

# Reliability of different methods of measurement of working length in endodontics

## Abstract

They compared measurements using radiographic images and mathematical calculations, computed tomography and electronic foraminal locator in vivo, comparing them with the real measurement determined by digital calipers after tooth extraction in 12 dental elements of patients of both sexes indicated. for tooth extraction due to advanced periodontal disease. The patients underwent Cone Beam Computed Tomography examination to determine the real length of the tooth. Afterwards, periapical radiographs were taken to establish the apparent length of the tooth. Subsequently, isolation of the operative field, the teeth had their canals accessed, emptied and subjected to conventional measurement by subtracting 3 millimeters from the radiographic vertex in this radiograph. Afterwards, a file was introduced inside the root canal, taking a new radiograph, measuring on this radiograph the distance between the tip of the instrument and the radiographic vertex, adding this measurement to the actual size of the instrument minus 0.5 millimeter as safety margin determined for the working length. Simultaneously, the canal was measured with an electronic foraminal locator. Next, the teeth were sealed and extracted, placed in containers with saline solution. The extracted teeth were measured using a digital caliper and these measurements were recorded in tables. It was concluded that odontometry using computed tomography represented the method that came closest to the real values of the dental elements, constituting the electronic locator with little significant difference in relation to the tomographic examination. Conventional dentistry, especially in anterior elements, showed a considerable degree of distortion.

**Keywords:** odontometry, diagnostic imaging, tomography, X-ray computed, cone beam computed tomography, dimensional imaging, electronic apex locator

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## Introduction

Endodontics is the specialty of dentistry that has benefited from technological advances in order to enable increasingly safer, easier and more predictable treatments, especially considering the microscopic magnitude of the operative field, however, possessing a network of millions of dentinal tubules that, in itself, reinforces the importance that the operator gives to every millimeter sanitized.

Odontometry is the stage of endodontic treatment, which aims to establish the working length of the root canal and the correct determination of the working length is one of the main factors that lead to success in endodontic treatment. The working length is that which goes from a coronal point to the apical constriction. The ideal working limit is the cemento-dentin junction. This junction is located approximately 0.5 mm from the apical foramen.<sup>1</sup>

Bregman<sup>2</sup> recommended placing a file inside the root canal followed by radiographic imaging. In this radiograph, the apparent length of the tooth and instrument was defined. Based on this information and previously knowing the real length of the instrument, a proportionality equation based on Talles' Theorem was used ( $CRD = (CRI \times CAD)/CAI$ ), the real length of the tooth was obtained, obtaining the working length, as this is obtained by subtracting 1 to 2 mm from the actual tooth length.

Kobayashi et al.,<sup>3</sup> demonstrated that electronic locators use a low-frequency electrical current that is transmitted to the endodontic file inserted into the root canal. When the file approaches the apex, a change in electrical impedance occurs, which is detected by the device. Based on this change, the electronic locator emits an audible or visual signal to indicate the position of the apex.

Gordon & Chandler<sup>4</sup> pointed out that before endodontic treatment, at least one undistorted radiograph is necessary to evaluate the morphology of the canal. Apical extent of instrumentation and final root filling play a role in treatment success and are primarily determined radiographically. Electronic apex locators reduce the number of radiographs required and assist where radiographic methods create difficulties. The CDJ is a practical and anatomical termination point for root canal preparation and filling and this cannot be determined radiographically. Modern electronic apex locators can determine this position with greater than 90% accuracy, but still have some limitations.

Ramos & Bramante<sup>5</sup> confirmed that the electronic apex locator provides a more accurate and reliable measurement of the length of the root canal, reducing the risk of underinstrumentation or overinstrumentation depending less on radiographs, which reduces the patient's exposure to ionizing radiation, but had limitations, therefore, changes in measurement accuracy were due to the presence of fluids, pulp tissue and the need to isolate the endodontic instrument during the measurement. The impedance reaches its highest value, precisely in the area of greatest constriction of the channel which, in most cases, coincides with the CDC limit.

Krajczár et al.,<sup>6</sup> compared the accuracy of determining the working length of the ProPex electronic apex locator (Dentsply -Maillefer) with the radiographic method in extracted molars. The length of the root canal was determined using the electronic apex locator and conventional radiographic method. Digital radiographs were taken and the distance between the tip of the file and the radiographic apex was measured. The average distance between the tip of the file and the radiographic apex in the mesiobuccal canals was 0.46 mm in the radiological method using the electronic apex locator and 0.23 mm

and 0.43 mm and 0.31 mm in the palatal canals, respectively. They concluded that the desired file position obtained by the electronic apex locator proved to be more accurate in the mesiobuccal canals than with the radiological method alone.

Costa et al.,<sup>7</sup> emphasized that cone beam computed tomography has been widely used in the dental field, with the objective of this work being a review of the literature on its applicability in Endodontics. It was concluded that CBCT is an important auxiliary resource in endodontic practice, mainly for locating root canals, identifying pathological lesions, resorptions and root fractures.

Accorsi-Mendonça et al.,<sup>8</sup> investigated that the correct diagnosis is an initial milestone for success in Endodontics. The radiographic examination, among its variations, has limitations because it presents a two-dimensional image of a three-dimensional structure. Currently, in the field of Imaging, Cone Beam Computed Tomography (CBCT), also known as Cone Beam, stands out as a possibility for obtaining three-dimensional images, which gives greater reliability to diagnoses and operative planning.

Guimarães et al.,<sup>9</sup> aimed in this study to evaluate the accuracy of the Root ZX, iPex and YS-RZ-A apex locators in teeth with incomplete apices in 30 human mandibular premolars without dental caries, fractured and with an apical diameter of 1-3mm and stage of  $\frac{3}{4}$  root development. After coronal access, the length of the tooth was determined by viewing a K-file, compatible with the diameter of the root canal, at the apex with the teeth included in alginate and measured with the three apical locators until reaching the apical foramen, the canals being flooded with 1% sodium hypochlorite. The Root ZX apex locator showed greater efficiency (53.3%), with a statistical difference in relation to the iPex apex locator (33.3%) and the YS-RZ-A apex locator (26.7%). They concluded that the results showed that all the apex locators studied were efficient in determining the length of the root canal in teeth with incomplete apex, considering the tolerance of  $\pm 1$  mm. The Root ZX apex locator showed greater accuracy with 100% agreement.

Bahrololoomi et al.,<sup>10</sup> confirmed that this method uses electronic principles to identify the position of the tooth apex and provides accurate information about the location of the working point in the root canal. Otherwise, the electronic foraminal locator was designed based on the principle of similarity of the electrical current between the buccal mucosa and the periodontal ligament. Therefore, for operation, one pole must be accommodated in the commissure through the labial hook and another pole in contact with the stem of the endodontic instrument that will invade the root canal. The circuit closes and begins the visual measurement process and with the sound effect of the device. The advantages are a considerable reduction in radiation exposure, greater safety for pregnant women and patients undergoing radiotherapy, greater comfort for patients in need of special care, situations where there are doubts in radiographic interpretation, in addition to a significant reduction in working time.

Haddad Filho<sup>11</sup> refers to the advantages of the apical locator such as constituting a more accurate method of measuring apical constriction, being quicker to obtain working length measurements, not suffering interference from the anatomical structures adjacent to the tooth, easy operation and precision in obtaining the results, they do not present risks to the health of the patient, the professional and auxiliary personnel and eliminate pertinent doubts regarding the result obtained through another method.

Aktan et al.,<sup>12</sup> showed that Cone Beam Computed Tomography is a tool commonly used in endodontics in recent years. The modern

radiological imaging system of this method was designed specifically for use in the maxillofacial skeleton. This system overcomes many of the limitations of conventional radiography, producing undistorted, three-dimensional images of the area examined.<sup>13</sup> The reliability of CBCT is high, since the gender and age of the patients, as well as the number of root canal curvatures, do not seem to influence the accuracy of the technique.<sup>14</sup> However, some thresholds when performing this task, such as the voxel, may interfere with the results obtained.

Aguiar et al.,<sup>15</sup> investigated the accuracy of the Root ZX (RZX), Root ZX II (RII), and Root ZX Mini (RM) locators. After accessing the cavity in 32 lower single-rooted human premolars, their real length was measured using a No. 15 type K manual file under magnification (25x), with electronic measurements taken by the devices until reaching the apical foramen (0.0). Each measurement was made with a file adjusted to the actual length of the teeth and checked with a digital caliper. The reliability of the locators was 68.8% (RZX), 65.8% (RII) and 68.8% (RM), considering  $\pm 0.5$  mm as a tolerance margin. The average errors of the devices were  $0.37 \pm 0.25$  mm (RZX),  $0.41 \pm 0.34$  mm (RII) and  $0.32 \pm 0.28$  mm (RM) with no statistically significant differences between them. They concluded that the 3 devices demonstrated accurate measurements of the actual channel length with no differences in performance between them.

Yildirim et al.,<sup>16</sup> aimed in this investigation based on cone beam computed tomography to compare the determination of the CT performance of the electronic apex locator, cone beam computed tomography and digital radiography in 30 newly extracted single-rooted permanent teeth. Root canal working length measurements were performed using actual length, electronic apex locator, digital radiography and cone beam computed tomography. Cone beam computed tomography was the most accurate method to assess root canal working length, with an accuracy of 70%. The accuracy of the apex locator and periapical radiograph was 40% and 30%, respectively. They concluded that cone beam computed tomography can be safe for use in determining the working length of the root canal. Due to the lower radiation dose, a pre-existing CBCT scan may be useful to detect root canal length more accurately.

Araújo et al.,<sup>17</sup> commented that three-dimensional radiographic imaging using cone beam computed tomography is used in different specialties in the dental field, such as implantology, orthodontics, periodontics, surgery, oral and maxillofacial traumatology, temporomandibular joint examinations and endodontics. The objective was to identify the scientific production on the current applications of cone beam computed tomography in dentistry carried out through a descriptive bibliographic review based on the VHL, PUBMED, SCIELO, GOOGLE ACADÊMICO and IBICT OASISBR database, including a total of twenty studies. Cone beam computed tomography is a useful and widely available tool in dentistry, the data/images collected in digital format are easily transferable between dental surgeons and facilitate the study of the patient's clinical situation, allowing for more accurate diagnosis and treatment in various dental specialties.

Amin et al.,<sup>18</sup> compared the accuracy and reliability of cone beam computed tomography (CBCT) and electronic apex locator in determining working length (CT) using bibliographical research carried out in several databases and literature and in five studies were identified as eligible for review. In all five studies, no statistically significant differences were found between CTFC and EAL CT measurements. They concluded based on limited evidence, CBCT appeared to be as accurate as EAL, however, more research is needed to conclusively evaluate the accuracy and reliability of CBCT compared to EAL.

Alam et al.,<sup>19</sup> inspected adult human odontometry with the aid of 3D cone beam computed tomography (CBCT) images in the population of Saudi Arabia, Jordan and Egypt in 252 individuals analyzed by 3D CBCT volumetric data. All measurements were made using 3D software on demand where the tooth size was measured from the 2nd molar to the 2nd molar of the upper and mandibular arch. They concluded that the 3D CBCT image allows measuring tooth size effectively and accurately. No significant differences were found in tooth size between sexes and races. TCFC can elevate the record-keeping problem; adult human odontometry for analysis can be obtained directly from the digital image.

Keratiotis et al.,<sup>20</sup> studied the level of acceptance between radiographic working length and electronic apex locator assessment methods in different diagnostic teeth. Working length measurements along with pulpal and periapical diagnostic data were collected from the Patient Registry Database. Electronic apex locator measurements generally agree with those provided by a 1.5 mm file placed below the radiographic apex in teeth with different pulp diagnoses. It was suggested that this configuration at this distance should be applied to all cases of endodontically treated teeth, despite differences in pulp diagnosis.

Parirokh et al.,<sup>21</sup> stated that apex locators are important devices that can be used in determining endodontic working length. However, it is not known whether electronic devices with frequencies of multiple wavelengths influence the accuracy of apex locators. The purpose of this study was to determine whether a cordless telephone, MP4 player, FM radio, asymmetric digital subscriber line (ADSL), or cell phone could influence the accuracy of working length determination by the Dentaport ZX Apex Locator. In this study, twenty-four healthy, intact, single-rooted extracted human teeth were used. After determining the length of the root canal with a file and microscope, the canals were measured with three separate Dentaport ZX apex locators while one of the testing devices (ADSL, MP4, FM radio, cell phone and cordless phone) was used at a distance of 50 cm from the apex locator. With the exception of the FM radio, all other devices showed a significant difference with the actual working length. ADSL and MP4 player showed less consistency compared to other devices. They concluded that based on this *in vitro* study, the use of ADSL, MP4 player, cell phone and cordless phone during endodontic treatment can influence the determination of the working length with the Dentaport ZX apex locator.

Abidi et al.,<sup>22</sup> determined the accuracy of measuring working length with Endomotor with integrated apex locator by comparing it with periapical radiographs on permanent maxillary anterior teeth. Preoperative radiography was performed using parallelism technique. Access surgery was performed and after initial filing and drying of the canal, the working length was obtained with Endomotor with integrated apex locator. Using a millimeter scale and after reaching the provisional working length from the preoperative radiograph, 1 mm was subtracted from the radiographic apex. A stainless steel K-file was placed in the canal at this length and a radiograph was taken by the paralleling technique using film support and the electronic and radiographic findings noted. Accuracy was considered positive if the Endomotor reading was 0-2mm below the radiographic working length. Data was analyzed using SPSS 16. It was concluded that the accuracy of measuring working length with Endomotor with integrated apex locator was considered a better measurement tool compared to conventional periapical radiographs.

Rathore et al.,<sup>23</sup> pointed out that the digital tactile detection technique and conventional radiography (CR) are common techniques

for determining the working length, presenting some limitations. The present study was carried out to compare the accuracy of the apex locator with a tactile and conventional radiographic method for determining working length in primary and permanent teeth. The study was carried out with 60 randomly selected children who were divided into two groups: deciduous and permanent. Within the limitations of this study, there was no statistically significant difference between the 3 methods in the working lengths obtained by the tactile method, the apical locator and the radiographic method, except in the mesiolingual and distobuccal canals of the permanent teeth. They concluded that the electronic apex locator can serve as a useful guide to determine the working length in permanent and primary teeth.

Van Pharm<sup>24</sup> investigated the accuracy of 3D Endo software, cone beam computed tomography (CBCT) software, and electronic apex locator in determining endodontic length in 302 extracted human molar root canals. The access cavity was made and the length of the root canal was measured with a digital caliper for real length and for electronic length. The teeth were then scanned using a CBCT device with a voxel size of 0.10 mm. Root canal length was measured using CBCT (Romexis Viewer), 3D Endo for proposed length (3D-PL) and correct length (3D-CL) and the average differences between the four methods with the actual tooth length were calculated and compared. The accuracy in the  $\pm 0.5$  mm range of the EAL Propex II was highest among the experimental modalities, but this method disagreed with the actual tooth length. The correct working length after semi-automatic length adjustment by 3D Endo software and Romexis Viewer measurements were in agreement with actual length.

Di Taranto et al.,<sup>25</sup> compared the working length measured with Root ZX (EAL1), Propex II (EAL2) and Endo Analyzer Model 8005 (EAL3) with radiographic measurements during endodontic treatment in 50 single-rooted teeth. After the endodontic access surgery, the pulp chamber was irrigated with 5mL of 5% sodium hypochlorite (NaOCl) and the canal was explored with a size 10 K file introduced slightly above the apex to check the patency of the canal. Working length was measured using all three devices and radiographically. Mean working length values for the EAL1 electronic apex locator were  $19.1 \pm 1.7$  mm; for EAL2 they were  $19.4 \pm 1.7$ ; for EAL3 they were  $19.4 \pm 1.6$  and for GP they were  $19.2 \pm 1.7$ . As for the average values compared to radiographic measurements, the Root ZX presented better results than the other devices tested, while the Endo Analyzer Model 8005 had the worst performance.

De Deus et al.,<sup>26</sup> compared the *in vivo* accuracy of the Wirele-X and RootZX II electronic apex locators in determining the position of the greater foramen using microcomputed tomography (micro-CT) as an analytical tool in 11 vital teeth planned for extraction from 5 patients. Type K files were used to determine the working length of the selected canals using the two apex locators until their numerical displays showed "0.0" and then the teeth were extracted and photographed on a micro-CT device using a dual scan protocol. They concluded that Root ZX II and Wirele-X had similar performance in the *in vivo* detection of the greater foramen. Using strict criteria, the accuracy of the Root ZX II and Wirele-X apex locators was 81.8% and 90.9%, respectively.

Pham & Pham<sup>27</sup> aimed to evaluate the agreement between root canal length estimates using cone beam computed tomography (CBCT) at different slice thicknesses, electronic apex locator, and actual lengths (AL) in 111 human molars extracted with 302 root canals which were scanned using a CBCT device. Root canal lengths were estimated using CBCT software at different section thicknesses (0.6, 1.2 and 2.4 mm) and software worked to proposed lengths or

by the operator. Root canal lengths were measured with an electronic apex locator for electronic length (EL) and a ruler for true lengths (AL). CBCT in evaluating the smallest slice thickness was not the best modality according to the AL. The electronic apex locator represented an accurate and reliable method for measuring root canal length.

Özata et al.,<sup>28</sup> aimed to evaluate the effectiveness of four electronic apex locators (Root ZX mini, Raypex 6, Propex Pixi and E-Pex Pro) and cone beam computed tomography (CBCT) and radiographic measurement in determining the working length in 30 pre- single-rooted lower molars extracted. Working length was determined using periapical radiography, four electronic apex locators, and CBCT. Compared to other measurement methods, CBCT showed values shorter than the actual working length. All four electronic apex locators used in this study are adequate and clinically acceptable measurements. Furthermore, our accuracy data suggested that these clinical devices demonstrated the reliability of these electronic apex locators.

Silva et al.,<sup>29</sup> commented that in endodontics, latent imaging is essential during all phases of treatment. In this sense, radiographic examination and cone beam computed tomography (CBCT) are complementary methods used in the diagnosis and planning of endodontic treatment. Thus, this study aims to analyze the use of cone beam computed tomography in endodontic treatment, considering its importance in clinical applicability to provide better diagnosis, planning, prognosis, advantages, disadvantages, limitations and contraindications. Thus, CBCT emerges as a technology that is approaching the dentist and overcoming radiographic limitations during the operative stages.

Nasiri & Wrbas<sup>30</sup> using a review, aimed to evaluate the accuracy of four generations of electronic apex locator in fifteen articles. They concluded that based on the results of this study, all four generations of apex locators under review were found to be accurate in measuring working length. Consequently, the generation of an apex locator does not play a significant role in the accuracy with which electronic devices determine working length.

Accuracy in establishing the working length will be a guarantee of successful endodontic treatment, therefore, the objective of the present study was to compare the measurement made using conventional radiography and mathematical calculations, computed tomography and the electronic foraminal locator *in vivo* with the actual measurement determined by a digital caliper after extraction of the dental element.

## Material and methods

12 dental elements were selected from patients of both sexes aged between 18 and 62 years, indicated for extraction due to advanced periodontal disease, from the Clínica Escola de Odontologia da Universidade São Francisco. The research participants were properly oriented and after reading they filled out the Free and Informed Consent Form, approved by the Research Ethics Committee at Universidade São Francisco under CAAE protocol N°67753823.0.0000.5514 considering voluntary participation, identification, objectives and all the steps of the procedures carried out, aware of the liberality of interrupting their participation in the research at any time. Participants also completed the donation form for the extracted element to the Human Teeth Bank of the Dentistry Course at Universidade São Francisco.

Participants were referred to the imaging clinic and the indicated teeth were subjected to Cone Beam Computed Tomography

examination in order to determine the actual length of the tooth (Figure 1).

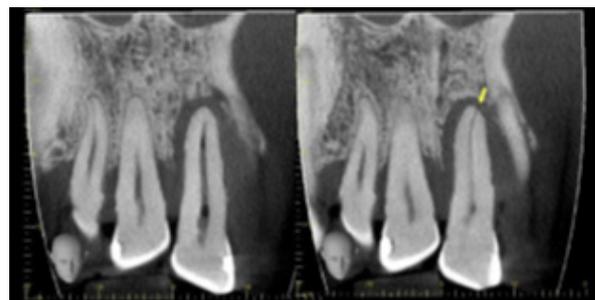


Figure 1 CBCT images of teeth.

For this, the Veraview X800 Morita device was used using the FOV 4 x 4 Endo technique and voxel 0.085, under the radiology operation.

They later returned to the Dentistry School Clinic to take periapical radiographs, where the apparent length of the tooth was established. Patients were anesthetized with 3% mepivacaine anesthetic with 1:100:000 epinephrine and 2% lidocaine with 1:100:000 epinephrine, using a technique inherent to each dental group and arch. After isolation of the operative field, the teeth had their canals accessed, emptied and were subjected to conventional measurement and from there, 3 millimeters were subtracted from the first measurement. Next, a fine-caliber endodontic instrument was introduced into the root canal and a new radiographic scan was taken. Based on this last radiograph, the distance between the tip of the instrument and the radiographic vertex is measured, and this measurement is added to the actual size of the instrument minus 0.5 millimeter as a safety margin determined for the working length (Figure 2).



Figure 2 X-ray of the tooth to determine the working length.

On the same occasion, measurements were also guided by the high-precision Finepex electronic foraminal locator device from the Schuster brand (Figure 3).



Figure 3 Measurement carried out by the electronic apex locator.

As soon as the measurements were obtained, the teeth were sealed and extracted, placed in containers containing saline solution while suturing was performed. Patients were instructed on postoperative care, medicated, scheduled for suture removal and discharged. Next, the extracted teeth were measured using a digital caliper from the Digimess brand with maximum precision (Figure 4).



**Figure 4** Measurement of the extracted tooth using a digital caliper.

## Results

The measurements collected by the four copies, CBCT, periapical radiographs and mathematical calculations, electronic resource and directly with a digital caliper were recorded in Table 1.

**Table 1** Values teeth examined in millimeters with their respective canals depending on the techniques used: Cone beam computed tomography, radiography, foraminal locator and caliper

Element	Canal	CBCT	Radiographic method	Foraminal localizer	Pachymeter (actual measurement)
21	Single	25,52	29,00	25,50	25,64
31	Single	22,15	23,00	21,50	22,18
32	Single	23,46	24,00	23,00	23,88
41	Single	21,40	24,00	21,00	22,00
44	MB	20,31	21,00	20,00	20,07
26	MB	18,47	20,00	18,00	22,00
37	ML	19,70	20,00	19,50	20,36
27	MB	20,50	22,00	20,30	20,52
46	MB	22,64	25,02	22,60	22,65
47	ML	22,10	24,00	22,00	22,10
23	Single	25,02	28,00	25	25,04
12	Single	22,00	20,00	21,50	22,03

## Discussion

This present investigation points out that the electronic apex locator can be used on teeth in various clinical situations, whether they have live or dead pulp, as mentioned by different authors. In fact, its purpose was to evaluate, in single-rooted teeth and only in one root of posterior teeth, the results of the application of various methods, understanding that the radiographic method shows some deficiencies in some situations.<sup>1</sup>

First, however, historical connotations must be observed, otherwise let's see: Bregman<sup>2</sup> used a proportionality equation based on Talles' Theorem ( $CRD = (CRI \times CAD)/CAI$ ), obtaining the real length of the tooth by obtaining the length of work, since this is obtained by subtracting 1 to 2 mm from the real length of the tooth, resulting in deficiencies apart from the elongations produced on the radiograph.

It is important to highlight, as corroborated by Kobayashi et al.,<sup>3</sup> that the electronic apex locator is a device used in endodontics that helped to improve the length of the root canal. Electronic locators use low-frequency electrical current that is transmitted to the endodontic file inserted into the root canal. As it approaches the apex, there is a change in the electrical impedance that is detected by the device and this change causes the device to emit an audible or visual signal, to indicate the position of the apex.

The cemento-dentine-canal junction (CDC) is a practical and anatomical termination point for the preparation and obturation of the root canal that cannot be determined radiographically and this fact already justifies the errors made by the radiographic technique. In turn, electronic apex locators can determine this position with accuracy greater than 90%.<sup>4</sup>

Ramos and Bramante<sup>5</sup> confirmed that the electronic apex locator provides a more accurate and reliable measurement of the length of the root canal, reduces the risk of underinstrumentation or overinstrumentation, depends on fewer radiographs, reduces patient exposure to radiation and the impedance reaches its highest value, precisely in the area of greatest constriction of the channel which, in most cases, coincides with the CDC limit.

Krajczár et al.,<sup>6</sup> confirmed that the desired file position obtained by the electronic apex locator proved to be more accurate in the mesiobuccal canals than the radiological method alone.

Costa et al.,<sup>7</sup> conclude that cone beam computed tomography is widely used in the dental field mainly as an auxiliary resource in endodontic practice, as it locates root canals, identifies pathological lesions, resorptions and root fractures.

Otherwise, referring to Cone Beam Computed Tomography, higher efficiency values and the number of root canal curvatures do not seem to influence the accuracy of the technique<sup>14</sup> producing undistorted and three-dimensional images of the examined area.<sup>13</sup>

The results expressed in Table 1 guarantee the greater effectiveness of Cone Beam Computed Tomography, which is probably due to its greater precision capacity, followed by the electronic apex locator, in fact, methods that came closest to the real values of the dental elements measured, on the digital caliper. This is Cone Beam Computed Tomography, a device commonly used in endodontics in recent years.

This experimental article aimed to provide a basis for clinical decision-making, with specific reference to the selection criteria for endodontic applications: Cone Beam Computed Tomography and the electronic apex locator. Therefore, the purpose of this investigation was to compare the degree of effectiveness and precision of three methods of determining tooth length, namely: cone beam computed tomography, foraminal locator, radiography comparing them with a digital caliper (real measurement).

With a view to this, Accorsi-Mendonça et al.,<sup>8</sup> that the radiographic examination has limitations because it presents a two-dimensional image in a three-dimensional structure. Unlike Cone Beam Computed Tomography (CBCT), which is evident as a possibility of obtaining three-dimensional images.

In fact, Guimarães et al.,<sup>9</sup> demonstrated that all apex locators studied were efficient in determining the length of the root canal in teeth with incomplete apex, considering a tolerance of  $\pm 1$  mm, with the Root ZX apex locator showing greater accuracy with 100% agreement.

Alongside these considerations, it is important to consider the advantages described by Bahrololoomi et al.,<sup>10</sup> such as reducing exposure to radiation, protecting pregnant women from radiation and patients undergoing radiotherapy, doubts in radiographic interpretation and reducing working time, events considered by Haddad Filho.<sup>11</sup>

Aktan et al.,<sup>12</sup> reaffirm that this method represents the ideal in all cases, and must be established according to exact indications, above all, with radiographic examination.

Among the methods that evaluate the accuracy in determining tooth length, electronic apex locators deserve special attention due to their high degree of effectiveness.<sup>15</sup> This same author evaluated the accuracy of the Root ZX (RZX), Root ZX II (RII) and Root ZX Mini (RM) locators, with a reliability of 68.8% (RZX), 65.8% (RII) and 68.8% (RM) and that the 3 devices demonstrated accurate measurements of the actual root canal length.

Furthermore, it is understood that, as ratified by Yildirim et al.,<sup>16</sup> that cone beam computed tomography is reliable when determining the working length of the root canal thanks to the lower radiation dose and, therefore, represents a more certain method in examining the working length of the root canal, with an accuracy of 70 % as opposed to the accuracy of the apex locator (40%) and periapical radiography (30%).

Thus, authors such as Araújo et al.,<sup>17</sup> explained that the three-dimensional radiographic image of cone beam computed tomography is used in different specialties in the dental field, especially endodontics. This is a technique of enormous precision, which makes it possible to research the patient's clinical situation.

Amin et al.,<sup>18</sup> commented that pre-existing computed tomography scans may be adequate in determining CT, but the investment of a new computed tomography scan for endodontic treatment is not advisable due to the cost, as CBCT appeared to be as accurate as EAL as it has method such as an electronic apex locator capable of efficiency like computed tomography.

Alam et al.,<sup>19</sup> confirmed that the 3D CBCT image makes it possible to measure tooth size effectively and accurately. So it is accepted that obtaining adult human tooth size through digital imaging. Pay attention according to Keratiosis et al.,<sup>20</sup> that the use of the electronic apex locator related to apical distance, that is, 1.5 millimeters from the radiographic vertex, is applied in all cases, whether in teeth with living or dead pulp.

On the other hand, the influence on the accuracy of the apex locators must be taken into account when determining the working length of the Dentaport ZX apex locator used by Parirokh et al.,<sup>21</sup> In fact, electronic devices with different wavelength frequencies interfere with the accuracy of apex locators.

The use of electronic apex locators has become a method of great applicability in endodontic practice, because, despite its perfection, it has positive points in its favor, among which it is necessary to consider not using ionizing radiation. However, comparing the average values with the radiographic measurements in the research carried out with Di Taranto et al.,<sup>25</sup> in fact, the results presented by the Root ZX electronic apex locator were better than the other devices tested and radiographic measurements while the Endo Analyzer Model 8005 demonstrated worse performance, showing that in some devices accuracy does not always occur.

Otherwise, in research carried out by Van Pharm<sup>24</sup> in whose method the lengths with the electronic apex locator were discordant with the

real length of the tooth, on the other hand, the CBCT using both records the lengths were in agreement with the real length. Contrarily, Rathore et al.,<sup>23</sup> confirmed that the working lengths obtained by the tactile method, the apex locator and the radiographic method were not different between the 3 methods, except in the mesiolingual and distobuccal canals of permanent teeth. In fact, the authors mentioned above confirm that the electronic apex locator is a useful guide in determining the working length in permanent and deciduous teeth.

It is important to note that in this present investigation, the precise measurement of the working length using the electronic apex locator and the radiographs were all different events, similar to those provided in research carried out by Abidi et al.,<sup>22</sup>

Some articles found in the literature showed that the radiographic method is inaccurate while the electronic method used in determining the working length is accurate and adjusted with the results of this present investigation. Still in relation to the radiographic method most used by undergraduate students and general practitioners during endodontic treatment, some research indicates that the radiographic examination is limited and, therefore, inaccurate measurements,<sup>29</sup> in four generations of apex locators were assessed accurate in measuring working length.<sup>30</sup> However, in four electronic apex locators used, they constituted adequate and clinically acceptable measurements and precision data clinically suggested that these electronic apex locators are efficient,<sup>28</sup> a fact corroborated by Pham and Pham,<sup>27</sup> contrary to research carried out by De Deus et al.,<sup>26</sup>

Another advantage of CBCT in relation to the conventional technique is that it eliminates the number of radiographic takes it requires, as it is often necessary to take X-rays to confirm the measurements obtained. However, according to Pham & Pham,<sup>27</sup> CBCT in evaluating the smallest cut thickness was not the best modality according to the real length of the tooth.

## Conclusion

With the results obtained, it was possible to conclude that Odontometry using Cone Beam Computed Tomography was the method that came closest to the real values of the dental elements. As for the electronic locator, it can be concluded that the difference was not significant in relation to CBCT, emphasizing that this tool is safe, practical and accurate in endodontic therapy. On the other hand, conventional odontometry, especially in anterior elements, presented a considerable degree of distortion and was therefore unreliable.

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## Conflicts of interest

The author declares that there are no conflicts of interest.

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