



## ABSTRACT

**Statement of problem.** Accurate working length (WL) determination is important for microbial control in root canal therapy. Current methods to determine WL have limitations. A new method for the paper point technique (PPT), has been claimed to be accurate and reproducible, but has not been formally evaluated.

**Hypothesis.** WL determination is more accurate when the Electronic Apex Locator Technique (EALT) is supplemented with the PPT compared to EALT alone.

**Materials and Methods.** The lengths of 84 root canals of unsalvageable human teeth were measured first using EALT, then PPT. Endodontic files were cemented to the position indicated by PPT. The teeth were extracted and microCT-scanned. In 71 canals that provided adequate readings for both EALT and PPT, the Root Canal Apical Exit (RCAE) to file tip distance was measured to 20 µm resolution.

**Results.** Both techniques showed (1) moderate agreement and (2) excellent repeatabilities. There was (3) a significantly greater accuracy in locating the RCAE when PPT was used compared to EALT alone ( $p \leq 0.0051$ ).

**Conclusion.** The results of this study support our hypothesis: supplementing the EALT with the PPT is more accurate than the EALT alone. **Clinical Implication.** Although the clinical significance of this degree of validity has not been established, it may be advisable to supplement current WL location techniques with PPT, since the results support our hypothesis.

## INTRODUCTION

Working length (WL) has been defined as "the distance from a coronal reference point to the point at which canal preparation and obturation should terminate"<sup>1</sup>.

Accurate determination of the endodontic WL is important. In the short term, in order to avoid flare-ups<sup>2-7</sup>. And in the long term to allow for successful treatment outcome because (1) being too short prevents adequate microbial control<sup>8,9</sup>, which has been shown repeatedly<sup>2,10,11,12</sup> ase the principal factor influencing the outcome and (2) being too long may cause a periapical foreign body reaction<sup>13-18</sup> and inability to optimally seal the root canal with the filling material.

The accuracy and limitations of available techniques to determine WL has been widely reported in the literature: periodontal sensitivity<sup>19-23</sup> radiographic<sup>24-29</sup> and electronic<sup>30-42</sup>. It has been recommended that, since both radiographic and electronic methods are not absolutely reliable, neither should be used as the only method of WL determination<sup>30,43-45</sup>.

A new method, the "paper point technique" (PPT), has recently been introduced<sup>46-47</sup>. This technique uses conventional absorbent paper points, and it is based on the assumption that when the contents of the root canal system are removed, the canal should be dry, while the environment outside the root canal is living and hydrated.

Rosenberg explains that if a paper point is placed into a dried canal short of the apical foramen, it should be retrieved dry<sup>46</sup>. If a paper point is placed into a dried canal and taken past the exit of the canal, it will be retrieved with fluid. The maximum length that a paper point can be placed into the canal and remain dry is then recorded as the length of the canal.

While Siqueira has stated that using paper points for working length determination is "imprecise, unreliable, empirical and fraught with limitations"<sup>60</sup> Rosenberg claims the PPT to be accurate and precise to within 0.25 mm tolerances. However, the PPT has not been formally evaluated.

## PURPOSE

**Hypothesis:** WL determination is more accurate when the EALT is supplemented with the PPT compared to using the EALT alone. **Purpose:** The purpose of the study was to test such hypothesis by calculating the (1) agreement and comparing the (2) accuracies and (3) repeatabilities of EALT alone and EALT/PPT.

## MATERIALS & METHODS

### In vivo

24 patients → 88 teeth → 93 root canals

3.6 cm3 of 2% lidocaine and 1:100.00 epinephrine were administered to obtain local anesthesia. Teeth were rubber-dam isolated and scrubbed with iodine solution. Teeth were decoronated just coronal to the gingival margin, providing a reproducible flat horizontal occlusal reference point for measurements. Remaining caries was removed and the pulpal space accessed.



### Obtaining EALT-Length



- with a Root-ZX EAL® (J Morita MFG. Corp., Kyoto, Japan)
- with 0.02 taper LEXICON™ files
- following manufacturer's manual

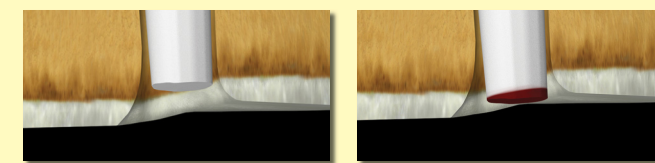
Insert file until meter reads 0.5  
Advance the file until the word "APEX" begins to flash. Then pull file out slowly until meter reads 0.5 again.

Since some canals have multiple constrictions, it is essential that the file be taken to the apex then returned to the 0.5 reading.

[www.jmoritausa.com](http://www.jmoritausa.com)

Measurements were made at 8.0 magnification to the nearest 1/2 of the ruler's resolution (0.25 mm) under an Entrée Extra Global microscope (Global Surgical™ Corp, St Louis, MO).

### Obtaining the PPT-length

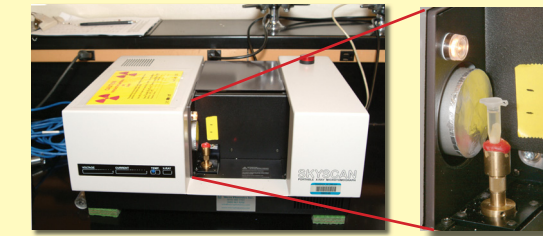


These two photos by Dr David B Rosenberg. Reprinted with permission of Dentistry Today.

- with Kerr Absorbent Points®
- following Rosenberg's<sup>61,62</sup> sequence:
  - root canal enlarged 0.5 mm short of EALT-length (with S1-S2 ProTapers® and a series 20 GT®)
  - root canal dried with paper points
  - a paper point advanced at 0.25mm increments, kept for one second in the canal and checked for moisture
  - until it is moist at the tip
  - length of longest dry paper point = PPT-length

Every time the point was checked for dryness, this was verified visually, at 8x magnification.

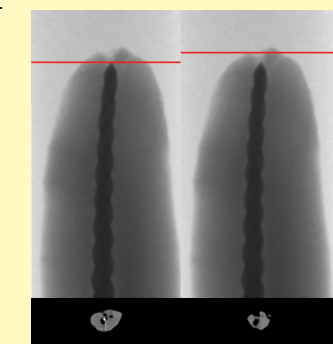
### Ex vivo



Roots were placed in 5% NaOCl for 1/2 hour, stored in Formalin 4% and labeled individually.

**(a) Micro-CT image acquisition.** A plastic vial containing one root and filled up with water was placed in a SkyScan 1074 (Skyscan, Belgium) x-ray micro-CT scanner. Specimens were placed such that (1) the apical portion of the cemented file was as vertical as possible, and (2) the plane of the foramen was horizontal. 206 angular projections were acquired over half the perimeter of the tooth (3D pixel size resolution: 22 µm). z

**(b) Measuring the file-tip to RCAE distance.** CT-Analysar software displays 50 tooth cross-sections for each 1 mm. One operator recorded the vertical coordinate of two horizontal cross-sections: the last ones to show (1) file tip presence, and (2) a complete oval cross-section of the root canal.



## DISCUSSION

Testing the PPT was justified since it had never been before and yet it had been claimed<sup>46,47</sup> to be more accurate and reliable than currently accepted techniques for WL determination.

study	readings beyond apical reference
Weik et al <sup>63</sup>	75%
Tselnik et al <sup>64</sup>	89%
present	85%

According to the results of this study, the accuracy of the combined use of EALT and PPT is better than that of the EALT alone. Therefore, it seems reasonable to supplement the EALT with the PPT into the routine root canal therapy procedures. The PPT may be used to refine the endodontic WL so that the final apical 1/3 instrumentation and the canal filling phases may be performed with a higher degree of length control.

Table 7. Two root canal therapy sequences incorporating the PPT.

access to pulpal chamber	
early WL measurement with EALT*	coronal 2/3 instrumentation
coronal 2/3 instrumentation*	early WL measurement with EALT
Early apical 1/3 instrumentation	
final WL measurement with PPT	
Final apical 1/3 instrumentation	
root canal filling	

\*sequence followed in this study (up to the "final WL measurement with PPT" step).

## CONCLUSION

Our hypothesis is supported by the results of the study: supplementing the EALT with the PPT is a more accurate way to determine WL than using EALT alone.

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## SAMPLE

This study enrolled 24 subjects, ages 24 to 68, from whom 88 teeth and 93 root canals were obtained.

93 total	9	PPT training	
		13 (15%)	8 (10%) PPT failed
84 (100%) experimental group	1	file was displaced during tooth extraction	(erratic readings)
	4 (5%)	EALT failed	
	4	no moisture at all	
	4	excess of moisture	
71 (85%)	both EALT and EALT/PPT worked		

## RESULTS

## AGREEMENT (n=71)

lengths mm	disagreement N (%)
0	10 (14)
≤0.25	32 (45)
≤0.5	52 (73)
≤0.75	62 (87)
≤1	69 (97)
≤1.5	71(100)

Figure 1 shows (1) the lack of agreement (otherwise dots would be closer to the x-axis than they are), (2) outlying observations and (3) that the difference between methods does not change with the tooth length.

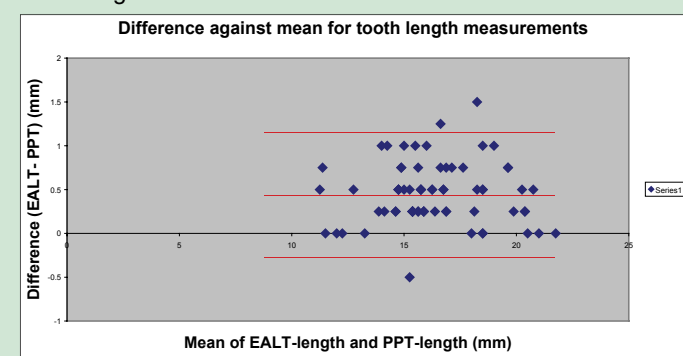


Figure 1. Parametric analysis of between-method agreement: paired mean reading lengths against paired difference of readings.

## REPEATABILITY (N = 9):

case #	EALT			EALT/PPT		
63	17	17	17	16.75	16.5	16.75
64	15.25	15	15	14.75	14.75	14.5
65	17	17	17	16.5	16.5	16.5
66	14.75	14.75	14.75	14.5	14.5	14.5
67	18.75	19	18.75	18.25	18.25	18.25
68	17.25	17.25	17.25	16.5	16.5	16.5
69	18.5	18.75	18.5	18.5	18.5	18.5
70	15.25	15.25	15.25	14.5	14.5	14.5
71	15.5	15.5	15.5	15.25	15.25	15.25

## Repeatability Coefficients:

- EALT → 0.231 mm
- EALT/PPT → 0.189 mm

## ACCURACY (n = 71)

distance from RCAE (mm)	EALT		EALT/PPT	
	n=71	%	n=71	%
-1<distance<-0.5	1	1.5	5	7
-0.5<distance<-0.25	2	3	15	21
-0.25<distance<0	9	13	25	35
distance=0	1	1.5	2	3
0.0<distance<0.25	11	15.5	12	17
0.25<distance<0.5	24	34	8	11
0.5<distance<0.75	14	19.5	2	3
0.75<distance<1	3	4	1	1.5
1<distance<2	6	8	1	1.5

Minus sign indicates short of (or coronal to) root canal Apical Exit

Table 5 shows the accuracy of each technique in specific accuracy ranges with clinical relevance. In each particular accuracy range, EALT/PPT has a significantly greater number of readings than EALT.

accuracy ranges (mm)	EALT cases (%)	EALT/PPT cases (%)	p-value*
(-0.25;0)	10 (14)	27 (38)	0.0023
(-0.5;0)	12 (17)	42 (59)	<0.0001
(-0.25;-0.25)	21 (30)	39 (55)	0.0051
(-0.5;-0.25)	23 (32)	54 (76)	<0.0001
(-0.5;-0.5)	47 (66)	62 (87)	0.0026

\*McNemar's exact test was used to compute p-value. Minus sign indicates short of (or coronal to) root canal Apical Exit