http://doi.org/10.35784/iapgos.2878 *received: 06.02.2022 | revised: 11.03.2022 | accepted: 28.03.2022 | available online: 31.03.2022*

DETERMINING THE WORKING LENGTH OF A ROOT CANAL USING INTRAORAL RADIOGRAPHY SEGMENTATION

Oleksii Perepelytsia, Tetyana Nosova
Kharkiv National University of Radio Electronics, Faculty of Biomedical Engineering, Kharkiv, Ukraine

Abstract. *Apexlocators are devices that determine the working length of the root canal. Measurement with the help of alternating currents of different frequencies in combination with the method of the ratio allows to achieve high accuracy in determining the location of the physiological tip of the root (over 80%). However, such devices cannot accurately visualize where a doctor's tool is. Using image processing algorithms, you can segment tooth root structures with high precision. Therefore, the combination of electronic determination of the root canal length (using apexlocator) with X-ray segmentation is relevant.*

Keywords: root canal, radiograph, endodontic treatment, apexlocator

OKREŚLANIE DŁUGOŚCI ROBOCZEJ KANAŁU KORZENIOWEGO ZA POMOCĄ SEGMENTACJI RADIOGRAFII WEWNĄTRZUSTNEJ

Streszczenie. *Apex locatory są urządzeniami, które określają długość roboczą kanału korzeniowego. Pomiar za pomocą prądów zmiennych o różnych częstotliwościach w połączeniu z metodą proporcji pozwala na osiągnięcie wysokiej dokładności w określaniu położenia fizjologicznego wierzchołka korzenia (ponad 80%). Urządzenia te nie są jednak w stanie dokładnie zobrazować miejsca, w którym znajduje się narzędzie lekarza. Wykorzystując algorytmy przetwarzania obrazu, można z dużą dokładnością segmentować struktury korzeni zębów. Dlatego też połączenie elektronicznego określania długości kanału korzeniowego (przy użyciu apex locatora) z segmentacją rentgenowską ma istotne znaczenie.*

Słowa kluczowe: kanał korzeniowy, radiogram, leczenie endodontyczne, apex locator

Introduction

The basis of successful endodontic treatment is the correct determination of the working length of the root canal (the distance between the external landmark on the crown of the tooth to the apical border). An apical constriction zone is recommended as a border for root canal treatment and filling. Intraoral radiograph allows you to obtain information about the direction of bending of the root canals, as well as to determine the working length. However, the radiograph is a two-dimensional total image and does not reproduce the entire anatomy of the apical part of the root therefore there are often layers and distortions of the image. When interpreting radiographs, there is a probability of error associated with the subjectivity of the evaluation result of the specialist. Thus, it is impractical to be guided exclusively by this method of determining the working length. The method of apexlocation is based on the difference of electrical resistance of tissues. The hard tissues of the tooth have a higher resistance than the mucous membrane of the mouth and periodontal tissue. Devices for electrometric determination of the working length of the root canal determine the impedance using alternating currents of different frequencies and apply the method of ratio. This measurement is stable and accurate even when working in wet channels and provides smooth visualization of all process of penetration of a top of the channel tool and high accuracy of definition of a place of physiological top of a root. Modern algorithms for electrometric determination of the working length of the root canal do not combine the data obtained from the radiograph. In this regard, it is important to develop new methods and means of displaying electrometric data on the radiograph to more accurately determine the location of the physiological apex of the root.

1. Electrometric method for determining the length of the root canal

There are 3 zones in the structure of the apex: the apex itself (radiological top of the root), large apical hole and apical constriction (the area of the apical part with the smallest diameter). The apical constriction zone is recommended as a limit for root canal treatment [8, 9]. The method of apexlocation is based on the difference in electrical resistance of tissues. The hard tissues of the tooth have a higher resistance than the mucous membrane of the mouth and periodontal tissue. The electrical circuit between the electrodes placed on the lip (lip electrode) and in the channel (electrode in the form of a file with a calibration stopper) remains closed until the periodontal tissue reaches the file. A sharp drop in resistance occurs in the area of apical narrowing, the circuit closes, this is what fixes the apexlocator [11].

Having used the mathematical method of determining the length of the canal (using tables), doctors began endodontic intervention. Knowing the range of tooth length is important factor in a successful operation.

Working length is the distance from the most protruding part of the tooth crown to the physiological narrowing – apical constriction. Apical constriction often has a complex configuration. The physiological tip is located at a distance of 1.0 mm from the anatomical – this is the final working length for the doctor. For an example, see the figure below.

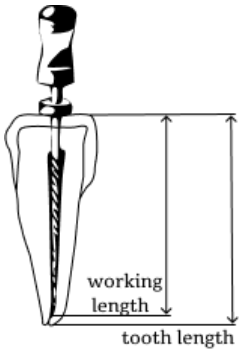

Fig. 1. Determination of working length

Devices for electrometric determination of the working length of the root canal determine the impedance using alternating currents of different frequencies. Using the ratio method, they allow you to find the total coefficient of resistance, which reflects the position of the file in the channel (Fig. 2).

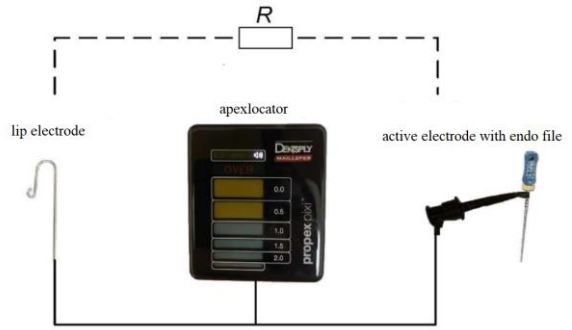

Fig. 2. Scheme of the apexlocator

The measurement scheme is shown in Fig. 2. This measurement indicates the presence of electrolytes in the pulp tissue, is stable and provides high measurement accuracy [10]. A significant disadvantage of the method is the requirement to work in relatively dry or partially dried channels.

The method of electrometric determination of the length of the root canal was performed in two stages. The first stage – with the help of the Propex Pixi device the previous working length was determined. In the process of processing the root canal is the expansion of the diameter and taper. The second stage – after the final treatment of the channel was performed another measurement by electrometric method. This value was defined as the final working length of the channel.

2. Method of radiological determination of root canal length

Monochrome photometric interpretation is used for dental radiographs (brightness of image pixels is represented by a gray scale with pointers from 0 to 255, where the brightness value of 0 corresponds to a pixel with black colour, the value of 255 – white).

The study used data obtained using a visiograph Planmeca ProSensor HD, which has a resolution of 1020 × 688 pixels. Matlab 2019 Image Processing Toolbox was chosen to develop software for segmentation and channel length measurement [5].

The threshold method was used to select the object of study (tooth root). The threshold method is a binarization method based on dividing an image into 2 parts based on threshold values. The value (T) is selected according to the task to be performed (from 0 to 255). All brightness values that are in the range of values higher than T are called object values, everything below is the background value. Next is the boundary layer – a curved line that separates the elements of the object and the background. A segment is selected along this line if it satisfies the low-pass noise filtering condition. Figures 3–5 show histograms.

This graphs of the distribution of image elements with different brightness, in which the horizontal axis shows the brightness from 0 to 255, and the vertical – the number of pixels with a specific value of the brightness of the corresponding images of teeth.

Physiologically sealed root canal corresponds to intervals with large brightness indicators. To select these areas, it is enough to select the value of T and determine all points that have $f(x, y) > T$, which belong to the object, and otherwise – belong to the background [14]. Then the original image (g) is defined by the following expression:

$$g(x,y)=\left\{\begin{matrix}1, if\ \ f(x,y)>T\\0, if\ \ f(x,y)\le T\end{matrix}\right\}. \quad (1)$$

here *1* – the value of the object; *0* – background value.

The threshold T = 210 was chosen to binarize the image of the tooth root. Given the resolution, filtering with the removal of segments with a pixel count below 30,000 was used to exclude binarization artefacts [2, 13]. The result of binarization is shown in Fig. 6.

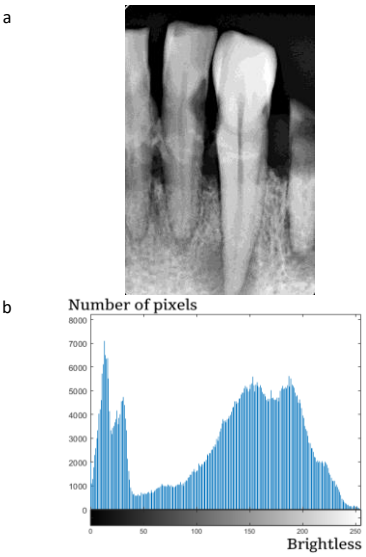

Fig. 3. Histogram analysis of the image: a — image of the tooth No 1, b — the corresponding histogram

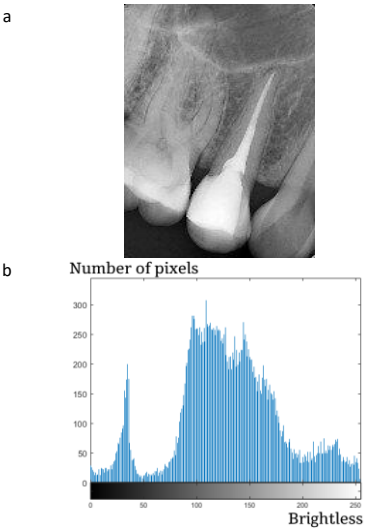

Fig. 4. Histogram analysis of the image: a — image of the tooth No 2, b — the corresponding histogram

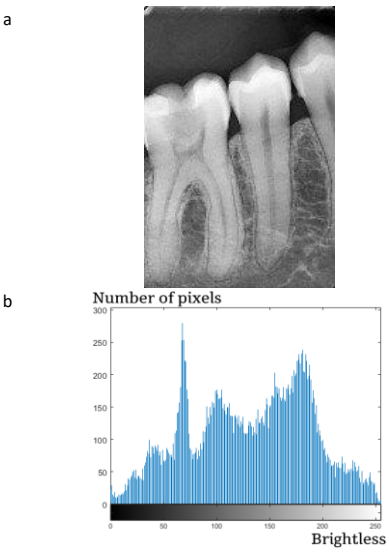

Fig. 5. Histogram analysis of the image: a — image of the tooth No 3, b — the corresponding histogram

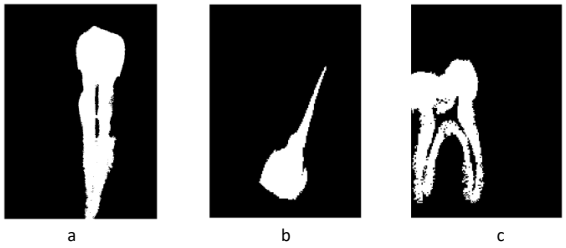

Fig. 6. The result of binarization of images with a threshold T = 210: a — segmented tooth No 1, b — segmented tooth No 2, c — segmented tooth No 3

At threshold segmentation it is necessary to consider the connection of components. If we consider two points of the image connected and there is a path between them, along which the characteristic function is constant, the points are connected. Marking objects on a discrete binary image is to select the point of the object from which the growth actually begins. The next step indicates the neighbouring points (except those already marked) and so on [3]. Upon completion of this recursive procedure, we obtain a closed loop (Fig. 7).

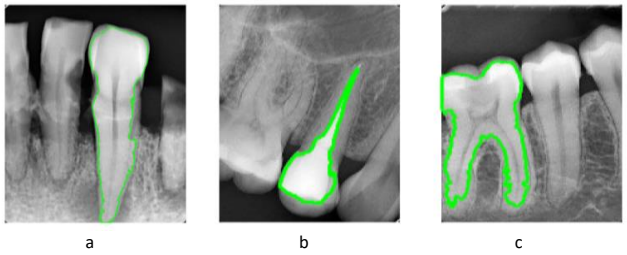

Fig. 7. The result of drawing segmented contours of the root of the teeth on the initial image: a — tooth No 1, b— tooth No 2, c — tooth No 3

3. Comparative characteristics of two methods

As a result of the work performed, the structures of the root canals of the tooth were segmented and their length was determined. Comparisons (Table 1) of the electronic determination of the working length with the radiological one showed that the electronic length and the radiological length determined by means of the program do not coincide. With lateral curvature of the canal, the X-ray may show a shorter working length than apexlocation devices [1, 15], and there is a possibility of incorrect segmentation of the tooth crown due to low brightness of the crown pixels and, consequently, the crown is not taken into account.

Table 1. Comparison of measurements performed using different methods of determining the length of the channel

Object	Mathematical method (average) according to J.I. Ingle, L.K. Buckland, J. Baumgartner [12]	Electrometric method	X-ray method with segmentation
tooth No1	22.4 mm	22.3 mm	21.64 mm
tooth No2	21.0 mm	21.5 mm	18.98 mm
tooth No3	20.9 mm	20.8 mm	20.31 mm

4. Conclusions

The advantage of measuring the length of the root canal with an apex locator is much greater accuracy (about 0.5 mm) compared to the method of radiography, but a combination of these two methods may be more reliable, which requires further statistical research. Particular attention should be paid to the peculiarities of methods of processing and segmentation of the obtained diagnostic images to ensure maximum quality of visualisation of the contours of the root canals. In segmentation, the main condition is the correct choice of the binary limit value. To do this, it is necessary to perform histogram analysis of the obtained images and in the process of post-processing to filter local artefacts using morphological operations.

References

[1] Avrunin O. G. et al.: Modern intelligent technologies of functional medical diagnostics. Press of the Kharkiv National University of Radioelectronics, Kharkiv 2018 [http://doi.org/10.30837/978-966-659-234-0].
[2] Avrunin O. G. et al.: Using a priori data for segmentation anatomical structures of the brain. Przegląd Elektrotechniczny 1(5), 2017, 102–105 [http://doi.org/10.15199/48.2017.05.20].
[3] Avrunin O. G.: Visualization of the upper respiratory tract according to computed tomography. Radio electronics and informatics 4, 2007, 119–122.
[4] http://www.dentsplysirona.com/content/dam/dentsply/pim/manufacturer/Endodontics/Motors__Apex_Locators/Apex_Locators/Propex_Pixi/PROPEX%20PIXI%20EUROP_DFU_1018_MASTER_DSE_EN.pdf (available: 10.01.2022)
[5] http://www.mathworks.com/products/image.html (available: 10.01.2022)
[6] Ingle J., Bakland L., Baumgartner J.: Endodontics. BC Decker, Hamilton, Ontario, Lewiston, NY 2008.
[7] Khomenko L. A., Bidenko N. V.: Practical endodontics. Tools, materials and methods. Kniga Plus, Moscow 2005.
[8] Kovetskaya E. E.: Comparative evaluation of the effectiveness of methods for determining the working length of the root canal. Modern dentistry 4, 2006, 11–13.
[9] Kovetskaya E. E.: Methods for determining the working length of the root canal. Modern dentistry 3, 2006, 35–39.
[10] Krainov S. V., Popova A. N., Firsova I. V.: Evaluation of the effectiveness of the electrometric method for determining the working length of the root canal using the example of the NovApex apex locator. Proceedings of the Conference Topical issues of modern dentistry 2010.
[11] Latysheva S. V., Abaimova O. I., Bondarik E. A.: Basic principles of endodontic tooth preparation. Dental journal 2, 2003, 2–6.
[12] Mounce R.: Determination of the true working length. Journal of Endodontics. 43(1), 2007, 17–19.
[13] Shamraeva E. O., Avrunin O. G.: Choice of a method for segmentation of bone structures on tomographic images. Bionics of intelligence: information, language, intelligence 65, 2006, 83–87.
[14] Shamraeva E. O., Avrunin O. G.: Construction of models of cranial implants based on radiographic data. Applied radio electronics 4(4), 2005, 441–443.
[15] Shchapov P. F., Avrunin O. G.: Obtaining information redundancy in measuring control systems and diagnostics of measuring objects. Ukrainian metrological journal 1, 2011, 47–50.
[16] Silva G., Oliveira L., Pithon M.: Automatic segmenting teeth in X-ray images: Trends, a novel data set, benchmarking and future perspectives. Expert Systems with Applications 107, 2018, 15–31 [http://doi.org/10.1016/j.eswa.2018.04.001].
[17] Solovyova A. M.: Features of conservative endodontic treatment for chronic periodontitis in teeth with incomplete root formation. Children's dentistry (Pediatric dentistry and dental profilaxis) 1–2, 2000, 79–83.

M.Sc. Oleksii Perepelytsia
e-mail: oleksii.perepelytsia@nure.ua

A participant of numerous exhibitions and scientific conferences. Received bachelor's and master's degrees with honours. Was a member of the Erasmus+ student exchange program with a stay at the Leibniz University in Hannover, Germany.

http://orcid.org/0000-0001-6850-2013

Prof. Tetyana Nosova
e-mail: oleksii.perepelytsia@nure.ua.

Associate Professor of the Department of Biomedical Engineering, Scientific Secretary of Specialized Scientific Council, Member of STC, Deputy Head of the Section 4 of STC, Doctor of Phylosophy. Scientific interests: development of methods of processing and analysis of biomedical signals.

http://orcid.org/0000-0003-4442-8001