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# ACCURATE MEASUREMENT OF CANAL LENGTH DURING ROOT CANAL TREATMENT: IN VITRO STUDY

# МЕТОДИ ЗА ОПРЕДЕЛУВАЊЕ НА ДОЛЖИНАТА НА КАНАЛОТ ПРИ ЕНДОДОНТСКИ ТРЕТМАН: IN VITRO СТУДИЈА

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## Abstract

**The aim** of this in vitro study was to compare the precision in determining the working length through three methods: radiological, electronic and tactile-sensitivity. **Material and method:** The working length was determined in 30 extracted teeth with single straight completely formed root canals. An X-ray image was made on each tooth and it was used as orientation in determining the working length. The teeth were randomized in three groups by the method used for determining the working length: I group – determination with an apex locator, II group - x-ray method and III group - sensitivity-tactile working length determination. In order to directly determine whether there is a matching of the required reference point with the physiological apical constriction, the apical third was opened to the full exposure of the root canal. We analyzed the apical part of the samples under 3X magnification. **Results:** Among the three groups examined, the electronic apex locator shows the exact position of the apical reference point in determining the working length. There was no statistically significant difference between the results obtained with the electronic and the radiological method, but the difference between the electronic and the x-ray and tactile-sensitivity method is statistically significant. **Conclusion:** Determining the working length of the root canal with an apex locator is simpler and faster than using the radiographic method, while reducing the need for unnecessary exposure to radiation. **Key words:** apical foramen, apical constriction, electronic apex locator, endodontic therapy, radiographic odontometric method, tactile-sensitivity method

## Апстракт

**Целта** на ова in vitro испитување беше да се спореди прецизноста во одредување на работната должина преку три методи: рендгенолошка, електронска и тактилно-сензорна. **Материјал и метод:** Работната должина беше одредувана кај 30 прави еднокорени екстрахирани заби со целосно формиран корен. На секој заб беше направена рендгенграфска снимка, која служеше како ориентација при одредување на работната должина. Примероците беа поделени во три групи според методот за определување на работната должина: 1 група - со помош на апекс - локатор, 2 група - рендгенолошка метода и 3 група - сензитивно-тактилно определување на работната должина. Со цел директно да го утврдиме дали постои совпаѓање на бараната референтна точка со физиолошкото апикално стеснување, апикалната третина ја отворавме до целосно експонирање на коренскиот канал. Апикалниот дел од примероците го анализиравме под зголемување од 3 пати. **Резултати:** Помеѓу испитуваните три групи, електронскиот апекс локатор ја покажува најточната позиција на апикалната референтна точка при одредувањето на работната должина. Помеѓу резултатите добиени со електронската и рендгенолошката метода не постоеше статистички значајна разлика, но разликата меѓу електронската и рендгенолошката и тактилно-сензорната метода е статистички значајна. **Заклучок:** Одредувањето на работна должина на коренскиот канал со апекс локатор е поедноставно и побрзо отколку користење на радиографската метода, а притоа е намалена и потребата од непотребно изложување на радијација. **Клучни зборови:** апикален отвор, апикално стеснување, електронски апекс локатор, ендодонтска терапија, рендгенолошка одонтометриска метода, тактилно - сензорна метода

## Introduction

The main goal of endodontic therapy is to thoroughly remove the contents of the whole root canal system. This is achieved by shaping the root canal simultaneously with intra-canal irrigation and medication. However, the first step towards endodontic therapy success is determining the exact length of the canal. Having this in mind, the purpose of the test is to compare the possibilities and precision of the various methods for determining the working length.

The aims of this in vitro study were to compare the accuracy in determining the working length of three methods: radiological, electronic and tactile-sensitivity method, and to assess whether there is a matching of the exact apical point of the radiological finding with physiological apical constriction.

## Material and methods

30 straight single-rooted extracted teeth with a fully formed root were used. From the examination, the teeth were excluded if they were carious, restored or fractured and if there was root resorption.

Before starting the examination, teeth were placed in 3% sodium hypochlorite to remove all residues from the periodontal ligament. To avoid any interpersonal differences, all teeth were processed by one examiner.

Each tooth underwent x-ray imaging, which was used as an orientation in determining the working length. For determining the length, a millimeter grid was used that we set up through the x-ray image. The assumed working length was established by subtracting 1 mm from the measured length of the x-ray image (Figure 1).

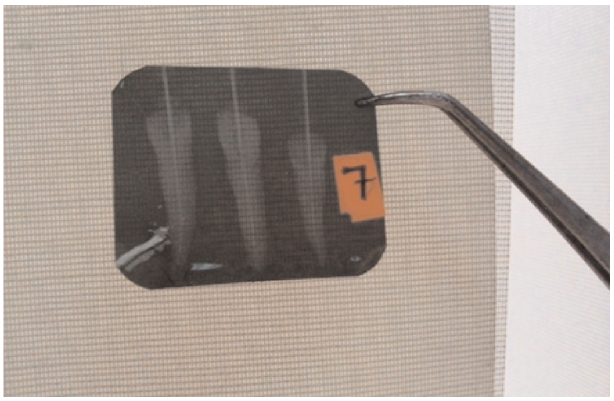

***Figure1.*** *Determining the canal length from the x-ray image with a millimeter grid*

The teeth were prepared by forming the accessory cavity and at the same time the remnants of the pulp were removed. The apex of each tooth was placed in the fresh mixed alginate. All the measurements were performed for a period not longer than 30 minutes to maintain the alginate moist, which is especially important when using apex locator.

The randomly selected teeth were divided into three groups according to the method used to determine the working length. The working lengths in the first group were determined with an apex locator (iPex NSK, Tokyo, Japan). In order to imitate the natural conditions in the oral cavity, the roots of the teeth were placed in a freshly mixed alginate, and the electrode which should be placed on the patient's lip was placed in the alginate as well (Figure 2). The resistance of the freshly mixed alginate is similar to the resistance of the vital tissues in the oral cavity, and therefore we obtained relevant measurement results.


***Figure 2.*** *Teeth from the first group placed in the alginate for determining the working length with an apex locator*

The Ingle method was used for the teeth of the second group.. The procedure was as follows: the length of the canal was measured on the first x-ray image (initial measurement); 1mm was subtracted from the initial measurement and then the second x-ray image was done together with the instrument (tentative working length). After the calculation we obtained the real working length with an additional 1mm shortening as a safety factor. Schematically, this method is shown in Figure 3.

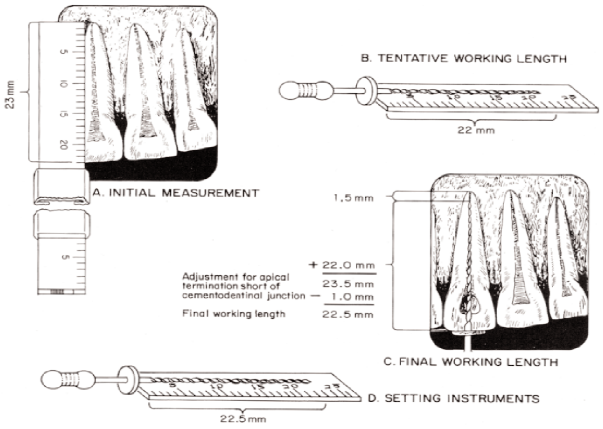


***Figure 3.*** *Schematic presentation of the Ingle method*

Working length of teeth from the third group was determined by the tactile-sensitivity method. To avoid any subjectivity, the roots of the teeth were also put in alginate.

After determining the working length, in all groups of teeth, the canal instrument was placed in the position previously measured and fixed in the specified position with glass ionomer cement. A second (or third image for the second group) X-ray was done, according to which we determined the accuracy of the measurement in each

of the three methods examined. The reference point in our study was located 1 mm shorter of the apical foramen as the point of apical constriction or as the WL gold standard.

In order to analyze the ratio of the top of the canal instrument with the physiological apical constriction, the apical third was opened by gradually removing the dentin on one side, layer by layer with a diamond burr. When only a thin layer of translucent dentin remained, it was removed with a scalpel (Figure 4). We analyzed the apical part of the samples under 3X magnification. The acceptability of the results obtained was again categorized as in the first part of the test.

***Figure 4.*** *Teeth with open-prepared apical part of the canal. The tips of the canal instruments can be noticed.*

Data from both groups were analyzed with the SAS System and the t-test. Statistically significant we will be considered the values that are $p<0.05$.

## Results

The obtained data from the precision of the three methods: electronic, X-ray and tactile-sensitivity are shown in the following tables. In Table 1, the accuracy expressed in mm is shown, and in Table 2 they are grouped according to clinical success or acceptability.

The correct determination was achieved by the electronic method. Precise determination of the length to the desired zero level in this method was achieved in 4 cases, and for an additional 5 deviation it was up to ± 0.5 mm (acceptable precision) which means that the success in the in vitro test in single-rooted teeth working length using the apex locator is 90% (Table 2).

In this part of the test, the acceptable errors were in the direction of a too high working length, but maximally 0.5mm. In the X-ray method, accurate results with a tolerance of ± 0.5mm were obtained in 80% of the examined samples, equal to the number of too high and too low specified lengths. The accuracy of the tactile-sensitivity method in single-rooted teeth was small and amounted to 40% with this group, although there was one case of too high working length, in the other samples the instrument was shorter. In this group the results were very uneven.

From the results on frequency distribution of the distance between the tip of the instrument and the desired reference point n (%) obtained by the electronic and the radiological method there was no statistically significant difference ($p=0.5390$). Among the results of odontometry obtained with the electric and tactile-sensitivity ($p=0.0154$), as well as between the X-ray and the tactile-sensitivity method ($p=0.0343$), there were statistically significant differences.

The results that provide in what measure the radiographic image is, is a real indicator of the structures in the apical part, i.e. how close is the tip of the instrument, whose radiographic images to the apical constriction (physiological foramen) are shown in Tables 3, 4, 5 and 6. We measured these results after opening the root canal in the apical part. In all examined samples, the apical aperture and apical constriction were clearly visible.

**Table 1.** Number of teeth according to the distance between the tip of the instrument and the desired reference point n (%) obtained by three examined methods

| Distance in mm | Electronic method | X-ray method | Tactile-sensitivity method |
|---|---|---|---|
| > 1.1 | | | 1 |
| 1- 0.6 | 1 | | |
| 0.5-0.1 | 4 | 2 | 2 |
| 0 | 4 | 4 | 2 |
| -0.1 - 0.5 | 1 | 2 | |
| 0.6 - 1 | | 1 | 2 |
| - 1.1 - 2 | | 1 | 1 |
| -2.1 - 3 | | | 2 |
| **total** | **10** | **10** | **10** |

In Table 3, 4 and 5, the difference between the radiographic findings and the direct visualization of the apical part is shown individually for each group where a different method of odontometry was applied. In 90% of the samples with electronically determined working

**Table 2.** Level of precision of the three examined odontometric methods

| Results | Electronic method | X-ray method | Tactile-sensitivity method |
|---|---|---|---|
| precise | 4 | 4 | 2 |
| acceptable | 5 | 4 | 2 |
| error | 1 | 1 | 2 |
| significant error | 0 | 1 | 4 |
| **total** | **10** | **10** | **10** |

lengths, and in 60% of the radiographic determined ones, the difference between the tip of the endodontic instrument and the apical constriction was within the range of ± 0.5 mm. Only 40% of the samples from the tactile-sensitivity group had such a match.

Among the results of the frequency distribution of the distance from the tip of the instrument to the physiological foramen obtained by the electronic and the x-ray method, there was no statistically significant difference (p=0.0694). In respect of the results obtained with the electronic and tactile-sensitivity method, the differences were statistically significant (p=0.0154). The difference between the X-ray and tactile-sensitivity method (p=0.1914) according to the analysis did not show any statistically significant differences.

It can be noted that in all examined samples there was a certain higher position on the tip of the instrument in the apical constriction than it seems on the X-ray.

## Discussion

In-vitro performed examinations are usually considered problematic because of the lack of apical periodontium. To simulate the clinical conditions, several experimental models are proposed, which suggest different media where extracted teeth should be placed, for example, alginate, agar, saline or gelatin. However, if it is necessary to examine the work of electrical apex locators,

**Table 3.** Electronic measurement according to x-ray image and direct visualization

| Up to | > 1.1 | 1<br>0.6 | 0.5<br>0.1 | 0 | -0.1<br>- 0.5 | -0.6<br>-1 | - 1.1<br>-2 | - 2.1<br>-3 |
|---|---|---|---|---|---|---|---|---|
| x-ray image | | | 2 | 4 | 2 | 1 | 1 | |
| direct visualization | | 2 | 3 | 3 | | 2 | | |

**Table 4.** X-ray measurement according to x-ray image and direct visualization

| Up to | > 1.1 | 1<br>0.6 | 0.5<br>0.1 | 0 | -0.1<br>- 0.5 | -0.6<br>-1 | - 1.1<br>-2 | - 2.1<br>-3 |
|---|---|---|---|---|---|---|---|---|
| x-ray image | | | 2 | 4 | 2 | 1 | 1 | |
| direct visualization | | 2 | 3 | 3 | | 2 | | |

**Table 5.** Tactile-sensitivity measurement according to x-ray image and direct visualization

| Up to | > 1.1 | 1<br>0.6 | 0.5<br>0.1 | 0 | -0.1<br>- 0.5 | -0.6<br>-1 | - 1.1<br>-2 | - 2.1<br>-3 |
|---|---|---|---|---|---|---|---|---|
| x-ray image | 1 | | 2 | 2 | | 2 | 1 | 2 |
| direct visualization | 1 | | 1 | 2 | 1 | 1 | 3 | 1 |

which operate on the principle of electricity, the conduction of the medium is more important than its biological properties.

It is best if the material used for this purpose provides the same electrical resistance as the periodontal ligament to obtain accurate measurement data[1]. The alginate has colloidal consistency, which is a good simulator of the periodontium, it is accessible and easy to prepare. Among those, the alginate, used in our examination, best imitates the electrical impedance of the human periodontium[2]. We made the measurements in the shortest possible time, to ensure that the alginate is sufficiently humid.

In the first part of this study, we evaluated the accuracy of the methods according to the X-ray image in line with the same principle as in the usual clinical trial. Although the radiological odontometric method is still considered to be the "gold standard" according to which all other methods are evaluated and is the most used method for determining the working length in the world, the obtained results have shown that the most accurate determination of the working length was achieved by the electronic method, where the exact determination was achieved in 90% of the samples tested, if the tolerated deviation was up to ± 0.5mm. Our results were in line with those of Puri[3], Nelson-Filho[4], Paludo[5] and Shanmugaraj[6] using the same methodology.

In the paper, the radiographic method according to Ingle was used, which yields the most accurate results[7], 8. Exact results were measured in 80% of the examined samples, which did not differ statistically from the electronic, which coincides with the results of Kqiku et al.[9]. The tactile-sensitivity method has again proved to be the most unreliable method for determining the working length, with the difference between the two methods being statistically significant.

The second aspect in our in vitro examination was to determine whether our assumed reference point corresponds to the apical constriction. We determined this by measuring the distance for which the tip of the instrument in the canal deviated from the apical constriction after its position was determined by one of the methods examined. Our results showed that among these three groups, the electronic apex locator shows the exact position of the apical reference point in determining the working length in endodontics.

According to the results of Vieyra[10], if the tip of the instrument is set to exactly 1mm from the radiographic apex, only 32% of the canals will be positioned on the apical constriction itself, while the remainder will be between the two apexes (anatomic and physiological). Another study of Hoer et al.[11] shows that apical constriction can be accurately determined in 43% of teeth.

This is explained by the correct configuration of the extracted teeth. As mentioned earlier, the apical constriction is the ideal point where the working length should be. However, it is also known that the exact position of the apical foramen can be reliably determined by the points between the physiological foramen and the constriction, but they cannot be metrically determined.

According to the results obtained, it can be concluded that in both methods (electronic and radiographic) the instrument is set slightly higher than it is monitored on the X-ray, but this is not as stressed as in the Alothmani test[8], which showed that in 28.5% of the cases the instrument exceeded the length of the canal despite the acceptable appearance of the recording. Similar conclusions to ours were obtained by Shanmugaraj[6] and Ravanshad et al.[12].

According to these results it can be concluded that the X-ray film should be considered as relative, since it only shows the relative position of the instrument in relation to the root and the radiographic peak of the root. Often, the location of the endodontic instrument tip that appears to be too low is in the correct position relative to the reference point[13,14], and if it appears to be higher, it means it is really higher and further than the desired reference point.

However, it should always be borne in mind that X-ray diagrams show us what cannot be seen with electronic apex locators, and also the advantages and possibilities of apex locators are much better than X-rays. This means that confrontation is the best way to determine the working length. The combination of both methods achieves the greatest success in work and the best service for the patient.

## Conclusion

There was no statistically significant difference between the electronic and the x-ray method, and the two methods yielded good results. A statistically significant difference was confirmed between the electronic and the X-ray versus the tactile-sensitivity method, i.e. the tactile sensitivity method precision is much smaller. The use of an electronic apex locator in odontometry is practical and reliable, mostly due to the reduction of unnecessary exposure to X-rays.

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