenberg[17,18] claims that PPT is accurate and precise to within 0.25 mm tolerances. However, we found no formal scientific evaluations of PPT to support either claim. Therefore, the aim of the present study was to investigate the repeatability and accuracy of PPT in estimating the location of the apical foramen (AF) after canal instrumentation.

MATERIALS AND METHODS

The University of North Carolina (UNC) Biomedical Institutional Review Board approved this study. Eighteen patients attending the UNC School of Dentistry (each of whom had signed a detailed informed consent form) contributed 78 upper and lower anterior and premolar teeth (n = 84 canals) planned for extraction. Inclusion criteria for teeth were: enough coronal structure to hold the rubber-dam clamp; radiographic apical curvature angle ≤10°; no root fracture; no acute apical

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abscess diagnosis; and possible to attain and maintain apical patency.

Two percent lidocaine with 1:100.000 epinephrine was administered. Teeth were rubber-dam isolated, scrubbed with iodine, and decoronated just coronal to the gingival margin to provide a reproducible reference for WL measurements. Remaining caries was removed and the pulpal space accessed.

The PPT then was initiated as described in the literature.[17,18] Proper application of PPT first requires initial WL measurement with an electronic apex locator; we used the Root-ZX (J. Morita Mfg. Corp., Kyoto, Japan) for this purpose. A 0.02 taper #10 or #8 Lexicon K-File (Tulsa Dental Specialties, Tulsa, OK) was inserted into the canal until the meter read 0.5, then advanced slowly until the word Apex flashed, and finally withdrawn until the meter read 0.5 again.[19] The stopper was positioned at the coronal reference and the file removed. The length from the file tip to the stopper was measured with a 0.5-mm-resolution endodontic hand ruler (Union Broach-Moyco, York, PA). Aligning the stopper with the ruler's 0 mm reading and at ×8.0 magnification under an Entrée Extra Global microscope (Global Surgical Corp., St. Louis, MO), the file tip position was compared against the ruler. This magnification enabled measurement to the nearest half of the ruler's resolution (i.e., 0.25 mm).[20] Canal patency was achieved with #8, #10, and #15 hand K-files used sequentially until the #15 file reached initial-WL. The root canal then was enlarged with S1 and S2 ProTaper files and a Series-20 GT file appropriate for the particular canal size ("partial" instrumentation), all three 0.5 mm short of (coronal to) initial-WL. Finally, apical patency was obtained with a #15 K-file taken 0.5 mm long of initial-WL, rotated 90° and removed. The chamber was filled with 2.5% sodium hypochlorite (NaOCl) at all times during the instrumentation phase. The canal space was recapitulated with small K-files and irrigated with NaOCl and 17% ethylenediaminetetraacetic acid (Pulpdent Corp, Watertown, MA) to ensure canal patency.[21] The canal was dried with the largest Kerr Absorbent Points (Sybron Dental Specialties, Orange, CA) fitting 0.5 mm short of initial-WL. The canal was considered to be dry when the absorbent point presented no moisture or color change.

Final-WL (hereafter called "PPT-WL") was determined using PPT.[17,18] A new absorbent point of lesser taper and size than the prepared canal was placed into the canal 2.0 mm short of initial-WL, removed, and the tip checked for wetness. If the paper point was dry it was advanced into the canal in 0.25 mm length increments, checking for moisture or color change between increments until moisture was seen at the tip (Fig. 1). The maximum length a paper point would still return dry was recorded as the canal length according to PPT (PPT-WL). For each length increment, paper points remained at full length for 1 second. Dryness/wetness was verified visually under the microscope, checking for moist appearance or color change (caused by either blood or tissue fluid), and each length-increment was measured under the microscope (Fig. 2) as described earlier for measuring files. The PPT-WL was obtained once for each canal, except for the last 9 cases, for each of which it was obtained 3 times so that repeatability could be calculated.

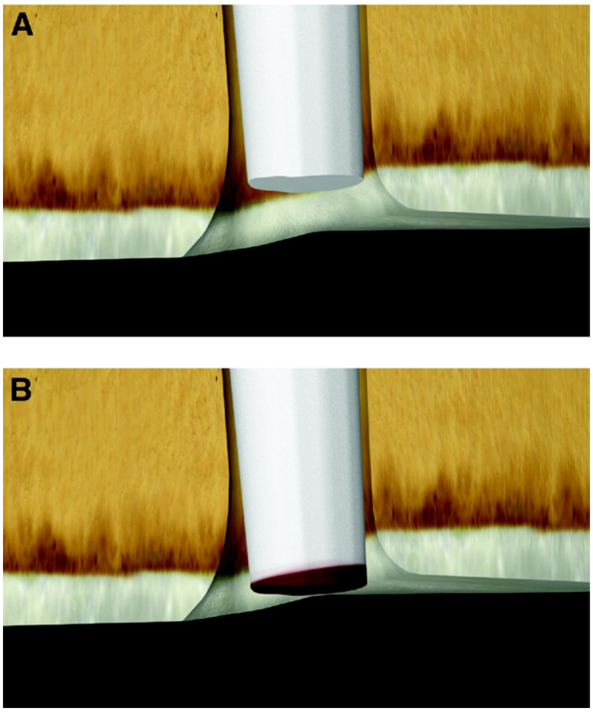

Fig. 1. Representation of a paper point (**A**) positioned at the apical foramen (AF), and then (**B**) immediately past AF. Illustrations by Dr. David B. Rosenberg.[17] Reprinted with permission of *Dentistry Today*.

To determine AF-to-file-tip distance, a ProFile .04 taper hand file (Tulsa Dental Specialties) that was snug in the canal was cemented to PPT-WL with flowable light-cure hybrid resin. The file portion extending from the occlusal surface of the tooth was sectioned and the rubber dam removed. The teeth then were extracted as atraumatically as possible and patients were given printed postoperative instructions.

Roots were placed in 5% NaOCl for 30 minutes, inspected (×8 magnification) for file or resin displacement, kept individually in plastic containers with 4% formaldehyde, and stored until measured.

Roots were transfered in sterile water–filled vials to a SkyScan-1074 X-Ray Microtomograph unit

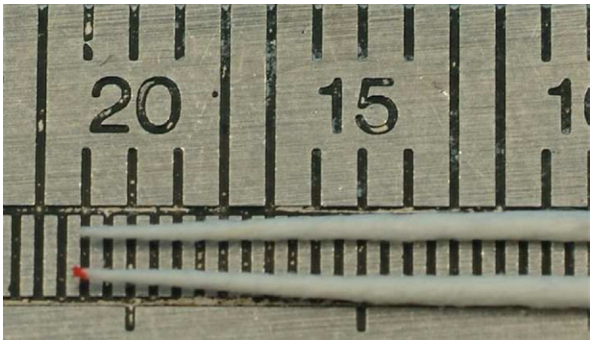

Fig. 2. **Top,** Length of the longest paper point returning completely dry. **Bottom,** First paper point returning moist had been inserted 0.25 mm longer than the last one to return dry.

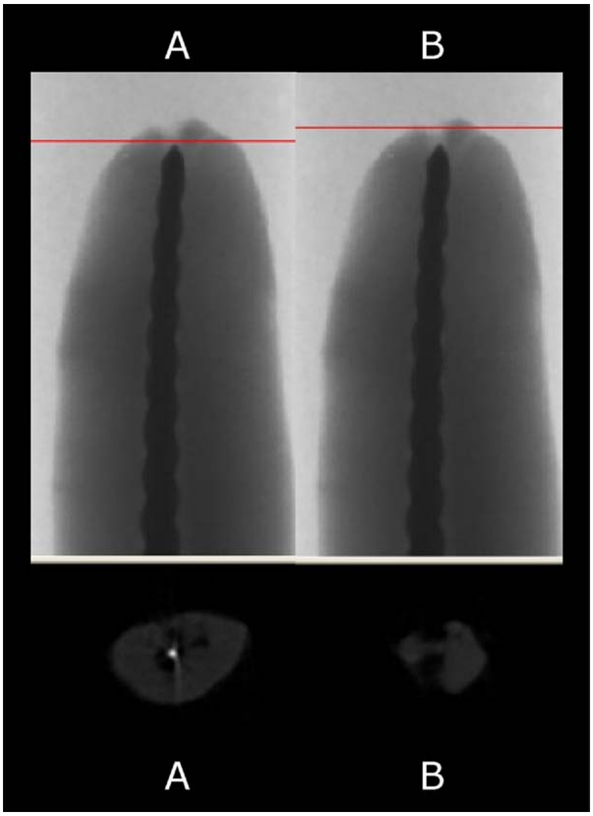

Fig. 3. Analysis of cross-sections: **A,** the one to show the last evidence of the file tip; **B,** the last one to show the root canal as a closed curve (with no end points, completely enclosing an area[22]).

(SkyScan, Kontich, Belgium), a compact micro computerized tomography (microCT) scanner with a single 22-μm-pixel-size spatial resolution. To facilitate the analyses, specimens were stabilized such that the apical portion of the cemented file was parallel to the scanner rotational axis. The scanner was operated at 40 kV and 1 μA, and acquired 206 vertical projections over 180 degrees in 480-540 seconds (rotation step was 0.9 degrees). Each projection generated a TIFF image, labeled with canal and projection numbers.

A set of horizontal cross-sectional BMP slices of each canal was generated from the TIFF images employing a modified Feldkamp algorithm using the SkyScan NRecon version 1.4.4 volumetric reconstruction software. The distance between cross-sections was 0.02 mm (50 sections/mm). Prereconstruction set-up included beam-hardening correction, alignment optimization, ring artifact correction, reconstruction of the volume of interest, external and internal calibration into Hounsfield units, and interactive density window selection.

Proceeding apically along each canal's horizontal cross-sections, one operator (JLMA) used the SkyScan CT-Analyser version 1.5.0.2 software to record the vertical (z) coordinate of 2 horizontal sections: z_1 being the last one with file tip presence (Fig. 3, *A*) and z_2 being the last one with a closed curve (with no end points, completely enclosing an area[22]) root canal section (any cross-section apical to it did not show a closed curve section of the canal; Fig. 3, *B*). Per canal, PPT accuracy was $z_1 - z_2$, the file-tip-to-AF distance. The repeatability coefficient[23] of PPT was calculated from the 9 canals in each of which 3 repeated PPT measures were obtained. All statistical analyses were conducted using MicroSoft Excel 2002 software.

RESULTS

Of the 84 initial canals, 13 were not analyzed because: Root-ZX gave erratic readings in 4 canals (in these, PPT was never attempted); PPT could be used but did not work owing to absence of moisture in 4 canals (even paper points taken considerably past initial-WL would return dry); PPT could not be used at all owing to excess moisture in 4 canals (large paper points taken 0.5 mm short of initial-WL would never return dry after instrumentation and before PPT); and the cemented file displaced during tooth extraction in 1 canal. This left 71 canals (within 68 teeth in 17 patients) for our evaluation.

Table I shows that in 87% of the canals, PPT was between 0.5 mm short and 0.5 mm long of AF (n = 71), with 60% of canals being 0-0.5 mm short of AF. Similar results were obtained when analyses were limited to vital pulp canals (n = 61). The repeatability coefficient[23] of PPT was 0.19 mm (n = 9), implying that, 95% of the time, the largest difference one should expect between 2 readings by PPT within a canal was 0.19 mm.

Table I. Accuracy of paper point technique after incomplete instrumentation

Distance from cemented file tip to apical foramen (mm)	*Vital and necrotic pulps, n (%)*	*Vital pulps only, n (%)*
≥−1 to <−0.5	5 (7.0)	4 (6.6)
≥−0.5 to <−0.25	15 (21.1)	12 (19.7)
≥−0.25 to <0.0	25 (35.2)	23 (37.7)
= 0.0	2 (2.8)	2 (3.3)
>0.0 to <0.25	12 (17.0)	11 (18.0)
≥0.25 to <0.5	8 (11.3)	6 (9.8)
≥0.5 to <0.75	2 (2.8)	2 (3.3)
≥0.75 to <1	1 (1.4)	0 (0.0)
≥1 to <1.25	1 (1.4)	1 (1.6)
	71 (100.0)	61 (100.0)

Negative distance indicates that reading was short of (coronal to) root canal apical foramen.

DISCUSSION

This project investigated the repeatability and accuracy of PPT to determine whether PPT is suitable for estimating the location of AF (when canal and apical patency are maintained). Evaluating PPT in this manner was justified because the technique had not been formally evaluated yet claims had been made about its performance.[16-18]

Nine methods were traditionally used for investigating the anatomy of root canals.[24] MicroCT technology, not available for this purpose until the 1990s, gives the highest resolution, with multiplanar visualization and no image distortion. To our knowledge, this is the first study using microCT technology to evaluate the accuracy of WL determination methods.

Endodontic outcomes studies assess root-filling length only in relation to the radiographic apex, which does not necessarily correspond with AF; the radiographic apex is 0.5-3.0 mm away from AF 50% of the time.[25] Here, we evaluated PPT using AF as the landmark because: 1) Neither the presence of the apical constriction,[25] the location of the CDJ,[26] nor the root apex–to–apical foramen distance[24,25] is reliable across canals[20]; 2) every root canal has an AF; and 3) the root apex has little relevance to the pathophysiology of periapical disease. For this study, AF was determined by microCT as the most apical root cross-section still showing a full closed curve[22] canal cross-section.

Only teeth with radiographic apical curvature angles ≤10° were selected to facilitate the orientation of the most apical portion of the canal parallel to the rotational axis of the microCT SkyScan scanner. Therefore, our results may apply only to teeth with a similar degree of radiographic root curvature.

Canal lengths were measured according to the only published description of the PPT clinical sequence,[17,18] which entailed using an electronic apex locator before instrumentation. The accuracy of Root-ZX for initial-WL determination was not evaluated because the actual canal length at the time of the microCT analysis could not be assumed to be the same as when the initial-WL measurements were obtained.[6,7] Furthermore, a comparison between Root-ZX and PPT for final-WL is not possible from the present data because a second Root-ZX reading was not obtained after instrumentation.

Kerr paper points were among the highest-absorbing in a 5-second fluid absorbency test.[27] This is relevant because Kerr points thus could be expected to very frequently give markedly inaccurate short canal-length readings. However, Table I shows that 1-second canal-length readings with Kerr points were, 40% and 60% of the time, only 0-0.25 mm and 0-0.5 mm, respectively, short from AF.

WL measurements attained within a ±0.5 mm tolerance of AF are considered to be highly accurate.[28,29] In the present study of 71 canals, PPT was in the ±0.5-mm-from-AF range 87% of the time, clinically similar to the largely accepted Root-ZX: 83% (n = 29),[30] 85% (n = 36),[20] 90% (n = 40)[31] and 86% (n = 65).[32]

Despite the similar performances of PPT (in the present study) and Root-ZX (in recently published articles), the PPT as described here is probably beyond average clinical practice, because wetness/dryness was checked at each .25-mm length increment. We opted for such an approach, however, in accordance with the (to our knowledge) only published description of PPT.[17,18] Instead, checking for wetness at each .5- or 1-mm increment would surely make PPT more user friendly, although we cannot recommend that, because we have not tested such an approach.

We found no published repeatability analysis for any endodontic WL-determination techniques**,** so we could not compare our repeatability findings with others. However, a repeatability coefficient <0.25 mm may arguably be considered to be clinically acceptable, because 0.25 mm is the smallest resolution to which WL measurements are likely to be made.

Five canals of the original sample (n = 84) were removed before the analysis owing to nonPPT-related issues (in 4, RootZX did not work, and in 1 the cemented file displaced during the tooth extraction). We can safely assume that the PPT accuracy and the PPT repeatability would have been similar to those reported here if those 5 canals had remained in the analyzed sample. That is, the results of this study were not biased by having left out those 5 canals.

Finally, we think PPT may be clinically useful, because in this study: 1) PPT gave readings in 94.7% (71+1 canals) of the 76 canals in which it was used; 2) PPT accuracy of the analyzed sample (n = 71) in the ±

0.5-mm-from-AF interval was 87% (similar to the reported RootZX-accuracy[20,30-32]); and 3) the PPT repeatability coefficient was beyond average clinical practice (0.19 mm; n = 9).

CONCLUSION

In this study, PPT was found to be suitable for estimating the location of AF in relatively straight patent canals, because its performance was similar to current clinically acceptable standards of estimating AF location. To improve generalization, further research of PPT in canals with greater curvature, and with more varied pulpal and periapical diagnoses, is warranted.

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REFERENCES

1. Glossary of endodontic terms. 7th ed. American Association of Endodontists; 2003.
2. Georgopoulou M, Anastassiadis P, Sykaras S. Pain after chemomechanical preparation. Int Endod J 1986;19:309-14.
3. Nair PNR, Sjögren U, Krey G, Sundqvist G. Therapy-resistant foreign body giant cell granuloma at the periapex of a root-filled human tooth. J Endod 1990;16:589-95.
4. Wu MK, Fan B, Wesselink PR. Leakage along apical root fillings in curved root canals. Part I: effects of apical transportation on seal of root fillings. J Endod 2000;26:210-6.
5. Chugal NM, Clive JM, Spangberg LS. Endodontic infection: some biologic and treatment factors associated with outcome. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2003;96:81-90.
6. Davis RD, Marshall JG, Baumgartner JC. Effect of early coronal flaring on working length change in curved canals using rotary nickel-titanium versus stainless steel instruments. J Endod 2002;28:438-42.
7. Schroeder KP, Walton RE, Rivera EM. Straight line access and coronal flaring: effect on canal length. J Endod 2002;28:474-6.
8. Botusanov P, Vladimirov S. [Clinical study on the possibilities of measuring root canal lengths using digital-tactile perception methods and periodontal sensitivity]. Stomatologiia (Sofiia). 1983;65:6-10. Bulgarian.
9. Stabholz A, Rotstein I, Torabinejad M. Effect of preflaring on tactile detection of the apical constriction. J Endod 1995;21:92-4.
10. Subramaniam P, Konde S, Mandanna DK. An in vitro comparison of root canal measurement in primary teeth. J Indian Soc Pedod Prev Dent 2005;23:124-5.
11. Bramante CM, Berbert A. A critical evaluation of some methods of determining tooth length. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1974;37:463-73.
12. Williams CB, Joyce AP, Roberts S. A comparison between in vivo radiographic working length determination and measurement after extraction. J Endod 2006;32:624-7.
13. Smadi LM. Comparison between two methods of working length determination and its effect on radiographic extent of root canal filling: a clinical study. BMC Oral Health 2006;6:4. Available at: http://www.biomedcentral.com/1472-6831/6/4.
14. Ebrahim AK, Yoshioka T, Kobayashi C, Suda H. The effects of file size, sodium hypochlorite and blood on the accuracy of Root ZX apex locator in enlarged root canals: an in vitro study. Aust Dent J 2006;51:153-7.
15. Consensus report of the European Society of Endodontology on quality guidelines for endodontic treatment. Int Endod J 1994;27:115-24.
16. Siqueira JF Jr. Reaction of periradicular tissues to root canal treatment: benefits and drawbacks. Endod Topics 2005;10:123-47.
17. Rosenberg DB. The paper point technique, Part 1. Dent Today 2003;22:80-6.
18. Rosenberg DB. The paper point technique, Part 2. Dent Today 2003;22:62-7.
19. J. Morita Mfg. Corp. Root ZX operation instructions. 2004. Available at: http://www.jmoritausa.com/Marketing/pdf/RootZXII_ifu.pdf. Accessed April 4, 2009.
20. Ounsi HF, Naaman A. In vitro evaluation of the reliability of the Root ZX electronic apex locator. Int Endod J 1999;32:120-3.
21. Rivera EM, Seraji MK. Effect of recapitulation on accuracy of electronically determined canal length. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1993;76:225-30.
22. Weisstein EW. Closed curve. 1999-2008 [cited 2009 Apr 4] [1p]. Available at: http://mathworld.wolfram.com/ClosedCurve.html. Accessed April 4, 2009.
23. Bland JM, Altman DG. Measuring agreement in method comparison studies. Stat Methods Med Res 1999;8:135-60.
24. Pineda F, Kuttler Y. Mesiodistal and buccolingual roentgenographic investigation of 7275 root canals. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1972;33:101-10.
25. Dummer PMH, McGinn, Rees DG. The position and topography of the apical canal constriction and apical foramen. Intern Endod J 1984;17:192-8.
26. Saad AY, Al-Yahya AS. The location of the cementodentinal junction in single-rooted mandibular first premolars from Egyptian and Saudi patients: a histologic study. Int Endod J 2003;36:541-4.
27. Pumarola-Suñé J, Solá-Vicens L, Sentís-Vilalta J, Canalda-Sahli C, Brau-Aguadé E. Absorbency properties of different brands of standardized endodontic paper points. J Endod 1998;24:796-8.
28. Fouad AF, Krell KV, McKendry DJ, Koorbusch GF, Olson RA. Clinical evaluation of five electronic root canal length measuring instruments. J Endod 1990;16:446-9.
29. Ricard O, Roux D, Bordeau L, Woda A. Clinical evaluation of the accuracy of the Evident RCM Mark II Apex Locator. J Endod 1991;17:567-9.
30. Pagavino G, Pace R, Bacceti T. A SEM study of in vivo accuracy of the Root ZX electronic apex locator. J Endod 1998;24;438-41.
31. D'Assunção FL, de Albuquerque DS, de Queiroz Ferreira LC. The ability of two apex locators to locate the apical foramen: an in vitro study. J Endod 2006;32:560-2.
32. Felippe WT, Felippe MCS, Reyes Carmona JR, Crozoé FCI, Alvisi BB. Ex vivo evaluation of the ability of the Root ZX II to locate the apical foramen and to control the apical extent of rotary canal instrumentation. Int Endod J 2008;41:502-7.

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