

## An in Vitro Comparison of Root Canal Length Measurements of Primary Teeth Using Different Techniques

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**Abstract:** *Aim:* The aim of this study was to compare the diagnostic efficacy of root canal length measurements in primary teeth, determined by tactile sense, digital radiography and electronic apex locator. *Methods:* 30 extracted badly decayed primary incisors with different degrees of root resorption were selected, which were stored in saline at 4°C. **Real (actual) root canal length determination:** was first determined for each numbered specimens by advancing number 15K-file apically with the rubber stopper touching the reference point until the tip of the file was seen by the naked eye to be with the level of the apical FORAMEN. **Root canal length determination by tactile sense method:** using no. 15 k- file, the file was introduced into the root canal until an increase in tactile resistance was detected. The stopper was adjusted to the same reference point. **Root canal length determination by digital radiographic method:** performed by using the paralleling technique using the digital x-ray sensor size # 1. On the digital radiographs, tooth length was measured directly on the screen using electronic ruler of the system software. **Root canal length determination by electronic apex locator (EAL) method:** The Root ZX, J. Morita Corporation was used. Blocks were made by embedding the teeth in alginate with 0.9% sodium chloride solution which act as a conducting gel simulating the periodontium. *Results:* Tactile method showed the statistically significantly highest mean percentage difference from actual length. There was no statistically significant difference between apex locator and digital X-Ray methods; both showed the statistically significantly lowest mean differences from actual length. *Conclusions:* The apex locator method can be considered reliable and precise since it is more superior to the tactile method. The digital parallel radiography is comparable to EAL in determining the working length of primary teeth.

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Key words: Primary teeth, tactile, digital radiography, electronic apex locator.

### 1. Introduction

Root canal treatment helps to maintain the integrity of primary dentition until normal exfoliation when their pulps become infected. Early loss of primary teeth and untreated endodontic pathology can cause a number of problems<sup>1</sup>.

In primary dentition, the exact location of the actual apex remains difficult to determine because of hard tissue deposition and root resorption. Root resorption by odontoclasts is a characteristic feature of primary teeth. Most of it is physiological root resorption with eruption of permanent successors. However, there is also pathological root resorption with apical periodontitis due to infection by microorganisms, dental trauma. Root resorption is not continuous and has resting periods, which sometimes showed cementum deposition in the resorbed root surface<sup>2</sup>.

These processes change the shape and the position of the root apex. For these reasons, the combinations of tactile sense and radiography have important limitations to estimate the ideal length<sup>3</sup>.

In primary teeth, it is important to estimate the exact root canal length during endodontic therapy to avoid injury to the succedaneous tooth bud<sup>4</sup>. There are also specific problems which are characteristic of

primary teeth: root canal walls are often thin and instrumentation of the canal may result in perforation or root fractures<sup>3</sup>.

The simplicity of the tactile perception technique and its virtual effectiveness, motivate few clinicians in endodontic practice to still follow this technique, however it's generally inaccurate in root canals with constricted canal, excessive curvature and immature apex<sup>5</sup>.

Radiographic determination of tooth length is one of the critical aspects of pulpectomy in primary teeth because minor degrees of resorption may not be obvious radiographically<sup>3</sup>. And an underlying permanent tooth germ can cause image superimposition. In order to establish the correct working length for instrumentation of the root canal system, the tooth length should be estimated from a preoperative radiograph, an endodontic file should be inserted up to the established length and another radiograph should be taken to check whether the instrument is positioned at the right level<sup>6,7</sup>.

Direct digital radiography systems are based on digital image capture by using a charge coupled device. The advantages of these systems include: reduction in radiation dosage, speed of image acquisition and the possibility of editing images and details<sup>8</sup>.

The electronic apex locator (EAL) which is used for electronic root canal working length determination has become increasingly popular for eliminating many problems associated with the radiographic methods<sup>9</sup>. It is more accurate, easy and fast, with no requirements of X-ray exposures and it may be helpful in overcoming the short comings of radiographic examination in teeth with resorption. It is a painless technique that's very useful to be used with uncooperative children<sup>10</sup>.

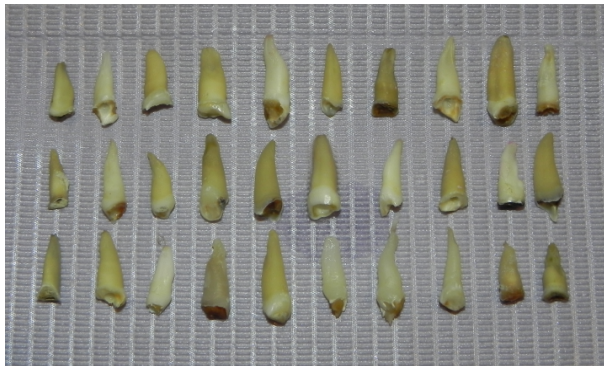
In theory; apex locator work is based on the ratio method<sup>11</sup>, in these method two electric currents with different signs wave frequencies will have measurable impedances that can be measured and compared as a ratio regardless of the type of electrolyte in the canal. The capacitance of the root canal increases at the apical constriction, and the quotient of the impedances reduces rapidly as the apical constriction is reached<sup>12</sup>.

Investigators who carried out *in vivo* and *in vitro* studies with apex locators on primary teeth with and without root resorption previously concluded that electronic apex locators are safe, painless, and useful because it avoids unnecessary radiation. Therefore, it is recommended for use in primary teeth<sup>3,13,14</sup>.

The purpose of this study was to compare the diagnostic efficacy of root canal length measurements in primary teeth, determined by tactile sense, digital radiography and electronic apex locator.

## 2. Materials and Methods

Thirty extracted badly decayed primary incisors with different degrees of resorption were selected for this study, which were stored in saline at 4°C until use. Roots, having more than 1/3 apical root resorption, were excluded from this study (Fig. 1).



**Fig (1):** Extracted primary teeth included in this study

### Real (actual) root canal length determination:

The thirty extracted single rooted primary teeth were numbered and kept in isotonic sodium chloride solution (0.9% NaCl). Access cavities were prepared using no.2 round-bur with slow speed hand piece. Extirpation of pulp was performed; the canals were irrigated using 3% sodium hypochlorite solution and

finally flushed copiously with distilled water. A fixed reference point on the incisal edge of each tooth was marked to adapt the rubber stopper on it each time. A real or actual root canal length was first determined for each numbered specimens by advancing number 15K-file apically with the rubber stopper touching the reference point until the tip of the file was showed by the naked eye to be with the level of the apical foramen, then the file was withdrawn carefully and the distance from the rubber stopper to the file tip was measured by using a graduated metal scale and documented as the real root canal length (RRCL) to be compared with the mean root length of each measurement method<sup>15</sup>.

### Root canal length determination by tactile sense method:

Tactile measurements were completed by using no. 15 k- file, the file was inserted into the root canal until an increase in tactile resistance was detected<sup>16</sup>. The stopper was adjusted to the reference point. The 15K-file was carefully withdrawn and the distance from the tip of the file to the rubber stopper was measured using a graduated metal scale; the values were noted down and registered as tactile root canal length (TRCL).

### Root canal length determination by digital radiographic method:

The radiographic measurement was taken by using the paralleling technique using the digital x-ray sensor size # 1 (RSV3 sensor, Visiodent S.A., SAINT-DENIS, FRANCE), the exposure factors and the distances between the source and the tooth, and the tooth and the sensor were standardized<sup>17</sup>. The digital x-ray sensor was placed in a holder and positioned parallel to the long axis of the tooth under investigation. The X-ray tube head (Trophy Radiologie, France) operating at 65 kV, 10 mA aimed at right angles (vertically and horizontally) to both the tooth and x-ray sensor (Fig. 2).



**Fig (2):** The X-ray tube head aimed at right angle to both the tooth and x-ray sensor.

On the digital radiographs, tooth length was measured directly on the screen of a high-resolution 14" monitor with 100% zoom magnification. The measurement method was the electronic ruler of the proprietary CDR system software (Visiodent imaging, Visiodent S.A., SAINT-DENIS, FRANCE). Using the left mouse button, a two-click measurement was performed for tooth length determination: one click at the visible edge of the crown and the other at the root apex. Prior to the measurements, the electronic ruler was calibrated by measuring an object of known length, #15 Mani file (Mani, Inc., Tochigi, Japan) (Fig. 3).

Enhancement features, such as brightness and contrast, were not used for the on-screen measurements. This value was registered as radiographic root canal length (RRCL).

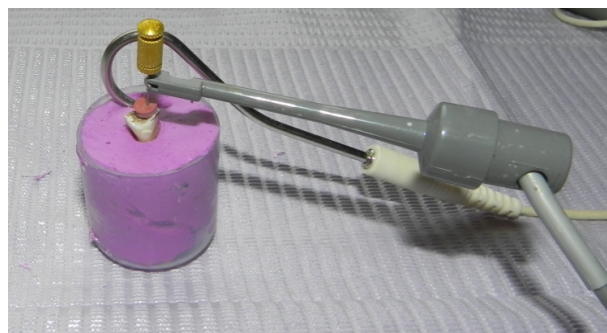


**Fig (3):** On screen measurements of tooth length using software electronic ruler

#### Root canal length determination by electronic apex locator (EAL) method:

The Root ZX, J. Morita Corporation was used on EMR Mode-Electronic measurement of a root canal (A full automatic apex locator, Tokyo, Japan). Blocks were made by embedding the teeth in alginate with 0.9% sodium chloride solution which act as a conducting gel simulating the periodontium<sup>18</sup>. The lip-clip (contrary electrode) was attached to the alginate block and the file holder was attached onto the shaft of the hand file. The size 15 K-file with the rubber stopper adapted to the reference point (the incisal edge) was advanced apically into the canal, until the beeping sound and the light emitting diode (LED) marked APEX on the panel began to glow, indicating that the tip of the file had reached the predetermined length of

the apical constriction. If the file penetrated the constriction, a caution light, a continuous alarm, as well as a flashing 'E' signal on the digital readout, provided the warning. The file was withdrawn with a slow counter clockwise turn until the pulsing audition and the flashing light went out. The distance from the tip of the instrument to the rubber stopper was measured using a graduated metal scale; the value was noted down and registered as electronic root canal length (ERCL) (Fig. 4).



**Fig (4):** Tooth embedded in alginate block, lip-clip attached to the alginate block and the file holder attached onto the shaft of the hand file.

#### Statistical analysis:

Percentage difference data showed non-parametric (non-normal) distribution so; Friedman's test was used to compare between the three methods. This test is the non-parametric alternative to repeated measures ANOVA test. Wilcoxon signed-rank test was used for pair-wise comparisons between methods when Friedman's test yields significant results.

Kruskal-Wallis test was used to compare between different canal length categories. This test is the non-parametric alternative to one-way ANOVA test. Mann-Whitney U test was used for pair-wise comparisons between the length categories when Kruskal-Wallis test is significant.

The significance level was set at  $P \leq 0.05$ . Statistical analysis was performed with IBM (IBM Corporation, NY, USA.) SPSS (SPSS, Inc., an IBM Company.) Statistics Version 20 for Windows.

#### 3. Results:

Root canal length measurements were presented as mean and standard deviation (SD) values table (1).

**Table (1):** The mean and standard deviation (SD) values of root canal length measurements using different methods

Actual length		Tactile measurement		Apex locator measurement		Digital X-Ray measurement	
Mean	±SD	Mean	±SD	Mean	±SD	Mean	±SD
13.07	±1.78	14.37	±1.95	12.87	±1.84	12.89	±1.82



### 1- Comparison between percentage differences from actual length of different methods:

The percentage difference from the actual length was calculated as:

$$\frac{\text{Method measurement} - \text{Actual length}}{\text{Actual length}} \times 100$$

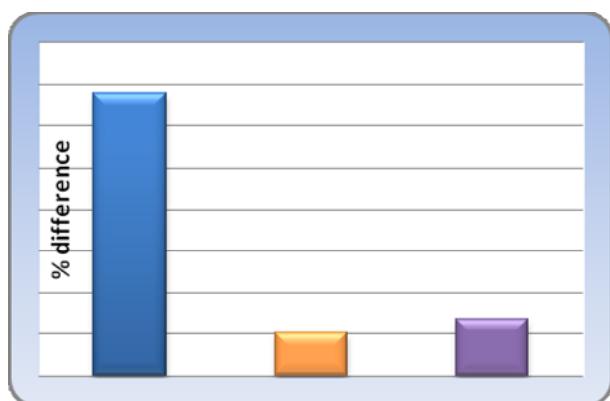
There was a statistically significant difference between different methods ( $P < 0.001$ ). Pair-wise

comparisons between the different methods revealed that tactile method showed the statistically significantly highest mean percentage difference from actual length. There was no statistically significant difference between apex locator and digital X-Ray methods; both showed the statistically significantly lowest mean differences from actual length (Table 2 and Fig. 5).

**Table (2): The mean, standard deviation (SD) values and results of comparison between percentage differences from actual length of different methods**

Tactile measurement		Apex locator measurement		Digital X-Ray measurement		P-value
Mean	±SD	Mean	±SD	Mean	±SD	
13.53 <sup>a</sup>	±7.68	2.02 <sup>b</sup>	±2.09	2.70 <sup>b</sup>	±2.37	<0.001*

\*: Significant at  $P \leq 0.05$ , Different letters are statistically significantly different



**Figure (5): Mean % difference from the actual length of different methods**

### 2- Comparison between percentage differences from actual length of different methods with different root canal length categories:

Table (3) and Figure (6) showed that teeth with root canal length  $<13$  mm, there was a statistically significant difference between different methods ( $P < 0.001$ )

Pair-wise comparisons between the different methods revealed that tactile method showed the statistically significantly highest mean percentage difference from actual length. There was no

statistically significant difference between apex locator and digital X-Ray methods; both showed the statistically significantly lowest mean differences from actual length.

Teeth with root canal length 13 – 14 mm, there was a statistically significant difference between different methods ( $P = 0.048$ ).

Pair-wise comparisons between the different methods revealed that tactile method showed the statistically significantly highest mean percentage difference from actual length. There was no statistically significant difference between apex locator and digital X-Ray methods; both showed the statistically significantly lowest mean differences from actual length.

As regards teeth with root canal length  $>14$  mm, there was a statistically significant difference between different methods ( $P = 0.002$ ).

Pair-wise comparisons between the different methods revealed that tactile method showed the statistically significantly highest mean percentage difference from actual length. There was no statistically significant difference between apex locator and digital X-Ray methods; both showed the statistically significantly lowest mean differences from actual length.

**Table (3): The mean, standard deviation (SD) values and results of comparison between percentage differences from actual length of different methods with each root canal length category**

Root canal length	Tactile measurement		Apex locator measurement		Digital X-Ray measurement		P-value
	Mean	±SD	Mean	±SD	Mean	±SD	
<13 mm	17.74 <sup>a</sup>	±7.12	2.13 <sup>b</sup>	±2.12	3.03 <sup>b</sup>	±3.01	<0.001*
13 – 14 mm	10.18 <sup>a</sup>	±6.82	1.63 <sup>b</sup>	±2.03	2.99 <sup>b</sup>	±1.67	0.048*
>14 mm	9.61 <sup>a</sup>	±6.21	2.15 <sup>b</sup>	±2.29	1.95 <sup>b</sup>	±1.64	0.002*

\*: Significant at  $P \leq 0.05$ , Different letters in the same row are statistically significantly different

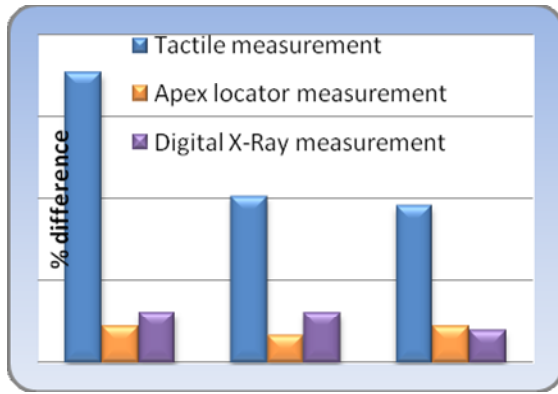


Figure (6): Mean % difference from the actual length of different methods with each root canal length

Table (4): The mean, standard deviation (SD) values and results of comparison between percentage differences from actual length of different root canal length categories

Root canal length	Tactile measurement		Apex locator measurement		Digital X-Ray measurement	
	Mean	±SD	Mean	±SD	Mean	±SD
<13 mm	17.74	±7.12	2.13	±2.12	3.03	±3.01
13 – 14 mm	10.18	±6.82	1.63	±2.03	2.99	±1.67
>14 mm	9.61	±6.21	2.15	±2.29	1.95	±1.64
<b>P-value</b>	<b>0.522</b>		<b>0.377</b>		<b>0.169</b>	

\*: Significant at  $P \leq 0.05$

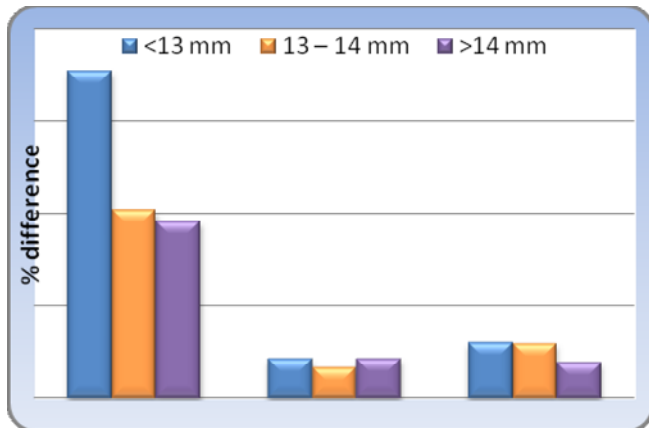


Figure (7): Mean % difference from the actual length of different root canal length categories with each method

**4. Discussion:**

The establishment of apical limit of canal preparation is an important phase of root canal treatment. It is generally accepted that canal preparation and filling should be limited within the root canal<sup>19</sup>.

Studies over the years have confirmed the reliability of electronic apex locators. Similarly, different studies that have compared digital and conventional radiography considered the reliability of

**3- Effect of root canal length on the accuracy of measurement:**

Table (4) and Figure (7) showed that tactile method has no statistical significant difference between different root canal length categories ( $P = 0.522$ ). With apex locator, there was no statistically significant difference between different root canal length categories ( $P = 0.377$ ). Digital X-ray method, also showed no statistical significant difference between different root canal length categories ( $P = 0.169$ ).

the former technique to be equal to or even superior to that of conventional radiography<sup>20</sup>.

In the current study statistical results showed a significant difference of the tactile method compared with the actual root canal length, this was in agreement with the study carried by *Shanmugaraj et al., 2007*, who concluded that an inaccuracy of the tactile method could be highly noticed in cases of incomplete pulp extirpation, periapical lesions, physiologic root resorption, narrow and curved root canals<sup>5</sup>.

In this study, a good accuracy was achieved by using digital parallel radiography in addition to other advantages such as the reduction in the dose, faster processing and information saving<sup>21</sup>. *Lamus et al., 2001* carried out a study to compare between conventional and digital radiography, he concluded that digital radiography had more accuracy in canal length measurement<sup>22</sup>.

Estimated tooth length in conventional radiography has been reported as similar ( $\pm 1$  mm range) to actual tooth length<sup>23</sup>. In the present study, a 1-mm difference between the actual tooth length and the digital radiographic estimation of tooth length was considered a clinically acceptable discrepancy because this difference would not allow the file to extend beyond the actual tooth length and past the apical foramen.

This study controlled possible sources of error in radiographic images, such as the distance from the tooth to the radiation source and to the sensor, as well

as the vertical and horizontal cone angulation. The X-ray equipment cone and the sensor in a fixed position. It was, therefore, possible to simulate the paralleling radiographic technique, in which the estimated tooth length is closer to the actual length<sup>23</sup>.

Digital image calibration was performed before tooth length determination using the on-screen calibration tool to measure the image of an endodontic file of a known length. It was done because it has been shown that calibrated digital measurements are more accurate than uncalibrated measurements<sup>8</sup>.

Our findings suggested that the tooth length obtained with straight-line measurement on direct digital radiographs using only a starting and end point to estimate the tooth length was similar to the actual tooth length. An electronic ruler was the best measurement instrument in an endodontic length study developed by *Vandre et al., 1995*<sup>24</sup>. A study by *Kim et al., 2003* showed that an onscreen straight-line measurement was effective in the radiographic assessment of tooth length<sup>25</sup>.

No significant difference in the electronic apex locator method from the actual root canal length was observed which in agreement with studies carried by *Shabahang et al., 1997*<sup>26</sup>. Also another study used Root ZX for measuring root canal length in vivo and found no differences between roots with and without resorption<sup>14</sup>.

This study found the least magnitude of deviation from the mean in measurements by the apex locator when compared to the other two methods. It may remark that the EAL can overcome the shortcomings of the former methods, since that the electronic devise based on electrical principles that can detect the narrowest of the canal even in the presence of moisture and conductive fluids. It is extremely useful in children who gag during radiography.

A study done by *Subramaniam et al., 2005* stated that incorporation of EAL and digital parallel radiography can be of immense use in pediatric endodontic procedures. He concluded that those methods can be reliable and precise because they increase safety and comfort of treatment in children<sup>4</sup>.

#### Conclusion:

1. From the results of this in vitro study it can be concluded that the apex locator method can be considered reliable and precise since it is more superior to the tactile method. It can detect the narrowest of the canal even in the presence of moisture and conductive fluids. It is extremely useful in children who gag during radiography.
2. The digital parallel radiography is comparable to EAL in determining the working length of primary teeth.
3. Tactile determination of the root canal length of primary anterior teeth is not a reliable method.

#### Recommendation:

Further research should be conducted, especially with primary molars, because only anterior teeth were used in the present study. It is likely that the discrepancy between the actual canal length and the estimated radiographic length will increase significantly as the degree of root curvature increases

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#### 5. References:

1. Takushige T, Cruz EV, Asgor Moral A, Hoshino E (2004). Endodontic treatment of primary teeth using a combination of antibacterial drugs. *Int Endod J.*, 37:132–138
2. Cotti E, Lusso D, Dettori C (1998). Management of apical inflammatory root resorption: report of a case. *Int Endod J.*, 31: 301–304
3. Mente J, Seidel J, Buchalla W, Koch MJ (2002). Electronic determination of root canal length in primary teeth with and without root resorption. *Int Endod J.*, 35:447–452
4. Subramaniam P, Konde S, Mandanna D (2005). An *in vitro* comparison of root-canal measurements in primary teeth. *J Indian Soc Pedod Prev Dent.*, 37:124-125.
5. Shanmugaraj M, Nivedha R, Mathan R, Balagopal S (2007). Evaluation of working length determination methods: An *in vivo/ ex vivo* study. *J Ind of Dent Res.*, 18(2):60-62.
6. Troutman KC, Reisbick MH (1982). Pulp therapy. In: Stewart RE, Barber TK, Troutman KC, Wei SHY, editors. *Pediatric Dentistry: Scientific foundations and clinical practice*. Toronto: Mo Mosby Co. p. 908-17.
7. Katz A, Mass E, Kaufman AY (1996). Electronic apex locator: a useful tool for root canal treatment in the primary dentition. *ASDC J Dent Child*, 63:414-7.
8. Loushine RJ, Weller N, Kimbrough WF, Potter BJ (2001). Measurement of endodontic file lengths: Calibrated versus uncalibrated digital images. *J Endod.*, 27:779-81.
9. Nekoofar M, Ghandi M, Hayes S, Dummer P (2006). The fundamental operating principles of electronic root canal length measurement devices. *J Int Endod.*, 39(8): 595–609.
10. Fan W, Fan B, Gutmann J, Fan M (2006). Evaluation of the accuracy of three electronic apex locators using glass tubules. *J Int Endod.*, 39(2): 127– 135.

11. Kobayashi C, Okiji T, Kaqwashima N, Suda H, Sunadi I (1991). A basic study on the electronic root canal length measurement: Part 3. Newly designed electronic root canal length measuring device using division method. *Jap J Cons Dent.*, 34:1442–8.
12. Oishi A, Yoshioka T, Kobayashi C, Suda H (2002). Electronic detection of root canal constrictions. *J Endod.*, 28:361–4.
13. Brunton PA, Abdeen D, MacFarlane TV (2002). The effect of an apex locator on exposure to radiation during endodontic therapy. *J Endod.*, 28:524–526
14. Kielbassa AM, Muller U, Munz I, Monting JS (2003). Clinical evaluation of the measuring accuracy of ROOT ZX in primary teeth. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod.*, 95:94–100
15. Katz A, Tamse A, Kaufman Y (1991). Tooth length determination: A review. *J Oral Surg Oral Med Oral Pathol Oral Radiol Endod.*, 72:238-242.
16. Ingle J, Bakland L. *Endodontics* (2002). 5<sup>th</sup> ed. Elsevier. Canada pp: 324 -327.
17. Leach H, Ireland A, Whaites E (2001). Radiographic diagnosis of root resorption in relation to orthodontics. *J Bri Dent.*, 190(1):16-22.
18. Ounsi H, Hadded G (1998). *In vitro* evaluation of the reliability of the Endex electronic apex locator. *J of Endod.*, 4:120-122.
19. Melius B, Jiang J, Zhu Q. (2001). Measurement of the distance between the minor foramen and the anatomic apex by digital and conventional radiography; *Journal of Endodontics.*; 65(10):985-990.
20. Martinez-Lozano MA, Forner-Navarro L, Sanchez-Cortes JL, Llena-Puy C. (2001). Methodological consideration in the determination of working length. *International Endodontic Journal.*, 34:371-6.
21. White, SC and M.J. Pharaoh (2004). *Oral radiology: principle and interpretation.* 5<sup>th</sup> Edn. Mosby, St Louis, MO USA, pp: 560.
22. Lamus, F., J.O. and A.G. Glaros, (2001). Evaluation of a digital measurement tool to estimate working length in endodontics. *J. Contemp. Dent. Practice*, 15:24-30.
23. Larheim TA, Eggen S. (1997). Determination of tooth length with a standardized paralleling technique and calibrated radiographic measuring film. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod.*, 48:374-8.
24. Vandre RH, Cruz CA, Pajak JC. (1995). Comparison of four direct digital radiographic systems with film for endodontic length determination [abstract]. *Dentomaxillofac Radiol*, 24:92.
25. Kim-Park MA, Baughan IW, Hartwell GR. (2003). Working length determination in palatal roots of maxillary molars. *J Endod.*, 29:58-61.
26. Shabahang S, Goon W, Gluxkin A. (1997). *An in vivo* apex locator Root ZX. *J Endod.* 15: 35–40.

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