

# Evaluation of the Accuracy of Two Apex Locators for Determining the Working Length of Endodontically Retreated Curved Mesial Roots of Maxillary Molar Teeth: An Ex Vivo Study

Dilara ARSLAN<sup>1</sup>



<sup>1</sup> Department of Endodontics, Faculty of Dentistry, Istanbul Aydın University, Istanbul, Türkiye

Mira KEBUDİ BENEZRA<sup>2</sup>



Endodontist, Private Practice, Istanbul, Türkiye

Fatma KAPLAN<sup>3</sup>



<sup>3</sup>Department of Endodontics, Faculty of Dentistry, Bezmialem Vakıf University, Istanbul, Türkiye

Mehmet Burak GÜNEŞER<sup>3</sup>



<sup>3</sup>Department of Endodontics, Faculty of Dentistry, Bezmialem Vakıf University, Istanbul, Türkiye

## Maksillar Molar Dişlerin Eğimli Mesial Kanallarının Kök Kanal Tedavisi Tekrarı Esnasında Çalışma Uzunluğu Belirlenmesinde İki Farklı Apeks Bulucunun Doğruluğunun Değerlendirilmesi: Ex Vivo Çalışma

### ABSTRACT

**Objective:** To evaluate the accuracy of PROPEX PİXİ (Dentsply Sirona, Ballaigues, Switzerland) and Apex ID (Sybron Endo, Orange, CA, USA) in determining the working lengths of curved mesial roots of upper molars during the retreatment procedure.

**Method:** Twenty curved mesial roots of upper molar teeth were selected. Canals were shaped with ProTaper Next instruments (Dentsply Sirona) up to X3. The canal lengths were determined with a stereomicroscope (Carl Zeiss GmbH, Oberkochen, Germany) at 2,5X magnification (DM) and then also detected electronically (EM1P and EM1A) with PROPEX PİXİ (Dentsply Sirona) and Apex ID (Sybron Endo) in an alginate model. Specimens were then obturated using a size X3 master gutta-percha cone and an epoxy resin-based root canal sealer. Seven days later, the coronal part of the filling was removed with a Gates Glidden drill size 3 and for the middle part Protaper Universal Retreatment File D2 used. Working lengths electronically were detected again by two different apex locators (EM2P and EM2A). Data were analysed by using the Wilcoxon Signed Rank and Mann Whitney u test. The analyses were carried out with MedCalc Statistical Software.

**Results:** No significant difference was found between direct measurements (DM) and electronic measurements before and during retreatment for PROPEX PİXİ and Apex ID ( $P>.01$ ). Also there was no significant difference between two apex locators before and during retreatment ( $P>.01$ ).

**Conclusion:** PROPEX PİXİ and Apex ID were considered accurate for the root canal length determination during retreatment procedure.

**Keywords:** Apex locator, curved molar, retreatment, working length

### ÖZ

**Amaç:** Bu çalışmanın amacı kök kanal tedavisinin yenilenmesi işlemi sırasında üst azı dişlerinin eğimli mesial köklerinin çalışma uzunluklarının belirlenmesinde PROPEX PİXİ (Dentsply Sirona, Ballaigues, İsviçre) ve Apex ID'nin (Sybron Endo, Orange, CA, ABD) doğruluğunu değerlendirmektir.

**Yöntem:** 20 adet üst molar dişin eğimli mesial kökü seçildi. Kanallar ProTaper Next (Dentsply Sirona) ile X3'e kadar şekillendirildi. Kanal uzunlukları stereomikroskopla (Carl Zeiss GmbH, Oberkochen, Almanya) 2,5X büyütmede (DM) belirlendi ve ardından PROPEX PİXİ (Dentsply Sirona) ve Apex ID (Sybron Endo) ile elektronik olarak aljinat model kullanılarak (EM1P ve EM1A) tespit edildi. Daha sonra kanallar, X3 boyutunda bir ana gutta-perka konisi ve bir epoksi reçine bazlı kök kanal patı kullanılarak dolduruldu. Yedi gün sonra dolgunun koronal kısmı #3 Gates Glidden frez ile orta kısmı ise Protaper Universal Retreatment egesi (D2) kullanılarak çıkarıldı. Çalışma uzunlukları elektronik olarak iki farklı apeks bulucu (EM2P ve EM2A) tarafından yeniden tespit edildi. Veriler Wilcoxon Signed Rank ve Mann Whitney u testi kullanılarak analiz edildi. Analizler MedCalc İstatistik Yazılımı ile gerçekleştirildi.

**Bulgular:** PROPEX PİXİ ve Apex ID için kanal tekrarı öncesinde ve kanal tekrarı sırasında yapılan ölçümler ile stereomikroskopla yapılan ölçümler arasında anlamlı fark bulunmadı ( $P>.01$ ). Ayrıca kanal tekrarı öncesinde ve sırasında iki apeks bulucu arasında anlamlı bir fark yoktur ( $P>.01$ ).

**Sonuç:** PROPEX PİXİ ve Apex ID'nin kanal tekrarı işlemi sırasında kök kanal uzunluğunun belirlenmesinde doğru olduğu kabul edildi.

**Anahtar Kelimeler:** Apeks bulucu, kavislisi azı dişi, geri çekilme, çalışma uzunluğu

Geleş Tarihi/Received 23.03.2023  
Kabul Tarihi/Accepted 29.08.2023  
Yayın Tarihi/Publication Date 15.10.2024

Sorumlu Yazar/Corresponding author:

Dilara Arslan

E-mail: dilaraendo@hotmail.com

Cite this article: Arslan D, Kebudi Benezra M, Kaplan F, Güneşer MB Evaluation of the Accuracy of Two Apex Locators for Determining the Working Length of Endodontically Retreated Curved Mesial Roots of Maxillary Molar Teeth : An Ex Vivo Study. *Curr Res Dent Sci* 2024;34(4): 253-257



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## INTRODUCTION

Achieving a successful root canal treatment relies on an ideal chemomechanical cleaning, shaping and hermetic closure that dominates the entire canal anatomy. The basis for the success of these stages is the correct determination of the apical constriction and working length.<sup>1</sup> The apical constriction is most commonly determined with a radiographic technique using average distance value.<sup>2</sup> The disadvantages of using this technique are encountered in cases such as the presence of an apical lesion, root resorption etc.<sup>3</sup> In these cases, the apical constriction is not detectable with average values from the radiographic apex. Because radiography provides a 2D view of a 3D object, radiography also has other technical disadvantages.<sup>4</sup> In addition, the radiographic working length determination may be difficult in certain cases, for example, in maxillary molars, as it is closely related to anatomical marks.<sup>5</sup> Thus, in addition to the radiographic technique, the use of electronic apex locators (EALs) has become increasingly important in determining the working length.

Many studies have shown that, in primary root canal treatment cases, the presence of canal contents, such as debris, dentinal chips, pulp remnants and irrigating solution, can affect the accuracy of electronic apex locators. Because root canal preparation and root canal filling material affect root canal impedance, in the retreatment cases, components such as gutta-percha pieces, sealer remnants and gutta-percha solvent may also affect the measurements.<sup>6-12</sup> In addition, during removal of the gutta-percha, dramatic changes can occur in the area that apex locators are trying to identify.<sup>13</sup>

Molar teeth have a more complex structure anatomically compared to other teeth with their variable number of roots and canals, inclined roots and isthmus.<sup>14,15</sup> It has been reported that the error rate in determining the working length by radiography increases in direct proportion with the degree of curvature of the canal, and the working length of the curved canals varies during different preparation processes. Although EALs have a greater clinical importance in curved canals, most EAL studies have been performed using straight single-rooted teeth.<sup>16</sup>

The purpose of the present study was to evaluate the accuracy of Propex Pixi (Dentsply Sirona) and Apex ID (Sybron Endo), Orange in determining the working lengths of curved mesial roots of upper molars during root canal retreatment. To the best of our knowledge, no study has evaluated the accuracy of these EALs in determining working lengths during the retreatment procedure of curved maxillary molar canals. The null hypothesis tested was that there was no difference between Propex Pixi and Apex ID in working lengths determination during root canal retreatment.

## METHODS

### Preparation of Teeth

Twenty roots of maxillary molar teeth with mature apices extracted for periodontal and orthodontic reasons were selected. The angle of canal curvature was calculated by using Schneider's technique, and a 10° to 20° degree of curvature of mesiobuccal canals was selected.<sup>17</sup> The roots were viewed radiographically and examined with a stereomicroscope. Roots with calcifications, multiple canals and apical foramen, immature root tip or root canal treatment, and apical diameter greater than 15-K file were excluded from the study. The 20 teeth selected with these inclusion criteria were immersed in 4°C distilled water until use.

Endodontic access cavities were prepared using a fissure bur, and a stable reference point was created by smoothing the mesiobuccal

cusps. A 10 K-file was advanced in the canal until it was just visible, the stopper was seated at the reference point and the file was removed from the canal. The working length was determined to be 0.5 mm shorter than the distance between the stopper and the tip of the file. The canals were prepared with ProTaper NEXT instruments (Dentsply Sirona,) up to X3 with 2 mL of 2.5% sodium hypochlorite (NaOCl) irrigation between each instrument.

### Measurement Using the Direct Method (DM)

Once canal preparation was complete, the working lengths were determined with a microscope (Carl Zeiss GmbH, Oberkochen, Germany) at 2.5X magnification using the DM, the same way as before the preparation. The distance from the stopper to the file tip was measured with a digital ruler to the nearest 0.25 mm. These values were reduced by 0.5 mm and recorded as the direct measurement (DM).

### Measurement Using the EAL (EM1A and EM1P)

An alginate model defined by Kaufman et al. was used.<sup>18</sup> The mesial canals of the teeth placed in the alginate model were irrigated with 2.5% NaOCl and dried with paper points. Apex ID (Sybron Endo) and Propex Pixi (Dentsply Sirona) were used in accordance with the manufacturers' instructions. For the Apex ID, a size 25 K-file (Dentsply Sirona) was advanced until the 'APEX' signal was seen on the LCD display and then withdrawn until a flashing bar showing '0.5' had been reached (the third green bar). For Propex Pixi, the file was advanced within the root canal until the 'OVER' bar appeared and was then withdrawn until the 0.0 mark signal appeared.

The stopper was seated at the reference point, and the file was removed from the canal. The distance between the tip of the file and the stopper was measured with a digital ruler and noted as EM1A (Apex ID) and EM1P (Propex Pixi).

### Root Canal Filling

The canals were irrigated with 2 mL 5.25% of NaOCl, dried with paper points and then obturated with a single cone technique using a size X3 master gutta-percha cone (Dentsply Sirona) and an epoxy resin-based root canal sealer (AH Plus; Dentsply DeTrey, Germany). Endodontic cavities were filled with temporary filling material (Cavit; 3M ESPE Dental Products, USA). The roots were stored at 100% humidity to set the sealer.

### Electronic Measurement after Removal of Root Filling (EM2A and EM2P)

After seven days, the coronal part of the filling material was removed using a Gates Glidden drill size 3 and then the Protaper Universal Retreatment File D2 was used for the middle part. The teeth were placed back into the alginate model. 0.1 mL of Eucalyptus oil was introduced into the root canal for 2 min to soften the gutta-percha at the apical third of the roots after using D2. Number #20 and #15 K-files were advanced through the softened apical gutta until reaching the working length. After the root canal was negotiated a 25 K-file was inserted into the canal and the working length was achieved, electronic measurements were repeated as described prior to the root canal filling. Measurements were recorded as EM2A and EM2P.

Electronic measurements were performed to insure that the alginate was kept fresh. These measurements were made at 2-h intervals, and the alginate was refreshed each time. The signals that flashed continuously for 5 s were taken into consideration. Measurements were made by a single operator to maintain consistency. All measurements were repeated three times, and average values were taken.

### Evaluation Criteria

Electronic measurements obtained before and after root filling (EM1A/P and EM2A/P) were compared with the direct measurement (DM), and EAL devices were compared with each other.

The differences were noted with a negative sign when the direct measurement was greater than the electronic measurements. Indicating that, in the electronic measurement, the file tip was inside the canal and did not reach the foramen. When the DM was less than the EM1A/P or EM2A/P, the difference was given as a positive sign, indicating the file tip had passed beyond the foramen. The means of differences between DM/EM1A,P and DM/EM2A,P were then calculated, and data was analysed by using the Wilcoxon signed-rank and Mann–Whitney *U* tests. Statistical significance was accepted at the alpha level of 5% ( $P < .05$ ).

## RESULTS

The differences between measurements detected by direct and electronic measurements before and after root canal filling are shown in Table 1 and Figure 1. It can be seen that the mean values of the differences between all electronic measurements and direct measurement are positive. In general, the electronic measurements were very close to the direct measurements, but they were found to be higher. According to these results, no statistically significant difference was found between direct measurements and electronic measurements before and after retreatment for Propex Pixi and Apex ID ( $P > .01$ ). Also, there was no significant difference between the two apex locaters before and during retreatment ( $P > .01$ ).

clinicians to perform over instrumentation and overfilling. Cimilli et al.<sup>19</sup> determined significant differences and indicated that Dentaport ZX (J Morita Corp, Kyoto, Japan) cannot detect the minor foramen accurately in molars during the root canal retreatment procedure. To the best of our knowledge, there is no information about comparing the accuracy of Apex ID and Propex Pixi devices during retreatment procedures. Therefore, the present study contributes valuable insights as it evaluated the accuracy of these two devices in establishing the working lengths of curved mesial roots of maxillary molars during the root canal retreatment.

While most EAL studies have preferred straight canal anatomy, in our study, we preferred to use the curved mesial roots of upper molars where root filling removal can be more complex.<sup>9,20,21</sup>

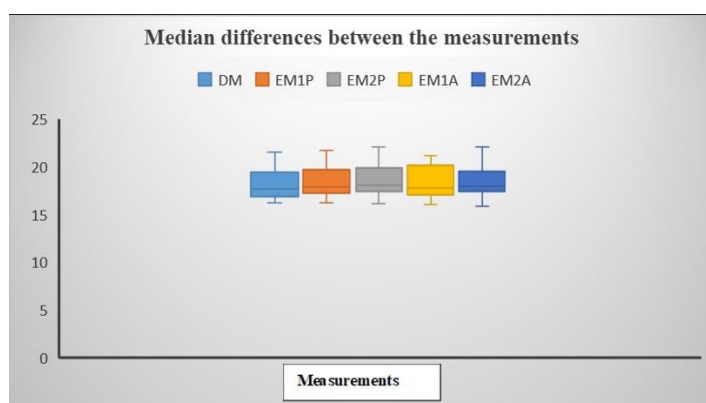
In this study, the alginate model, frequently used in EAL studies and described by Kaufman et al.<sup>18</sup> was performed. Alginate is a conductive medium which imitates the human periodontium by means of wrapping tooth roots during measurements and providing electricity transmission.<sup>22</sup> The referenced canals length measurement (DM) was obtained just before the root canal filling because the shaping procedures can affect the channel length.<sup>20</sup>

The study showed that there was no significant differences between two apex locaters before and during root canal retreatment. The null hypothesis can be accepted. Yolagiden et al.<sup>23</sup> stated that the ApexID showed acceptable measurements similar to Raypex 5 and 6 of the working length. Serna-Peña et al.<sup>24</sup> showed that no statistically

**Table 1.** Means, Standart Deviations, Minimum and Maximum of difference and ratio values of between electronic measurements before and after root canal filling and direct measurements

Measures	DM	EM1A	EM1P	EM2A	EM2P	EM1A-DM	EM1P-DM	EM2A-DM	EM2P-DM	Ratio EM1A/DM	Ratio EM1P/DM	Ratio EM2A/DM	Ratio EM2P/DM
Mean	18.2	18.3	18.4	18.4	18.6	0.1	0.2	0.2	0.4	1.0	1.0	1.0	1.0
SD	1.6	1.7	1.6	1.8	1.8	0.5	0.3	0.4	0.4	0.03	0.02	0.02	0.02
Minimum	16.2	16	16.2	15.9	16.2	-0.54	-0.09	-0.6	-0.19	0.97	0.99	0.97	0.99
Maksimum	21.6	21.1	21.7	22.1	22.1	1.8	1.4	1.1	1.4	1.1	1.1	1.1	1.1

DM,direct measurements; EM,electronic measurements; SD,standart deviation; 1,before root filling; 2,after root filling; A,apex ID; P, propex pixi



**Figure 1.** Mean differences between the all measurements, **Bold** lines Show median values.

## DISCUSSION

Studies have shown that retreatment procedures affect the success of the EALs. Mancini et al.<sup>11</sup> showed that measurements obtained with Root ZX (J Morita Corp, Kyoto, Japan) during retreatments can lead

significant differences were observed amongst the Apex ID, Propex Pixi and Root ZX. Also, de Vasconcelos et al.<sup>12</sup> showed that Apex ID measurements were not affected by foraminal obstruction. Ustun et al.<sup>3</sup> indicated that there were no significant measurement differences between the Raypex 6 and Propex Pixi. Saxena et al.<sup>25</sup> found that similar accuracy results were obtained amongst the iRoot, iPex II, and Propex Pixi apex locaters. In our study, the analysis of the results of the electronic measurement performed before the canal filling was similar to those found in these studies. In their work on mesial curved canals of mandibular molar teeth, Piasecki et al.<sup>14</sup> showed that the Root ZX and Apex ID devices were equally accurate in determining the working length and stated that the 0.5-mm mark on both EALs were more acceptable than subtracting 0.5 mm from the 0.0-mark. In our study, we used the value of 0.5-mm mark as a reference in EM1A and EM2A measurements. Although, there is no retreatment study comparing Apex ID and Propex Pixi, there are few studies examining the measurements of Propex Pixi during root canal retreatment. Tufenkci and Kalayci, examined the accuracy of Dentaport ZX, Propex Pixi and iPex II devices in root canal retreatment and found their accuracy at %83.3,-%83.4-%80 respectively, even if there was no statistical significance between them.<sup>26</sup> Similarly, our study gave safe results in the application of Propex pixi during root canal retreatment. Tejaswi et al.<sup>27</sup> reported that Dentaport Root ZX apex locator showed more accuracy in detecting the apical and middle root canal perforation when compared with the Propex pixi apex locator during root canal

treatment. This result is inconsistent with our study, this might be the due to presence of irrigating solutions or penetration of the conducting media into the root canal.

The most significant goal of this study was to identify the reliability of two untested devices in determining the working length in a canal with the most complex mixture of contents, such as debris, dentin chips, organic remnants, gutta-percha pieces, sealer and solvent. However, according to our analysis, no significant difference was found between DM and electronic measurements before and after retreatment with Propex Pixi and Apex ID or between EALS.

## CONCLUSION

Within the limitations of this study, it can be concluded that the accuracy of Apex ID is similar to that of Propex Pixi when used with curved mesial roots in the retreatment process and that both devices can be safely used in endodontic treatment.

**Etik Komite Onayı:** Bu makale, insan veya hayvan katılımcılar ile yapılan herhangi bir araştırma içermemektedir.

**Hasta Onamı:** Hasta üzerinde çalışma yapılmadığından onam formu alınmamıştır.

**Hakem Değerlendirmesi:** Dış bağımsız.

**Yazar Katkıları:** Fikir – D.A.; Tasarım- D.A., M.B.G.; Denetim- D.A., M.B.G.; Kaynaklar – D.A, M.B.G.; Malzemeler – M.K.B., F.K.; Veri Toplama ve/veya İşleme – M.B.G.; Analiz ve/veya Yorum – M.K.B., F.K.; Literatür Taraması – M.K.B., F.K.; Yazma –D.A. ; Eleştirel İnceleme – D.A., M.K.B., F.K., M.B.G.

**Çıkar Çatışması:** Yazarlar, çıkar çatışması olmadığını beyan etmiştir.

**Finansal Destek:** Yazarlar bu çalışmanın herhangi bir finansal destek olmadığını beyan etmişlerdir.

**Ethics Committee Approval:** This article does not contain any studies with human or animal participants.

**Informed Consent:** A consent form was not obtained because no study was conducted on the patient.

**Peer-review:** Externally peer-reviewed

**Author Contributions:** Concept –D.A.; Design- D.A., M.B.G.; Supervision - D.A., M.B.G.; Resources – D.A, M.B.G.; Materials – M.K.B., F.K.; Data Collection and/or Processing – M.B.G.; Analysis and/or Interpretation – M.K.B., F.K.; Literature Search – M.K.B., F.K.; Writing Manuscript– D.A.; Critical Review – D.A., M.K.B., F.K., M.B.G

**Conflict of Interest:** The authors have no conflicts of interest to declare.

**Financial Disclosure:** The authors declared that this study received no financial support.

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