

Electronic foramen locators: when and how to use them

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ABSTRACT

New technologies have been incorporated into endodontic protocols in order to facilitate or make the performance of the professionals who perform them easier or more efficient. In this perspective, foraminal electronic locators (LEFs) present themselves as almost indispensable tools for a correct determination of the actual length of the ducts. The latter, in turn, is of vital importance so that endodontic procedures are more accurate and are limited to the extensions desired by the endodontist, not delegated by chance or anatomical variations in the relationship between the apical foramina (FA) and the radiographic vertices. Given the above, the goal of this article is to discuss the LEFs' employment protocols and the influence that some clinical conditions can have on the accuracy

of these devices. Based on the available scientific evidence, aspects such as the adjustment of the instrument and its relationship with cervical preparation, the apical penetration limit and the sequence of use of the LEF, as well as the foraminal condition, seem to significantly interfere with the observed precision values. It is evident that the knowledge of the operation of the locators and their relationship with the different clinical situations allows them to be used more effectively, increasing their precision and extracting from the equipment, whatever the best result, favoring the correct obtaining of the length of the root canal, thus collaborating for the realization of a more predictable and quality Endodontics.

Keywords: Endodontics, Foraminal Electronic Locators, Clinical Protocols.

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Introduction

One of the main challenges encountered by professionals during the execution of endodontic treatment is the correct determination of the actual root canal length. Such determination presents as the main complication the fact that the apical foramen does not coincide, in the great majority of times, with the radiographic vertex.¹ Assuming the need to prepare the entire extension of the root canal in order to eliminate as much as possible microbial contamination, the correct determination of this length is of great importance, having been pointed out as fundamental to increase the success rates of treatment.^{2,3} No matter how different levels of apical preparation have been suggested, below,^{4,5} in the foraminal limit⁶ or even beyond it,^{7,8} the basis for this delimitation remains the original position of the apical foramen.⁶

As a solution to this difficulty, a series of studies led to the development of foraminal electronic locators (LEFs). These electronic devices, sometimes mistakenly referred to as apical locators, are undoubtedly the most accurate and reliable method for determining the anatomical extension between a coronary reference and the apical foramen, with precision rates above 90%.^{1,6,9-11} Having undergone great evolution since its inception, the LEFs currently available operate electronic determinations through the generation of an alternating electric current that crosses the dental structure from one pole to the other (instrument and labial clip), sequentially, in both directions. Due to this current flow through the tissues, and considering the electrical conductivity coefficient of them, the electronic devices determine the impedance, in two or more frequencies, in order to have them, operate mathematical ratios between them and finally point out the distance of the instruments in relation to the apical foramen.

However, despite all the technology on board, LEFs cannot be, unrestrictedly, considered infallible tools or similar.¹²⁻¹⁴ There are studies in the literature that point out reading errors and differences between devices,^{15,16} however, such variations seem to arise when used incorrectly or when clinical conditions differ from a situation considered “ideal”.^{7,17,18} In this sense, it is essential that the operator has the knowledge of these possible complications and the performance of his device before them. Likewise, the evolution of the locators and the tendency to simplify the protocols led to the emergence of hybrid equipment, devices that associate LEFs with electric

motors to drive mechanized instruments for preparing the canal system. These devices end up eliminating the need for a specific moment to carry out the determination of the actual length, performing it simultaneously when preparing. However, the complexity of the dynamic determination of apical instrumentation limits makes the correct measurement by LEFs even more complex, which can generate reading errors that, in this case, may represent preparations in unwanted apical limits.^{11,19}

In parallel with the observation of the clinical aspects that may influence the accuracy of the LEFs, some researchers dedicated themselves to assess both the influence of the use protocol of electronic devices,⁶ and the moment in which electronic dentistry is actually performed.²⁰ The results of these studies call attention to the need to rethink the way we use them and the moment, or moments, in which we carry out the determinations.

In view of the above, considering the importance of a correct measurement of the length of the canals, and the influence of this in determining the apical limit of endodontic treatment, the present study aims to discuss aspects related to the use of foraminal, conventional or hybrid electronic locators, seeking to highlight the points that can influence their precision indexes; as well as addressing aspects related to the moment when electronic dentistry can, or should, be performed in order to increase the accuracy of these devices.

General operating principles

The introduction of an electronic method to measure the working length of the root canal was made in 1918 by Custer.²¹ Adding Suzuki's findings,²² which, in 1942, determined the electrical resistance values between the periodontal ligament and the oral mucosa, the knowledge base was created, culminating in the development of the first LEF capable of measuring the electrical resistance of tissues teeth, a fact that occurred in 1962.²³

Currently, LEFs are based on the frequency-dependent impedance method, determining electrical resistance values as a function of at least two alternating current frequencies.²⁴ This impedance depends on two electrical factors, resistance and capacitance, the first refers to the energy transmitted by the device through the tip of the instrument, relating to the apical limit; the second, to the energy released throughout the instrument, related to its adaptation to the root canal walls.²⁴ With these data, the devices perform mathematical operations (quotient, dif-

ference, square root, etc.) in order to point the distance from the tip of the instrument inside the channels with the apical foramen.

Some factors that could be configured as problems are no longer present, pulp condition,²⁵ presence of exudate or pulp tissue inside the channels,²⁵ the type of irrigation solution²⁶ or the metal alloy in which the instrument is manufactured no longer interfere with reading performed by currently available devices.^{9,11,24}

The first device to meet the standards used today was the Root ZX (J. Morita, Tokyo, Japan). This device offers precision indexes close to 95% and average error values below 0.5 mm in most of the many studies of which it was part; this fact has been pointed out as the gold standard by many authors.^{20,27} However, a very large universe of devices is available for Endodontists, some with less, others with more embedded technology, some just different designations of the same device, others, variations that may represent improvements in the way of interacting with the operator or even with the electrical system into which the tooth is transformed during electronic determination. At this point, factors have shown potential to influence the accuracy of LEFs, not always in a similar way between them, it is important that the professional knows them and can understand how to favor the accuracy of their device, or even, its limitations; some of these factors are covered in the topics that follow.

Factors that can influence locator accuracy

Adjustment of the instrument used in dentistry and its relationship with cervical preparation

When deciding to perform electronic dentistry, the selection of the instrument with which it is performed has demonstrated a significant influence on the precision indices offered by the devices. Selecting a randomly chosen low-caliber file and inserting it into the channel does not seem to be the best option. Vasconcelos et al.²⁸ evaluated the accuracy of three electronic devices when using adjusted, loose (one smaller size) and very loose (two smaller sizes) files, observing that, in the three tested devices, the highest precision indexes were observed with adjusted files; results in the same direction had been previously reported by Stoll et al.⁸

However, the effective adjustment of the instruments in the apical portion of the canals has been pointed out as being directly dependent on the previous performance of cervical preparation.²⁹ The relationship between

this and the accuracy of the locators had already been demonstrated by Camargo et al.⁷ when they observed an increase in the precision of electronic determinations performed after the cervical preparation was performed. As if consolidating this understanding, data not yet published collected by the present research group indicate that the use of cervical preparation led to a greater change in the apical adjustment file in 72.5% of cases. In this way, it is reinforced the statement that the elimination of cervical dentinal interferences allows the free passage of endodontic instruments, which in turn can be introduced more easily to the apical portion³⁰⁻³², in addition to allowing a larger file caliber reaches the apical foramen, providing an improvement in the accuracy of the devices.³³

In the opposite direction, the preparation of cervical and middle thirds has been undergoing discussions in recent years. Authors have stated that cervical enlargement could weaken the dental structure, consequently increasing the risk of root fractures.³⁴⁻³⁶ This statement has been debated, and other studies are available that point to results that disagree with this position.^{37,38} Regardless of the point of view in relation to fracture resistance, a study carried out by the present research group evaluated the accuracy of three LEFs using different cervical preparation protocols: absent, conservative (#25/.06) and conventional (#25/.12). In this, they concluded that there was a significant increase in the accuracy of the devices when the cervical preparation was performed with greater amplitude. As a suggestion, even conservative wear should be performed since the absence of cervical preparation negatively affects the reliability and precision of the LEFs, possibly because it does not allow the correct adjustment of the instrument.

Apical penetration limit

Another point of great importance when using LEFs is the apical limit of penetration of instruments during electronic determinations. Over many years, the vast majority of endodontic schools in the country adopted 1.0 mm below the radiographic apex as the penetration limit in bio-pulpectomies and, when not in necro-pulpectomies without periapical rarefaction; this limit was used as a way of preventing damage to the periodontal stump, cited as responsible for the biological sealing after treatment.^{8,39} In necro-pulpectomies with periapical rarefaction, this limit could be extended, either through foraminal debridement

or, more recently, through foraminal enlargement.¹⁷ However, regardless of the protocol used during preparation, including the LEFs functioning mechanism, the influence of this apical penetration limit would need to be evaluated since the impedance considers not only the energy emitted along the file, but also at its end, in this case, the tip of the instrument used during the measurement.

In this sense, several studies have found that the accuracy of LEFs is compromised when determinations are made below the apical foramen.^{11,19,40,41} Thus, it seems lawful to state that the instruments used during electronic determinations must extend to the apical foramen, that is, until they reach 0.0 mm or “Apex” on the device’s display,^{9,19,42} under penalty of damage accuracy of determinations.

Still in relation to the penetration limit, some professionals believe that it is necessary to overcome the apical foramen in order to “close the circuit”; such a protocol would guarantee better precision to the determinations. In this regard, Oliveira et al.⁶ dedicated themselves to assess the accuracy of five electronic devices using as sequences of use: insertion limited to 1.0 mm below the foramen, insertion taken to the foramen followed by indentation up to 1.0 mm below, insertion limited to the apical foramen, and insertion taken beyond the apical foramen (“over”) followed by retreat to 0.0 mm. The authors observed lower levels of precision in the determinations below the foramen, regardless of whether the apical foramen was reached or not. Higher precision indexes were observed in the apical foramen determinations, with no advantages being observed due to the fact that the same was exceeded. In view of the above, it can be said that the transposition of the apical foramen during electronic dentistry does not have an advantage, and may also cause an adjustment of the instrument when it retreats to the foraminal level.

Foraminal morphology (incomplete rhizogenesis, deciduous teeth or areas with apical resorption)

In cases of teeth with incomplete rhizogenesis or affected by extensive resorptive processes, the electronic interpretation made by the LEFs may be compromised. Studies available in the literature have demonstrated good LEF accuracy when determining with files adjusted in teeth with enlarged foramina^{17,43,44} and deciduous.⁴⁵ However, the correct use of the devices may be difficult

when cases whose apical dimension is larger than the most coronal portion occur, preventing proper contact of the instrument with the surrounding walls of the channel, resulting in inaccurate readings for interfering with the capacitive factor that makes up the interpretation of impedance.⁴⁶

Recently, the present research group developed a study evaluating the precision of LEFs in face of different foraminal morphologies (complete, wide with parallel walls, and wide with divergent walls). It was concluded that, in cases of diverging walls, the accuracy of the devices is significantly reduced, suggesting that the lack of apical adjustment of the instrument forces the devices to define the position of the instruments even with the impaired capacitive factor, which can lead to measurement errors. Thus, it is suggested to recognize the limitation of LEFs in these conditions, redoubling the need for the association of a radiographic control due to the importance of a correct cleaning of the end portions of the root canals.

Absence of foraminal patency

Accepting the assumption of the need to reach the apical foramen with a properly adjusted instrument, the importance of obtaining foraminal patency is evident, however, the foramens are not always patent, which could make it difficult to determine the length of the channels. By definition, a patent means open, which would be natural since the apical foramen is the orifice through which arterioles, venules and nerves enter and leave the tooth, maintaining their functions. However, such an orifice may be obstructed or not accessible to the instruments, and may be caused by an apical delta-shaped anatomy, by the lateral opening of the foramen or even by dentin shavings impacted during the instrumentation.^{47,48}

In the presence of an obstructed apical foramen, the electronic device will never inform the operator that it has reached 0.0 mm. In these cases, patent protocols are indicated, however, in some of them, the risk of “creating a foramen” is assumed, which in fact would be an artificially created channel, a perforation. Assuming that this occurrence in no way favors the treatment prognosis, Vasconcelos et al.¹⁸ evaluated the accuracy of three LEFs in teeth without foraminal patency. They observed that foraminal obliteration interfered differently in the precision of the assessed LEFs, reducing the accuracy of some, but not influencing that of others. In the light

of the foregoing, it is suggested that the absence of patency may have prevented the devices from interpreting the resistive factor properly, interfering with its accuracy. Thus, it becomes valid for professionals to be aware of the general limitations of the locators, however, the fact that they present different behaviors under certain clinical conditions highlights the importance of knowing the specific limitations of each device.

The right time to perform electronic dentistry

Due to the aspects discussed so far, it seems legitimate to state that the best time to perform electronic dentistry would be after the cervical preparation has been performed, and it is, however, different from what you are used to doing, we now have the knowledge of the importance of continuous monitoring of the root canal length. Vasconcelos et al.²⁰ demonstrated significant changes in the extension of the real length of the canals during the chemical-mechanical preparation (PQM) performed with a reciprocal-rotational system, revealing a reduction of approximately 0.34 mm after the cervical preparation; some samples even reduced to 1.5 mm. After cervical preparation, no major reduction was observed in relation to the final instrumentation, but some cases decreased their extensions by up to 0.6 mm. It is important to note that specimens have “reduced their lengths” by 1.75 mm when considering the difference in determination after coronary access and final preparation.

More recently, the present research group carried out an unpublished study evaluating this pattern of length reduction due to different profiles of cervical preparation, absent, moderate, performed with reciprocal-rotational instrument, and conventional, performed with dedicated instrument. It was observed that, regardless of the standard of cervical preparation adopted, all systems provided a reduction in the actual length of the teeth close to 0.5 mm; some specimens even reduced 1.7 mm.

Due to the findings, the importance of constant monitoring of the actual length of the teeth is emphasized, with no more “just” dentistry being performed. When not considering the possibility of reducing the length of the canals due to the removal of dentinal excess, the possibility of involuntary overextension of the preparation is assumed, or, more severely, of the filling, which may result in fillings beyond the apical foramen, which increases the failure rate, failure or even accident during endodontic treatment. Thus, it is suggested to perform

electronic dentistry after cervical preparation, to delimit the preparation procedures, and at the end of the instrumentation, to determine the apical limit of filling.

Hybrid equipment

Given the success of the locators, the emergence of hybrid equipment that combined an electric motor with mechanized instrumentation and a LEF was natural. They emerged based on the security provided by mechanized instruments in the preparation of root canals and the proven precision of LEFs.^{11,49-51} In this context, the control of the apical limit of instrumentation and/or the continuous monitoring of the length of the canals is extremely valid, since, as previously discussed, it can vary during the procedure.²⁰

However, the electronic determination carried out dynamically using this hybrid equipment presents difficulties not experienced during the use of LEFs conventionally. It cannot be imagined that these measuring devices retain memory, they do perform hundreds of mathematical determinations and calculations every second, thus the dynamics of the instrumentation, which by nature produces movements of penetration and exit of the instruments, could produce some kind of compromise in the accuracy of these hybrid devices.

In this regard, studies show high precision values attributed to this equipment, both using rotational and reciprocal-rotational kinematics.^{11,50} However, the findings in the literature point to something that could be expected, such control of the apical limit becomes reliable only in cases where the instruments are taken to the FA, and this reliability is significantly compromised in instruments below FA.¹¹ Such knowledge may generate the need for protocol changes, especially in cases of bio-pulpectomies, since preparation with these devices does not seem to be indicated in apical limits other than the apical foramen.

Discussion

The introduction of new equipment reflects a constant concern of companies and researchers to develop technologies that can facilitate, and why not improve, the performance of endodontists. In this context, the advances in precision and reliability of foraminal electronic locators over time are notorious, making them indispensable tools in the clinical arsenal today. The need for its use becomes even more evident when it is understood that

endodontic treatment needs precise limits, regardless of what this is, and the correct determination of its extension is not randomly delegated. Having proved that the apical foramina do not coincide with the radicular vertices identified radiographically, the use of electronic devices as a measurement tool does not seem, today, optional.

Regardless of the precision offered by the LEFs currently available, the importance of anatomical information provided by a periapical radiography of odontometrics is undeniable. In it, countless additional data such as visualization of the path of the canals, position of the apical foramen, presence of perforations, deviations, curvatures and root resorption can be identified⁵². Thus, it is suggested, whenever possible, to perform this radiography as an additional form of diagnosis. Although it seems counterintuitive, it is understood that the “simple” determination of the length between the apical foramen and the coronary reference would not be enough for an effective and safe planning of the clinical case. It should be noted that, in cases of overextension or large sub-extensions, it is up to the professional to consider the possibility of reading errors on the electronic device, even if without any clear reason for doing so.

Considering the information available in the literature consulted and addressed throughout this article, some important points are suggested when using LEFs, conventional or hybrid: the electronic determination must be preceded by a cervical preparation in order to increase the precision regarding the definition of the adjustment the instrument, the latter being of great relevance;^{28,32,33} the measurement instruments should be inserted up to the foraminal level,^{11,19,40,41} however, without the need to reach the space of the periodontal ligament;⁶ when the presence of very large apical foramen or with resorption, cases where the adjustment of the instrument may be compromised, the LEF reading may not be as accurate; when it is impossible to obtain foraminal patency, the reading of some devices may not present reliable exten-

sion estimates;¹⁸ finally, due to the significant reduction of the extension during the steps of endodontic treatment, it is necessary to perform electronic measurements not only in the initial stages of the procedure (immediately after access or cervical preparation), but also when filling procedures of the canal system.²⁰

Therefore, in general, this article seeks to help professionals in the field to define clinical protocols that could help them to get the best out of their devices, without highlighting specific brands or models; such information can be found in the articles that served as the basis for this review. It is evident that for the best use of LEFs, it is necessary to understand their operation in a clear and objective way, understanding how they operate and what could actually impair their accuracy, highlighting the need for knowledge of the clinical conditions that may favor or disrupt your job. However, even in the face of so much evidence, some more skeptics could claim that Endodontics was performed for many years without such a tool, obtaining satisfactory results, a fact that would make LEFs unnecessary. In this area, an important question arises, the need to further increase the success rates of treatments and, in this sense, the inclusion of quality in any of the treatment steps can help in the successful conclusion of the case; in the case of dentistry, LEFs are definitely this tool.

Conclusion

The foraminal electronic locators are precise and essential equipment to obtain the correct root canal length. However, knowledge of its functioning and the different clinical situations that could influence its proper functioning allows its use more effectively.

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