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Research Article

To Determine the Accuracy and Dependency of Different Available Methods of Working Length Determination During Root Canal Treatment– An In-Vitro Study

Dr. Jaya Singh[*1], Dr. Rohit Kumar Sharma[2], Dr. Vishnu Valsan[3], Sushma Singh[4], Medha Roy[5], Dr. Lairikyengbam Sujata Devi[6]

1. Dr. Jaya Singh, Final year Post graduate, Department of Conservative Dentistry and Endodontics, Teerthanker Mahaveer Dental College and Research Centre, Moradabad, Uttar Pradesh, India.

2. Dr. Rohit Kumar Sharma, MDS, Professor, Department of Conservative Dentistry and Endodontics, Teerthanker Mahaveer Dental College and Research Centre, Moradabad, Uttar Pradesh, India.

3. Dr. Vishnu Valsan, Second year Post Graduate, Department of Conservative Dentistry and Endodontics, Teerthanker Mahaveer Dental College and Research Centre, Moradabad, Uttar Pradesh, India.

4. Sushma singh, Departement of Pedodontic and preventive dentistry, Teerthanker Mahaveer Dental College and Research Centre, Moradabad, Uttar Pradesh, India.

5. Medha Roy, Departement of Pedodontic and preventive dentistry, Teerthanker Mahaveer Dental College and Research Centre, Moradabad, Uttar Pradesh, India.

6. Dr. Lairikyengbam Sujata Devi, First year Post graduate, Department of Conservative Dentistry and Endodontics, Teerthanker Mahaveer Dental College and Research Centre, Moradabad, Uttar Pradesh, India.

[*]**Correspondence to**: Dr. Jaya Singh, Final year Post graduate, Department of Conservative Dentistry and Endodontics, Teerthanker Mahaveer Dental College and Research Centre, Moradabad, Uttar Pradesh, India.

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Abstract

Introduction: *Accurate determination of working length (WL) is crucial in endodontic therapy, as it influences the success of root canal procedures, including cleaning, shaping, and obturation. Recent advancements like electronic apex locators and cone beam computed tomography (CBCT) address the limitations of traditional methods like radiography. Electronic apex locators enhance the efficiency of locating the canal terminus while reducing treatment time and radiation exposure. In contrast to traditional radiovisiography's two-dimensional images, CBCT provides three-dimensional views, improving precision in locating the apical foramen. This study aimed to compare the accuracy of WL determination using digital radiographic methods (RVG), electronic apex locators, and CBCT against actual WL confirmed by a magnifying loupe.*

Materials And Method: *Thirty-three single-rooted teeth were decoronated up to the cemento-enamel junction. A #15 K-file with a silicone stop was used to measure WL with RVG, electronic apex locator, and CBCT. Subsequent measurements were taken with another K-file placed until visible at the apical foramen, confirmed by a magnifying loupe, establishing the actual WL.*

Results: *Statistical analysis revealed significant differences among the methods (p-value 0.001 to 0.010). CBCT and electronic apex locator demonstrated the highest reliability, followed by RVG, with CBCT showing the strongest positive correlation with the actual WL.*

Discussion: *Multiple methods for WL determination exist, yet consensus on the optimal approach is lacking. This study compared the accuracy of tactile sensation, RVG, EAL, and CBCT against actual WL measurements.*

Conclusions: *The findings indicate that CBCT is the most reliable and accurate method for WL determination among those evaluated.*

Keywords: *RVG, CBCT, Apex Locator, WL.*

Introduction

The success of root canal treatment hinges on the effective integration of instrumentation and obturation techniques, particularly given the complexities of root canal anatomy.[1] A critical element in endodontic therapy is the determination of working length (WL), which requires a deep understanding of the root canal system's morphology, especially at the apex.[2] The American Association of Endodontists (2003) defines WL as the distance from a coronal reference point to where canal preparation and obturation should cease.

The anatomical apex represents the tip of the root based on morphological criteria, while the radiographic apex is identified through imaging techniques. [3] Various factors, including root morphology, anatomical variations, and radiographic distortions, can result in discrepancies between these two apex locations. The dentin-cementum junction is recommended to serve as the ideal termination point for root canal preparation, although its precise position can vary significantly within the canal. [4]

An apical constriction, often found near the dentin-cementum junction, creates a natural boundary for canal preparation, but its exact topography is typically not visible through radiography. [4] Research by Kuttler highlights that the distance from the apical constriction to the root's vertex tends to increase with age, which aids in estimating its location. [5]

Several methods have emerged to achieve accurate WL determination, each with unique advantages. This study focuses on three clinically reliable approaches: Radiographic Method, Electronic Apex Locators (EALs), and Cone Beam Computed Tomography (CBCT). Radiovisiography (RVG), a digital radiographic technique, enhances image clarity and reduces radiation exposure while providing precise distance measurements. EALs utilize electrical impedance to ascertain WL, offering a modern alternative to traditional visual methods.

CBCT imaging represents a significant advancement in dental radiology, providing high-resolution, three-dimensional views of root canal anatomy. This study aims to explore the efficacy of RVG, EALs, and CBCT in determining WL through in-vitro analysis, addressing a gap in existing literature regarding the precision and reliability of these methods compared to actual WL measurements using magnifying loops.

Material and Methods

Ethical Considerations

The study protocol was reviewed and approved by the Ethical Committee of TMDC & RC, Moradabad, under Reference No. TMDCRC/IEC/21-22/CDE5. Since this was an in vitro study with no direct human involvement, informed consent was not required.

Armamentarium

Sample Collection

- Sound extracted human single-rooted teeth
- Air-tight container
- Gloves
- Tweezers
- Kidney tray
- 0.2% Thymol solution
- Distilled water

Sample Processing Materials

1. Diamond disc (Strauss, Israel)
2. Gates-Glidden drills no. 1-3 (MANI, Tochigi, Japan)
3. High-speed airotor handpiece (NSK Pana Max Plus, Japan)
4. Endo access bur EX 41 (MANI Dia-Burs, EX-41)
5. 2.5% Sodium hypochlorite solution (Prime Dental, India)
6. K files #10 to 40 (MANI, Tochigi, Japan)
7. EDTA gel (Endo Prep gel, Globus Medicus, India)
8. Normal saline (NS, Orchid Pharma, India)
9. 2ml and 5ml disposable syringes (DispoVan, India)
10. Alginate (DPI Algitex, India)
11. Alginate mould impression tray
12. Mini Endo Bloc (Dentsply Maillefer, Ballaigues, Switzerland)
13. Modelling wax (Hindustan Dental, India)
14. Propex Pixi apex locator (Dentsply Maillefer, Ballaigues, Switzerland)
15. SOPIX-RVG unit (Satelec, Acteon Sopix 2 Dental Oral Sensor)
16. Magnifying loupe (ZUMAX, Suzhou New District, China)
17. CBCT unit (NEWTOM cone beam CT, Radiology, Verona, Italy)

Methodology

A total of thirty-three extracted permanent single-rooted teeth were collected from the Department of Oral & Maxillofacial Surgery, TMDC & RC, Moradabad, Uttar Pradesh. Teeth meeting the inclusion criteria were cleaned, thoroughly washed to remove debris, and stored in 0.2% thymol solution to prevent dehydration.

Selection Criteria

Inclusion Criteria:

- Single-rooted teeth
- Teeth with a single canal
- Teeth with straight root canals
- Non-carious teeth
- Teeth extracted for orthodontic or periodontal reasons
- Teeth with closed apex

Exclusion Criteria:

- Teeth with metallic restorations
- Previously endodontically treated teeth
- Teeth with evident root fractures
- Teeth with dilacerated roots
- Teeth with calcified canals
- Teeth with fractures or fracture lines
- Teeth with developmental malformations
- Teeth with carious lesions or restorations

Study Design

Duration: 18 months

Sample Size Calculation: Calculated at 90% power, a sample size of 33 was determined based on variations in measurements across techniques, with a Type I error (α) of 5% and Type II error (β) of 10%.

Procedure: Freshly extracted teeth were thoroughly washed to remove blood and adhering tissues. Surface debridement was performed using a hand scaler, followed by an ultrasonic scaler and a rubber cup with slurry pumice.The samples were preserved in a 0.2% thymol solution at 4°C for a maximum of 7 days. After this period, they were stored in distilled water, with weekly changes to prevent sample deterioration. For horizontal sectioning, teeth were cut at the cemento-enamel junction using a diamond disc to ensure unobstructed canal access and a flat surface for a rubber stop. Canal orifice flaring was performed with Gates-Glidden drills (Dentsply Maillefer, Ballaigues, Switzerland), sizes 1 to 3. The canal was irrigated with 5 ml of saline solution and dried using paper points. The patency of the canal and major foramen was confirmed with a K-Flexo file size 10 along with EDTA gel. All samples were then tested using four distinct techniques.

Sectioning and Preparation: Teeth were horizontally sectioned at the cemento-enamel junction using a diamond disc. Canal orifice flaring was performed with Gates-Glidden drills, followed by irrigation with saline solution and drying with paper points. The canal patency was confirmed using a K-Flexo file with EDTA gel. All samples were tested using four distinct techniques.

Working Length Determination:

1. Radiographic Working Length (RWL): A #15 K-file was placed into the canal, and a digital radiograph was taken. RWL was calculated by subtracting 1 mm from the radiographic measurement.

2. Electronic Working Length (EWL): After rinsing the canal with 2.5% sodium hypochlorite and drying it, thirty-three teeth were mounted on alginate molds. A 15 K-flex file was connected to the Propex Pixi apex locator, and the file was introduced into the canal. The digital display showed the distance to the apical constriction. Upon reaching the constriction, the locator signaled through a digital reading, sound, and light. Measurements stable for at least 5 seconds were recorded, and the distance to the rubber stop was measured using a Mini Endo Bloc as the electronic working length (EWL)

3. CBCT Analysis: Two dental models were created using 33 extracted single-rooted decoronated teeth in modeling wax. The canal length was measured with a field of view (FOV) of 100 mm x 80 mm, using a voxel size of 0.260 mm, 90 kVp, 8 mA, and an exposure time of 9.4 seconds. Teeth were examined in transverse, sagittal, and coronal views without files. The operator rotated the teeth to find a plane where the reference point and foramen were visible. Measurements were taken from the coronal reference point to the canal's termination in both views, with the final measurement being the mean of these values. A straight line was drawn from the reference point to the foramen to record the distance as the CBCT working length.

4. Actual Working Length (AWL): A 15K file was placed into the root canal until the tip was visible at the apical foramen, confirmed with a magnifying loupe. The stopper was aligned with the reference point, and the distance was measured using a digital caliper, recorded as the apical working length (AWL).

Statistical Analysis

The means of groups were compared using repeated measures ANOVA with Greenhouse-Geisser correction, followed by Bonferroni post hoc tests for multiple comparisons. The correlation between actual root canal length and RWL, EWL, and CBCT measurements was evaluated using Pearson correlation coefficient, with a confidence interval set at $P < 0.05$. Statistical analyses were performed using SPSS version 27 software (IBM Corp., Armonk NY, USA).

Table 1: Descriptive statistics

Methods	N	Minimum	Maximum	Mean	Std. Deviation
RVG	33	12.0	16.5	13.652	1.2530
Apex Locator	33	12.5	16.5	13.886	1.1523
CBCT	33	12.3	16.3	13.924	1.2445
Loupe	33	12.0	16.5	14.106	1.2485

Table 2: Intergroup comparison of mean values.

Methods	Df	Sum of squares	Mean Square	F	P-value
RVG	32	50.242	5.374	65.923	**.001***
Apex Locator		49.879	5.025	24.857	
CBCT		42.489	4.627	126.098	

Table 3: Paired Sample Correlation Percentages

Pair	Methods	Samples	Correlation
1.	RVG vs Loupe	33	94 %
2.	Apex Locator vs Loupe	33	97 %
3.	CBCT vs Loupe	33	98 %

Table 4: Pearson's Coefficient Correlations

METHODS		RVG	Apex Locator	CBCT	Loupe
RVG	**Pearson Correlation**	1	.928**	.972**	.941**
	Sig. (2-tailed)		.000	.000	.000
	N	33	33	33	33
Apex Locator	**Pearson Correlation**		1	.960**	.975**
	Sig. (2-tailed)			.000	.000
	N		33	33	33
CBCT	**Pearson Correlation**			1	**.988****
	Sig. (2-tailed)				.000
	N			33	33
Loupe	**Pearson Correlation**				1
	Sig. (2-tailed)				
	N				33
****. Correlation is significant at the 0.01 level (2-tailed).**					

Results

The multiple inter-group comparison of mean values was evaluated using Repeated Measures ANOVA with Green-Geisser correction, followed by the post hoc Bonferroni test. The sample consisted of 33 teeth, with working length measured in millimeters using RVG, EAL, and CBCT.

Tables 1 and 2 presents the mean and standard deviation of the different groups.From the data, there is a noteworthy distinction between the RVG (13.652 mm) and Loupe method (14.106 mm) mean values. In contrast, the working length values measured by CBCT (13.924 mm) and EAL (13.886 mm) did not show significant differences compared to the Loupe method. Post hoc analysis with a Bonferroni adjustment was conducted for pairwise comparisons among the three techniques.

Using Pearson's correlation analysis, correlation percentages of each method - RVG, Apex locator, and CBCT were assessed in comparison with the Loupe method, as shown in (Table: 3). The correlation percentages showed that the CBCT and Apex locator methods have almost the same level of correlation (statistically significant difference) with actual WL measured by the Loupe method, while the RVG showed a lower level of correlation with actuál wòrking length measured by the Loupe method. (Statistically significant difference).

Table 4: The correlation between actual ròot canal length measurements using magnifying loupe and RVG,

apex locator, and CBCT measurements was evaluated, usịng the Pearson correlation coefficient. The cònfidence interval was determined to be $p < 0.05$. There is a strong positive relationship between the working length values measured by CBCT (0.988) & Loupe (1.000) followed by Apex locator (0.975). Correlations were significant at the 0.01 level. However, the RVG (0.941) showed the least correlation with actual wòrking length measured using the Loupe method.

Discussion

The apical portion of a tooth root displays essential landmarks: the apical constriction (AC), the apical foramen (AF), and the root apex, known as the cemento-dentinal junction (CDJ). Accurate identification of these structures is crucial for successful endodontic procedures and minimizing post-operative discomfort. An insufficient working length (WL) can leave uncleaned canal space, while an excessive WL can lead to over-instrumentation and discomfort. [6] Therefore, concluding canal preparation and obturation at the AC is preferred for several reasons:

1. Prevention of apical injury.
2. Avoidance of injury to the periodontal ligament.
3. Preservation of accessory lateral canals.
4. Prevention of extrusion of root canal filling material.
5. Mitigation of apical transport of infected pulpal tissues.
6. Facilitation of adequate compaction of the root canal filling against the canal walls.
7. Elimination of infected tissue remnants within the canal.

Variability exists in the position of AC relative to AF, with studies indicating a range of 0.4 to 1.2 mm (Levy and Glatt). This variability highlights the challenges in clinical assessments, emphasizing the need for precise techniques in WL determination. Although the CDJ is considered the ideal endpoint for sealing the root canal, it is often not clinically identifiable.[4]

Conventional radiography remains the primary method for WL determination, but it presents limitations, such as the need for ionizing radiation and two-dimensional images of three-dimensional objects. Digital radiography has improved upon these limitations, offering enhanced image quality and measurement capabilities. Research by Ong et al. (1995) emphasizes the benefits of RVG, which facilitates precise measurements down to a tenth of a millimeter, although it may still be less effective than newer technologies. [7]

Electronic apex locators (EALs) have emerged as valuable tools for assessing root canal length. In a randomized clinical trial by Ravanshad et al. (2010), EALs demonstrated statistically significant advantages over radiographic methods, reducing the likelihood of overestimation. [8] This aligns with findings from Paredes Vieyra et al. (2018), [9] who noted that EALs exhibit higher accuracy in locating minor foramina compared to traditional radiographs.

Cone Beam Computed Tomography (CBCT) offers significant advancements in imaging for endodontics, providing volumetric data that accurately defines the location of the apical foramen. Studies, including those by Liang et al. (2015), [10] demonstrate a strong correlation between CBCT measurements and actual lengths, showcasing its superiority over conventional radiographic methods. The current study's findings, with an accuracy of 98% for CBCT compared to RVG (94%) and EAL (97%), further support the effectiveness of CBCT in endodontic assessments.

Moreover, the high reliability of CBCT in distance measurements has been documented in previous research, indicating a mean difference of only 0.2 mm between CBCT and EAL measurements (Shabhaz et al., 2018). [11] This precision reinforces the notion that integrating EAL and CBCT can lead to improved clinical outcomes.

The current study highlights the importance of utilizing multiple methods for WL determination. By integrating EAL, CBCT, and traditional radiography, clinicians can achieve a more accurate WL, thereby improving treatment success. The strong correlations observed between CBCT, EAL, and actual lengths suggest that these methods should be standard practice for enhanced diagnostic accuracy.

Conclusion

Precise WL determination is fundamental in endodontics. As technology progresses, the integration of EAL and CBCT can significantly enhance clinical outcomes while reducing patient exposure to radiation. Future advancements in apex locator technology and training in imaging techniques will further improve the precision of endodontic treatments, ensuring better patient care and treatment efficacy. The evidence from related studies reinforces the need for a multimodal approach to WL determination, combining the strengths of each technique for optimal results.

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Conflicts of Interest: There are no conflicts of interest.

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