Accuracy of Different Apex Locators in Teeth with Simulated Apical Root Resorption: an In Vitro Study

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Background: Accurate working length (WL) determination is necessary in achieving optimal healing by non-surgical root canal therapy in teeth with inflammatory apical root resorption. Electronic apex locators (EALs) are one of the mainstays in determination of WL of teeth.

Aim: This study evaluated the accuracy of three EALs [RootZX (third generation), iPex (fourth generation) and Raypex 6 (modification of a fifth generation)] in determining the WL of teeth with simulated apical root resorption in permanent teeth.

Materials and methods: Forty freshly extracted maxillary anterior teeth were collected and a 45° oblique cut was made at the root apex with a drill to simulate apical root resorption. Actual working length (AWL) was determined by direct visual method and was used as a control. Electronic working length (EWL) values were measured by three different apex locators that are RootZX (Group I), iPex (Group II) and Raypex 6 (Group III) at apex, 0.5 mm and 1 mm from apex. All values obtained were tabulated and statistical evaluation was carried out.

Results: At apex, EWL obtained using iPex (p=0.05) showed a statistically significant difference from AWL. At 0.5 mm and 1 mm tolerance, iPex showed non-acceptability for WL measurement in 67.5% and 17.5% of samples compared to Root ZX (12.5% and 2.5%) and Raypex (7.5% and none) respectively.

Conclusion: Within the limitation of this study, it can be concluded that Raypex 6 and RootZX show statistically significant accuracy in WL measurement compared with iPex in teeth with apical root resorption.
tion. Apical constriction, which is considered to be the most appropriate landmark for termination of endodontic therapy, is not always present in teeth with root resorption or open apices.4,5

Over the years, various methods have been investigated that determine the WL of teeth accurately. Electronic apex locators (EALs) are one of the mainstays in determination of WL of teeth. Today, various generations of EALs are available with every generation “claiming” its superiority over the previous one. It has been established that the accuracy of EALs is greatly influenced by the diameter of the apical foramen. However, there is a lacuna in the literature about the impact of apical resorption in permanent teeth on the efficiency of EALs. Hence, extrapolating from this information, this study was planned and conducted to measure the accuracy of three EALs [RootZX (third generation), iPex (fourth generation) and Raypex 6 (modification of a fifth generation)] in determining the WL of teeth with simulated apical root resorption in permanent teeth.

MATERIALS AND METHODS

SAMPLE COLLECTION AND SAMPLE PREPARATION
Forty freshly extracted single-canalled maxillary anterior teeth were collected (Fig. 1a). Teeth were cleaned off the blood, kept in 5.25% sodium hypochlorite for 2 hours and stored in sterile 0.9% saline solution till the further procedure. Teeth were de-coronated at cementoenamel junction with a diamond disc to simplify access to the root canal and to obtain a fix occlusal landmark. To simulate apical root resorption, a 45° oblique cut was made at the root apex with a disc such that the palatal wall was shorter than the facial wall by 3 mm (Fig. 1b). Cervical and middle thirds of the root canal were prepared using Gates Glidden burs sizes #5, #4 and #3 sequentially. Following this, canal patency was established with a No. 15 stainless steel K-file and irrigated with a 2.5% sodium hypochlorite solution. All teeth were subjected to working length determination procedure that is actual and electronic working lengths determination.

WORKING LENGTH DETERMINATION

ACTUAL WORKING LENGTH DETERMINATION (AWL) (n=40) (CONTROL):
Actual working length (AWL) was determined using a visual method. An ISO size 15 Stainless Steel K-file was placed into the root canal and progressed till its tip was just visible on the palatal wall. The silicone stopper was adjusted to coronal reference point. The file was removed and measured using an endoblock. The obtained direct visual measurement was reduced by 0.5 mm and recorded. Three
readings were taken by two trained endodontists independently and then average of two values was considered as final AWL. It was kept as control.

**MODEL PREPARATION (N=40)**

Canal of each tooth was packed with cotton up to the root apex to prevent retrograde entry of alginate material. Freshly mixed alginate was poured into the plastic cylindrical container keeping space for tooth insertion and lip clip. Canal patency was checked using an ISO size 15 stainless steel K-file. Excess alginate around the teeth and mould was trimmed out with a scalpel blade.

**ELECTRONIC WORKING LENGTH DETERMINATION (EWL) (N=40)** (**Fig. 2**)

Before electronic working length (EWL) measurement, 0.5 ml of saline was placed inside the canal to keep the root canal moist. The excess solution present in the chamber was carefully suctioned. All 3 apex locators [that is RootZX (EAL 1), iPex (EAL 2) and Raypex 6 (EAL 3)] were used to record the electronic working lengths (EWL) using an ISO size 15 stainless steel K-file. EWLs were recorded at three levels that is at apex, 0.5 mm and 1 mm from the apex. All values were recorded by two trained endodontists independently and then average of two values was considered as final EWL to eliminate any observer bias. For all three EALs, the readings were taken in accordance with the manufacturer’s instruction and all measurements were recorded using the same measuring endoblock previously used during AWL measurement. Values obtained by RootZX (EAL 1), iPex (EAL 2), Raypex 6 (EAL 3) were categorised under group I, group II and group III, respectively.

Data was recorded and results were compared with the actual working length, allowing a tolerance of 0.5 mm and 1 mm. At 0.5 mm tolerance, measurements were considered as accurate if the difference between electronic and actual working length was less than 1 mm and non-acceptable if this difference is more than or equal to 1 mm. Similarly, at 1 mm tolerance, measurements were considered as accurate if the difference between electronic and actual working length was less than or equal to 1 mm and non-acceptable if this difference is more than 1 mm. Data obtained was subjected to statistical evaluation.

**STATISTICAL PROCEDURES**

Data obtained was compiled on a MS Office Excel Sheet (v 2010). Data was subject to statistical analysis using statistical package for social sciences (SPSS v 21.0, IBM). Comparison of the actual working length, electronic working length and the actual difference for the three apex locators was performed using ANOVA test. Moreover, unpaired t test was done to compare the actual working length and electronic working lengths (EAL1, EAL2 and EAL3). Measurements recorded with each apex locator at the 0.5 mm and 1 mm tolerance were analyzed with chi-square test (**Tables 1, 2**).

**RESULTS**

A total of 120 electronic measurements were made, 40 with each EAL (electronic apex locator). All the measurements were recorded in millimetres (mm). Results obtained with 0.5 mm and 1 mm tolerances are summarized in **Table 1** and **Table 2**, respectively. There is a statistically significant difference between actual working length (AWL) and electronic working length (EWL) obtained using iPex (p=0.05). However, electronic working lengths obtained using RootZx (p=0.38) and Raypex (p=0.46) do not differ significantly from the AWL. Difference between AWL and EWL is lowest for Raypex (0.37 ± 0.2) followed by Root ZX (0.43 ± 0.3) and iPex (0.92 ± 0.3). Three apex locators showed highly significant difference at 0.5 mm tolerance (p=0.001) (**Table 1**) and significant difference at 1 mm tolerance (p=0.003) (**Table 2**).
Accuracy of Apex Locators

Table 1. Comparison of the acceptability and non-acceptability for all the 3 electronic apex locators using chi-square test (0.5 mm tolerance)

<table>
<thead>
<tr>
<th>Tolerance 0.5</th>
<th>Group I EAL 1 (RootZx)</th>
<th>Group II EAL 2 (iPex)</th>
<th>Group III EAL 3 (Raypex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accurate</td>
<td>Count</td>
<td>35</td>
<td>13</td>
</tr>
<tr>
<td>% within Group</td>
<td></td>
<td>87.5%</td>
<td>32.5%</td>
</tr>
<tr>
<td>Non-acceptable</td>
<td>Count</td>
<td>5</td>
<td>27</td>
</tr>
<tr>
<td>% within Group</td>
<td></td>
<td>12.5%</td>
<td>67.5%</td>
</tr>
<tr>
<td>Total</td>
<td>Count</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>% within Group</td>
<td></td>
<td>100.0%</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

p < 0.05 - significant*, p < 0.001 - highly significant**

Table 2. Comparison of the acceptability and non-acceptability for all the 3 electronic apex locators using chi square test (1 mm tolerance)

<table>
<thead>
<tr>
<th>Tolerance 1.0</th>
<th>Group I EAL 1 (RootZx)</th>
<th>Group II EAL 2 (iPex)</th>
<th>Group III EAL 3 (Raypex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accurate</td>
<td>Count</td>
<td>39</td>
<td>33</td>
</tr>
<tr>
<td>% within Group</td>
<td></td>
<td>97.5%</td>
<td>82.5%</td>
</tr>
<tr>
<td>Non-acceptable</td>
<td>Count</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>% within Group</td>
<td></td>
<td>2.5%</td>
<td>17.5%</td>
</tr>
<tr>
<td>Total</td>
<td>Count</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>% within Group</td>
<td></td>
<td>100.0%</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

p< 0.05 - significant*, p < 0.001 - highly significant**

iPex show least accuracy at apex, 0.5 mm and 1 mm compared to Raypex and RootZx.

DISCUSSION

Accurate working length (WL) measurement is critical for the success rate of root canal treatment. Teeth with apical root resorption or open apex pose difficulties to contemporary methods of root canal length determination. In such teeth, dentinal walls have irregular margins ending at different levels resulting in overestimation of the radiographic working length. Moreover radiographic method is subjected to interpretation bias (due to two-dimensional nature of the image and variation in apical extent of root in case of teeth with open apex or resorption) and shows anatomic noise (overlapping of various anatomic structures like zygomatic arch, maxillary sinus etc). Tactile technique has steep learning curve with vast inter-operative difference in measurement. With the advent of electronic apex locators (EALs), assessment of working length (WL) in teeth with apical root resorption has become more predictable. During the WL determination by EALs, it is recommended to withdraw the instrument by approximately 0.5–1.0 mm. Hence in the present study WL measurements taken at apex, 0.5 mm and 1.0 mm were compared.

Several electro-conductive media such as agar, gelatin, flower sponge soaked with 0.9% saline, simple saline solution, alginate etc can be used to simulate clinical situation for performing in vitro evaluation of accuracy of EALs. However,
alginate is found to be superior to other materials because its electro-conductive properties simulate the periodontal ligament. In addition it firmly supports the teeth to remain intact for the duration of the study, it is economical, easy to handle and may hide the roots resulting in an objective and unbiased measurement. Hence in the presented study, alginate model was used. However alginate mass tends to dehydrate quickly. Hence all measurements were performed within 30 min to prevent any decline in the accuracy of the readings. Apical resorption was mimicked using an oblique 45° cut at the apex. In the enlarged canals, electronic working length measurements obtained with small and large size files were comparable. The presence of resorption in teeth did not affect the accuracy of electrical measurement of root canal length in vitro. A pilot study using different endodontic files to determine electronic working length recommended 15 no K-file to be the most precise. Moreover, previous study used 15 no K-file for working length determination in teeth with apical root resorption. Hence in the present study 15 no K-file was used. The same file size was used in every case (No. 15 K-file) to create comparable conditions for the in vitro measurements.

In the present study, in vitro evaluation was preferred as it provides better standardization and...
objective evaluation of different variables. The morphology and location of the minor and major foramen influence the performance of EALs. Therefore, different results obtained in various studies could be explained partly by the nature of the teeth used in the studies. It is important to use the same teeth to be able to compare precisely the accuracy and differences amongst types of EAL in the determination of the WL. Hence in the present study same teeth were used for all groups. Standard deviation (SD) measurement gives idea regarding the reliability of reproducing the same working length. Hence it is important to analyze the SD of the measurements obtained with different EALs as was done in the present study. Mean and standard deviation of the difference between actual working length (AWL) and WL obtained using EAL indicates its accuracy and reproducibility respectively. Hence in the present study both SD and mean were evaluated. The Root ZX (J Morita, Tokyo, Japan) is a third generation EAL that use two frequencies and impedance technology to measure location within canal. It has powerful microprocessors that process the mathematical quotient and algorithm calculations required to give accurate readings. It is accurate even in presence of different electrolytes in the canal and under different clinical conditions. The iPex (NSK, Tochigi, Japan) is a fourth generation EAL that measures capacitance and resistance simultaneously to determine the location of the file tip in the canal. Raypex 6 (VDW, Munich, Germany) is the last member of Raypex series that utilizes the multi-frequency apex locator technology.

In the present study, Raypex and Root ZX were found to be significantly accurate at apex and within limits of 0.5 mm and 1.0 mm in comparison to iPex. At 0.5 mm and 1.0 mm tolerance, iPex reading showed non-acceptability for WL measurement in 67.5% and 17.5% of samples compared to Root ZX (12.5% and 2.5%) and Raypex (7.5% and none) respectively. There are various reasons contributing to this finding. iPex performs well in relatively dry or in partially dried canals, whereas the canals in this study were pre-irrigated with saline solution. Moreover, iPex relies on both capacitance and resistivity and hence it is absolutely necessary for the tip of the file to reach the periodontal tissue to achieve precise measurement which is difficult in case where apical resorption is present. On the other hand, Root ZX and Raypex (that measures the difference in impedance values at different frequencies) were able to maintain an acceptable degree of precision even when the file did not reach the apical foramen.

CONCLUSIONS
Within limitation of study, it can be concluded that Raypex 6 (modification of a fifth generation) and Root ZX (third generation) shows statistically significant accuracy in WL measurement compared to iPex (fourth generation) in teeth with apical root resorption.

REFERENCES
Точность различных апекслокаторов при зубах с имитацией апикальной резорбции корня: исследование in vitro

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Ключевые слова: электронный апекслокатор, апикальная резорбция корня, рабочая длина


Введение: Точное определение рабочей длины (РД) необходимо для обеспечения оптимального лечения нехирургической терапии корневых каналов в зубах с апикальной резорбцией корня. Электронные апекслокаторы (ЭАЛ) являются одним из основных инструментов для определения РД в зубах.

Цель: Настоящая работа исследует точность трёх ЭАЛ - RootZX (третьего поколения), iPex (четвёртого поколения) и Raypex 6 (модификация пятого поколения) при определении РД постоянных зубов с имитацией апикальной резорбции корня.

Материалы и методы: Было отобрано сорок недавно удалённых верхнечелюстных передних зубов и при помощи диска был сделан скошенный 45° разрез для имитации апикальной резорбции корня. Фактическая рабочая длина (ФРД) была установлена непосредственным визуальным методом и использовалась в качестве контроля. Величины электронной рабочей длины (ЭРД) измерялись тремя различными апекслокаторами: RootZX (группа I), iPex (группа II) и Raypex 6 (группа III) у апекса, на расстоянии 0.5 мм и 1 мм от апекса. Все измеренные величины были введены в таблицу и был проведён статистический анализ.

Результаты: У апекса ЭРД, измеренный iPex (p = 0.05), показал статистически значимое отличие от ФРД. С допуском 0.5 мм и 1 мм, iPex показал несовместимость для измерения РД при 67.5% и 17.5% образцов по сравнению соответственно с Root ZX (12.5% и 2.5%) и Raypex (7.5% и отсутствие).

Вывод: Учитывая ограничения этого исследования, можно утверждать, что Raypex 6 и RootZX показывают статистически значимую точность измерения РД по сравнению с iPex при апикальной резорбции корня.