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# Comparison of Accuracy of Working Length Determination Using CBCT and an Apexlocator

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## Abstract

*The correct measurement of the working length is one of the most important factors which influence the success of the root canal treatment. The aim of this study is to compare the accuracy of working length determination using an electronic apexlocator and CBCT as a diagnostic tool. A total of 100 single-rooted teeth undergoing an endodontic treatment were examined clinically to determine their working length by an apexlocator, as well as the working length was measured on already existing CBCT-scans. The results of the study showed that the CBCT-scan has a similar accuracy to the apexlocator measurement regarding the working length determination, so a preexisting CBCT scan can be used for WL-determination in clinical cases, in which an apexlocator measurement cannot be considered reliable enough.*

***Keywords:* endodontic treatment, working length, CBCT, apexlocator**

## Introduction

The European Society of Endodontics identifies as one of the main goals of the endodontic treatment the prevention or the treatment of pre-existing periapical pathology (1). Accurate determination of the working length is an important factor influencing the success of endodontic treatment. The most commonly used methods for determining the working length are related to radiographic imaging or the use of an apex locator. Determining the working length using conventional radiographs is very difficult on the one hand due to their

shortcomings such as superposition of anatomical structures, and on the other - due to the mismatch of the apical foramen with the radiological apex in most clinical cases (2), (3). In the routine endodontic practice, the apexlocators are identified as the most accurate and reliable tool for determining working length (2). The principle of their action is related to the consideration of the boundary zone between the pulp and the periodontium, the zone according to which the apical border of the root canal preparation is determined (4), (5). However, the complexity of the apical part of the root canal system can affect the accuracy of the measurement and lead to inadequate results. It has been found that in 15% of the clinical cases apexlocators cannot adequately determine the working length (6). Such are the cases of teeth with incomplete root development or wide apical foramen, artificial metal crowns, calcified root canals, root fractures and perforations. The use of apexlocator may be contraindicated in patients with available pacemakers. In such cases, the working length determination relies mainly on x-ray images. Cone-beam computed tomography presents a number of advantages over X-ray imaging, mainly related to the ability to visualize both the medio-distal and vestibulo-lingual diameter of the root canal, as well as to determine the position of the apical foramen (7), (8).

## Aim

The aim of the present study is to conduct a comparison between the working length determined on the basis of measurement by electrometric method and cone-beam computed tomography.

## Materials and methods:

The subject of the analysis are 130 single-rooted teeth, subject to endodontic treatment due to existing diseases of the pulp and / or the periodontium.
The examined teeth are from the following groups: maxillary and mandibular incisors, maxillary and mandibular canines and maxillary and mandibular premolars (Table 1). Thirty of the analyzed teeth do not meet the set criteria and are excluded from analysis.

**Table 1. Distribution of the total number of teeth included in the study by groups**

| Teeth | Amount |
|---|---|
| Incisors | 45 |
| Canines | 24 |
| Premolars | 31 |
| Total count | 100 |

**Object of study:** 70 patients aged 18-69 without systemic diseases and contraindications for X-ray examinations. Prior to the endodontic treatment, CBCT was ordered for the purpose of diagnosis and planning of upcoming dental treatment and not for the purposes of the present study and the planned endodontic treatment.
**Examination unit:** the working length of the root canal of each tooth included in the study.
**Place of research:** X-ray Diagnostics Department at the University Medical and Dental Center, Faculty of Dental Medicine, Medical University of Varna.
**Inclusion criteria:** the analyzed teeth should be single-rooted with complete root development, without available radiographic data for external root resorption and without clinical and radiological data for endodontic treatment performed so far.

**Exclusion criteria:** teeth with endodontic treatment, incomplete root development, multi-rooted teeth, as well as single-rooted teeth with strongly curved roots and root canals, which do not allow the measurement to be performed on the three-dimensional images in one plane. Single-rooted teeth with more root canals available were not included in the study. Teeth with radiographic evidence of external root resorption, as well as those with extensive metal restorations, were excluded from the present study.

**Study methodology:** CBCT images were obtained after scanning with a cone-beam computed tomograph Planmeca ProMax 3D Max. The time for scanning of the device is 9-40 s, and for image reconstruction - 2-55 s. In images of the jaws and maxillary sinus, the area of interest (FOV) varies between 130 x 90 mm and 130 x 160 mm. Voxels are isotropic and reach up to 600 μm when shooting jaws and the whole skull. The ability to rotate the arm is between 210 to 360 degrees. Radiation doses measured in microSieverts vary depending on the volume of the image: from 19 -652 microSieverts for small image volume, 45-860 microSieverts for medium image volume, and 68-1073 microSieverts for large image volume.

The CBCT image is stored and read by Planmeca Romexis image processing software. Patients are registered via an electronic card in the image processing software. The electronic card includes the patient's name and age, as well as data from the three-dimensional image.

The methodology for determining the working length on the three-dimensional images begins with their orientation relative to the axial, sagittal and frontal planes. Sagittal sections of CBCT images were examined in detail to determine the length of the root canal. The axis of the examined tooth in the sagittal plane changes until the moment when it is possible to visualize the root canal along its entire length from the orifice to the apical foramen. Using the linear measurement option of the Planmeca Romexis image processing software, the working length is measured from the highest point of the crown of the examined tooth to the area of the apical foramen (Fig. 1). 0.5 mm is subtracted from the obtained value in mm, which aims at the determined value to reflect the distance to the physiological narrowing. In this way we achieve equal conditions on both parts of the task.


**Fig.1 - Measurement in the sagittal plane**

The methodology for determining the working length by electrometric method is as follows: after preparation of the endodontic cavity, localization and expansion of the orifice, vital or mortal extirpation and removal of canal contents is performed depending on the diagnosis of the tooth to be treated. The root canal was irrigated with 5.25% sodium hypochlorite solution and saline, then dried with paper points. An ISO №15 K-file is inserted into the root canal and connected to an Apex ID (KerrDental) (Fig. 2). The file is inserted into the root canal until the apical foramen is reached, which is visualized by the appearance of a value of 0.0 on the apex locator display and an audible signal. The file is then pulled until the physiological narrowing is

reached - a value of 0.5 appears on the apex locator display and an audible signal. Upon reaching this position, the silicone stopper of the file is placed in contact with the highest part of the crown of the examined tooth.

Fig. 2 Apexlocator - Apex ID (KerrDental)

The file is removed from the root canal and the distance from the tip of the instrument to the silicone stopper is measured with an endodontic ruler. The value obtained is recorded. Measurements in which the value read on the apex locator display does not remain stable for 5 seconds are not included in the present study.
The working length measured electrometrically in clinical conditions and on CBCT images was reported and compared. The results are recorded in tables and statistically processed with a specialized statistical analysis package IBM SPSS Statistics 20.

## Results:

When analyzing the results obtained for the group of incisors, we found an average value of the working length determined after measurement on CBCT-images - 19,788 and the average value of the working length after measurement with an apex locator is 19,967. (Table 2).

**Table 2. Comparative data on the working length determined in the group of incisors, with apexlocator and CBCT measurement**

**Paired Samples Statistics**

| | | Mean | N | Std. Deviation | Std. Error Mean |
|---|---|---|---|---|---|
| Pair 1 | CBCT measurement | 19.788000 | 45 | 1.7745750 | .2645380 |
| | Apexlocator measurement | 19.967 | 45 | 1.9051 | .2840 |

When comparing the values of the working length determined by CBCT and by apexlocator in the group of incisors, we establish a correlation value of 0.959 (Table 3). The value of the correlation is close to 1, which means that a high degree of dependence between the two types of measurement is established. Significance Sig. = 0.000 <0.01, therefore the correlation coefficient is considered statistically significant.

**Table 3. Degree of correlation between the values of the two types of measurement in the group of incisors**

Paired Samples Correlations

| | | N | Correlation | Sig. |
|---|---|---|---|---|
| Pair 1 | CBCT measurement & Apexlocator measurement | 45 | .959 | .000 |

For the purposes of statistical processing of the obtained results, we assume as a null hypothesis the lack of statistically significant difference between the two types of measurements in all three studied groups of teeth. As an alternative hypothesis, we assume the existence of a statistically significant difference between the measurements with apexlocator and on CBCT-images.

After statistical processing of the results from the group of incisors, we establish the average value of the reported difference between the two types of measurements - -0.1786667. The determined p-value is 0.033. With a confidence interval of 95% (α = 5%) we can say that the difference between CBCT-measurement and measurement by electrometric method in the general population is statistically significant for the group of incisors (Table 4).

**Table 4. Statistical analysis of the difference between the measured values of working length using the two described methods for the group of incisors.**

Paired Samples Test

| | | Paired Differences | | | | | t | df | Sig. (2-tailed) |
|---|---|---|---|---|---|---|---|---|---|
| | | Mean | Std. Deviation | Std. Error Mean | 95% Confidence Interval of the Difference Lower | Upper | | | |
| Pair 1 | CBCT measurement - Apexlocator measurement | -.1786667 | .5434971 | .0810198 | -.3419513 | -.0153821 | -2.205 | 44 | .033 |

Given the p-value obtained after statistical processing for the group of incisors, we have reason to reject the null hypothesis in favor of an alternative hypothesis at a significance level of α = 1%, α = 5% or α = 10%. With 99%, 95% or 90% certainty we can say that the difference between CBCT-measurement and apexlocator measurement in the general population is statistically significant for the group of incisors.

**Table 5. Comparative data on the working length determined in the canine group with apexlocator and CBCT measurement**

Paired Samples Statistics

| | | Mean | N | Std. Deviation | Std. Error Mean |
|---|---|---|---|---|---|
| Pair 1 | CBCT measurement | 23.415000 | 24 | 2.9213160 | .5963111 |
| | Apexlocator measurement | 23.688 | 24 | 3.0532 | .6232 |

When analyzing the results obtained for the group of canines, we found an average value of the working length determined after measurement on CBCT-images - 23,415 and the average value of the working length after measurement with an apex locator is 23,688. (Table 5).

When comparing the values of the working length determined by CBCT and by apexlocator in the group of canines, we found a correlation value of 0.997 (Table 6). Here, as in the group of incisors, the value of the correlation is close to 1 and a high degree of dependence between the two types of measurement is established, and the correlation coefficient is considered statistically significant.

**Table 6. Degree of correlation between the values of the two types of measurement in the group of canines**

**Paired Samples Correlations**

| | | N | Correlation | Sig. |
|---|---|---|---|---|
| Pair 1 | CBCT measurement & Apexlocator measurement | 24 | .997 | .000 |

After statistical processing of the results for the group of canines, we establish the average value of the reported difference between the two types of measurements - -0.2725. The determined p-value is 0. With a confidence interval of 95% (α = 5%) we can say that the difference between CBCT-measurement and measurement by electrometric method in the general population is statistically significant for the group of canines (Table 7).

Given the p-value obtained after statistical processing for the canine group, we have reason to reject the null hypothesis in favor of an alternative hypothesis at a significance level of α = 1%, α = 5% or α = 10%. With 99%, 95% or 90% certainty we can say that the difference between CBCT-measurement and apexlocator measurement in the general population is statistically significant for the canine group.

**Table 7. Statistical analysis of the difference between the measured values of working length using the two described methods for the canine group.**

**Paired Samples Test**

| | | Paired Differences | | | | | t | df | Sig. (2-tailed) |
|---|---|---|---|---|---|---|---|---|---|
| | | Mean | Std. Deviation | Std. Error Mean | 95% Confidence Interval of the Difference Lower | Upper | | | |
| Pair 1 | CBCT measurement - Apexlocator measurement | -.2725000 | .2824774 | .0576605 | -.3917797 | -.1532203 | -4.726 | 23 | .000 |

When analyzing the results obtained for the group of premolars, we establish the average value of the working length determined after measurement on CBCT-images - 18.920645 and the average value of the working length after measurement with apexlocator is 18.984 (Table 8).

**Table 8. Comparative data on the working length determined in the group of premolars, with apexlocator and CBCT measurement**

**Paired Samples Statistics**

| | | Mean | N | Std. Deviation | Std. Error Mean |
|---|---|---|---|---|---|
| Pair 1 | CBCT measurement | 18.920645 | 31 | 1.5566458 | .2795818 |
| | Apexlocator measurement | 18.984 | 31 | 1.5302 | .2748 |

When comparing the values of the working length determined by CBCT and by apexlocator in the group of premolars, we establish a correlation value of 0.948 (Table 9). The value of the correlation is close to 1, which means that a high degree of dependence between the two types of measurement is established. Significance Sig. = 0.000 <0.01, therefore the correlation coefficient is considered statistically significant.

**Table 9. Degree of correlation between the values of the two types of measurement in the group of premolars**

**Paired Samples Correlations**

| | | N | Correlation | Sig. |
|---|---|---|---|---|
| Pair 1 | CBCT measurement & Apexlocator measurement | 31 | .948 | .000 |

After statistical processing of the results for the group of premolars we establish the average value of the reported difference between the two types of measurements - -0.0632258. The determined p-value is 0.485. With a confidence interval of 95% (α = 5%) we can say that the difference between CBCT-measurement and measurement by electrometric method in the general population is not statistically significant for the group of premolars (Table 10).

**Table 10. Statistical analysis of the difference between the measured values of working length by the two described methods for the group of premolars**

**Paired Samples Test**

| | | Paired Differences | | | | | t | df | Sig. (2-tailed) |
|---|---|---|---|---|---|---|---|---|---|
| | | Mean | Std. Deviation | Std. Error Mean | 95% Confidence Interval of the Difference Lower | Upper | | | |
| Pair 1 | CBCT measurement - Apexlocator measurement | -.0632258 | .4975164 | .0893566 | -.2457163 | .1192647 | -.708 | 30 | .485 |

Given the p-value obtained after statistical processing for the group of premolars, we have no reason to reject the null hypothesis in favor of an alternative hypothesis at a significance level of α = 1%, α = 5% or α = 10%. We do not have sufficient information to claim that the difference between CBCT measurement and apexlocator measurement in the general population is statistically significant at α = 1%, α = 5% or α = 10% (confidence interval 99%, 95% or 90%)

## Discussion

Due to the fact that in clinical practice when determining the working length differences in the measured values below 0.5 mm are not taken into account, the results of our study show that cone-beam computed tomography is a method that can be used to determine the working length of the root canal during endodontic treatment. Due to its three-dimensional nature and the possibility of linear measurements, CBCT allows measuring the length of the root, the root canal, and thus the working length during endodontic treatment.

Possible variations in the anatomy of the apical zone of the root canal sometimes make it difficult to accurately position the zone of physiological narrowing. Despite the generally accepted position of physiological narrowing of 0.5 mm to 1 mm from the radiological apex of the tooth, the possibility of variations in its level can lead to errors associated with over-instrumentation and extrusion of the canal-filling material. The electrometric method, as one of the most commonly used methods for determining the working length, is characterized by varying degrees of accuracy according to the in vivo and in vitro studies performed. It was found that the accuracy of determining the working length by apexlocator is greatest in the presence of healthy periapical tissues or those with minimal pathological changes. Various factors can negatively affect the electrometric measurement, such as the length of the tooth root, the presence of a wide apical foramen, the presence of irrigants and drug inserts in the root canal, as well as the type of tooth, the file size used in the measurement and the degree of development of the root canal. There are contraindications to the use of apexlocator in patients with pacemakers.

The results of our study prove that the determination of working length based on CBCT-measurement is a method characterized by accuracy compatible with that of the electrometric method.

The high radiation load, as well as the higher cost, severely limit the use of cone-beam computed tomography as a means of determining the working length. The accuracy and the possibility of clinical application of the electrometric method make the appointment of CBCT-scan for this purpose irrational. In the presence of strongly curved root canals, where it is not possible to perform the measurement in one plane, the accuracy of the CBCT measurement is expected to decrease. It can be used in clinical cases with severe, persistent exudation from the root canal, in which drying is difficult and accurate measurement values are not expected when using an apexlocator to determine the working length. In cases indicated for apical surgery and necessary pre-surgical endodontic treatment, information from the already scheduled 3D-examination can be extremely useful for the endodontist, especially in cases of difficult to control exudation and uncertainty when using an apex locator.

The differences in the measured values by the two methods may be due to minimal displacement of the coronary landmark despite our attempts to unify the coronary reference point, as well as some inaccuracies in measurement on CBCT images with minimal and unreported curves of roots and root canals of the teeth included in the study. In the presence of significant curvatures of the root canals, which do not allow the measurement on the three-dimensional images to be performed in one plane, we expect larger differences in the obtained values. The smaller observed difference in the reported working lengths by the two methods in the group of premolars may be due to their straighter roots, and thus root canals, than those of incisors and canines.

The values of the difference in the reported working length obtained by us by the two methods differ to a different extent from those established by other studies on the topic. The differences can be explained by the different methods of the performed analyzes, the different technical parameters of the used apex locators and cone-beam computed tomographs, as well as by the different qualities of the software for processing the three-dimensional images. Numerous clinical studies have found that apical canal filling significantly affects the healing process of periapical tissues (9), (10), (11). This is determined according to

the position of the apical foramen (11). It has been found that in 92% of the teeth the position of the apical foramen differs from the position of the tooth apex (12). El-Ayouti A. et al. 2009 found that in cases where the apical level of instrumentation is at a distance of 0-2 mm from the radiological apex, overinstrumentation is observed in 22% of the studied molars and 51% of the premolars (6). These data suggest that the use of the radiological apex of the tooth as a reference point for determining the apical level of root canal preparation in most cases leads to over-instrumentation. The physiological narrowing is defined as the ideal endpoint of root canal treatment. This is the narrowest area of the root canal, which determines the creation of the smallest wound surface during treatment, allowing optimal healing process (13). Independently of each other Kojima K. et al. 2004 and Schaeffer M. et al. 2005 discuss the ideal endpoint of preparation and obturation of the root canal system and found that it is directly dependent on the pathological condition of the pulp and periodontium (14), (15).

Liang Y. et al. 2013 found high accuracy of the CBCT working length, comparing it with the directly measured with an apexlocator (16). Deviation of the apical foramen from the apex of the tooth was found in 44% of the examined teeth. This means that the location of the apical foramen does not affect the accuracy of CBCT measurements. The coronary reference point when considering the different sections may not coincide with the one used for direct measurement of the working length. This fact explains the differences between the CBCT measured and the clinically measured working lengths. Due to the difficulty of visualizing the entire root canal in one section in cases with a higher number of curves of the root canals, larger differences in the measured working lengths are observed in the studied molars.

Connert T. et al. 2017 in an in vitro study compared the working length determined by CBCT images with the real one and found an average difference between the obtained values of 0.41 mm (17). Thus, the authors conclude that CBCT can be used to determine the working length, as a difference in values up to 0.5 mm can be defined as clinically insignificant. Similar results have been reported by Jeger F. et al. 2012 (8), who conducted an in vivo study and found an average difference between the obtained value of working length, measured with an apex locator and determined by CBCT, of 0.51 mm. A greater accuracy of the working length measured by CBCT image is established, in the cases when the measurement is made in one plane or when the available curvature of the root canal is below 25 degrees. In cases with an existing curve above 25 degrees or a measurement performed in two planes, the accuracy decreases, but no statistically significant differences are found (17).

The different results obtained may be due to the different conditions of the experiments and the described criteria, the different apexlocators and cone-beam computed tomographs used, as well as the differences in the settings of the devices used.

## Conclusion

The results of our study confirm the accuracy of the CBCT measurements when determining the working length. This type of working length determination can be used in clinical cases when the apexlocator measurement is considered not reliable enough. In cases with pre-existing CBCT-scans, the information obtained can be significantly useful for the endodontic treatment.

## References

1. European Society of Endodontology Quality guidelines for endodontic treatment: consensus report of the European Society of Endodontology. International Endodontic Journal. 2006; 39, 921–30.
2. Gordon MP, Chandler NP. Electronic apex locators. Int Endod J. 2004; 37:425–437.

3. Krajczár K, Marada G, Gyulai G, Tóth V. Comparison of radiographic and electronical working length determination on palatal and mesio-buccal root canals of extracted upper molars. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2008; 106:90–93.
4. Wu MK, Wesselink PR, Walton RE. Apical terminus location of root canal treatment procedures. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2000; 89(1):99–103.
5. Ponce EH, Vilar Fernandez JA. The cemento-dentino-canal junction, the apical foramen, and the apical constriction: evaluation by optical microscopy. J Endod. 2003; 29(3):214–9.
6. El-Ayouti A, Dima E, Obmer J, et al. Consistency of apex locator function: a clinical study. J Endod. 2009; 35:179-81.
7. Janner SF, Jeger FB, Lussi AL, et al. Precision of endodontic working length measurements: a pilot investigation comparing cone-beam computed tomography scanning with standard measurement techniques. J Endod. 2011; 37:1046-51.
8. Jeger FB, Janner SF, Bornstein MM, et al. Endodontic working length measurement with preexisting cone-beam computed tomography scanning: a prospective, controlled clinical study. J Endod. 2012; 38:884-8.
9. Liang YH, Li G, Wesselink PR, Wu MK. Endodontic outcome predictors identified with periapical radiographs and cone-beam computed tomography scans. Journal of Endodontics. 2011; 37(3):326–331.
10. Ng YI, Mann V, Rahbaran S, et al. Outcome of primary root canal treatment: systematic review of the literature – part 2. Influence of clinical factors. Int Endod J. 2008; 41:6-31.
11. Liang YH, Li G, Shemesh H, et al. The association between complete absence of posttreatment periapical lesion and quality of root canal filling. Clin Oral Invest. 2012; 16:1619-26.
12. Martos J, Lubian C, Silveira LF, et al. Morphologic analyses of the root apex in human teeth.J Endod. 2010; 36:664-7.
13. Ding J, Guttmann JL, Fan B, et al. Investigation of apex locators and related morphological factors. J Endod. 2010; 36:1399-403.
14. Kojima K, Inamoto K, Nagamatsu K, Hara A, Nakata K, Morita I, Nakagaki H, Nakamura H. Success rate of endodontic treatment of teeth with vital and nonvital pulps. A meta-analysis. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2004; 97(1):95–9.
15. Schaeffer MA, White RR, Walton RE. Determining the optimal obturation length: a meta-analysis of literature. J Endod. 2005; 31(4):271–4.
16. Liang YH, Jiang L, Chen C, Gao XJ, Wesselink PR, Wu MK, et al. The validity of cone-beam computed tomography in measuring root canal length using a gold standard. J Endod. 2013; 39: 1607–10.
17. Connert T, Zehnder MS, WEiger R, et al. Microguided endodontics: accuracy of a miniaturized technique for apically extended access cavity preparation in anterior teeth. J Endod. 2017; 43:787-90.

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