Apical Limit and Working Length in Endodontics

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Apical Limit and Working Length in Endodontics

Abstract: Establishing the working length is an important step in endodontic treatment as inaccurate length determination may lead to failure. There is an ongoing debate regarding the extent of the apical limit of root canal preparation. This controversy is based upon different clinical opinions concerning the distance between the end point of the root canal preparation and the periodontal tissues. In this paper, we review the different schools of thought for working length determination, and how apex locators work and how they must be used for optimal accuracy. The reliability of these devices has been proven; the price is moderate and apex locators are now part of the basic armamentarium in the achievement of quality and predictable endodontic treatment.

Clinical Relevance: The technique of determining the working length from a single radiograph remains empirical, and apex locators should be considered an essential aid in establishing working length.

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Nickel titanium rotary instruments have been reported as the most significant advancement in the field of endodontics over the last ten years. This statement, however, does not recognize a further important advancement, which has led to improvement in the quality of endodontic treatment: that is the development of apex locators, improperly named electronic measuring devices. Working length in endodontics is defined, as 'the length between a coronal reference point and the apical limit of preparation.' This length may be determined in a number of ways, with two of the most popular being a working length radiograph or an instrument coupled to an electronic apex locator. The electronic apex locator allows the apical end of the canal to be located in a reproducible manner and a silicone stop may be adjusted to this length or shorter, referring to the same reliable coronal reference point. The working length is 'the distance (in millimetres) between the tip of the instrument and the silicone stop' (Figure 1). This 'working length' or specified distance short of it may be transferred to subsequent instruments which allow shaping to be performed to a chosen limit.

Figure 1. Once the apical limit is noted, the working length is measured with the silicone stop on a millimetre ruler.

The purpose of this article is to discuss the apical limit of preparation in endodontics, and to review the techniques available to establish this limit thereby determining the working length. However, the desired end point of preparation must first be chosen and defined prior to determining the working length.

Where is the apical limit of preparation?

There is an ongoing debate regarding the extent of the apical limit of root canal preparation. This controversy is based upon different clinical opinions concerning the distance between the end point of the root canal preparation and the periodontal tissues. The objective of endodontic treatment is to disinfect and fill the root canal system, to prevent further infection and inflammation of the periapical tissues. Extrusion and presence of core filling material beyond the canal is a potential

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Figure 2. Shaping according to the Scandinavian school. Apical filling is performed by the compaction of dentine chips in the bottom of the canal.

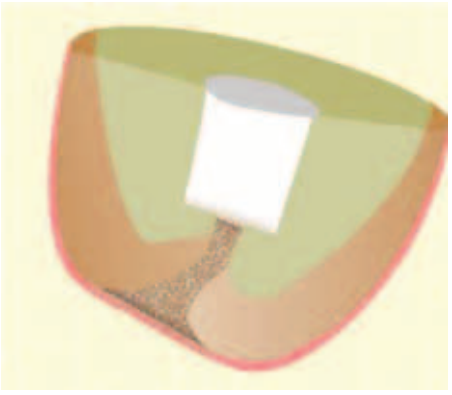

Figure 3. In case of an infected canal, a calcium hydroxide medication must be placed for two to three weeks in order to disinfect the non-instrumented portion.

Figure 4. Type of filling obtained after performing an apical box.

Figure 5. Endodontic treatment according to the North American school of thought.

irritant and is seen as a major contributor to failure by some, whereas for others it remains an indication of canal patency up to the foramen.

To date, the advantage of one approach over the other cannot be clearly demonstrated by an objective analysis of the literature. Rather, differences represent conflicting opinions concerning the apical limit of preparation and overall differences in concepts.

The Scandinavian and North American conceptions of endodontics

At its most basic level, the controversy may be considered to originate from two schools of thought: Scandinavian and North American. The Scandinavian concept of preparation is to leave it 'short' with the shaping stopping one or two millimetres from the radiographic apex. The shaping is performed by instrumentation of the canal until the formation of an 'apical box' with an apical diameter ranging from 0.35–0.80 mm (Figure 2). The preparation allows an irrigation needle to penetrate deeply in order to deliver and renew irrigating solution in the apical third of the canal. In the case of an infected tooth, an intra-appointment medicament (calcium hydroxide) is placed in the canal for one to four weeks (Figures 3 and 4); this material has a high pH, and its properties allow disinfection of the last few millimetres that have not been instrumented or irrigated.

This therapeutic approach appears more biological than the North American approach. An interesting concept is the creation of an apical plug (of dentine chips), which is thought to create an apical biological barrier. However, technical difficulties limit this type of shaping. A #80 file is stiff (even in NiTi), and prevents the clinician maintaining the original curvature of the canal; transportation, ledges or elbows can then occur.

The North American concept teaches shaping of the canal to the 'radiographic apex terminus'. According to Schilder's concepts[1,2] the apex, as seen on the film, is the only reliable reference point for the clinician, and the filling must reach this landmark. A detailed histological analysis of the apical area clearly shows that, if the filling reaches this point, there will always be some filling material beyond the root canal system. However, this slight overextension of sealer must be considered as part of an overall concept, where the shaping must be tapered, and the apical foramen kept as small as is practical (ideally 0.20–0.25 mm) (Figure 5).

A number of publications describe problems occurring from the presence of filling material in the periapical tissues, such as irritation and lack of biocompatibility.[3] Although the biocompatibility of the materials has not been clearly proven, they are not responsible for failure,[4,5] as the studies relating a failure to overfilling also demonstrate overinstrumentation, and it is likely that these failures are more related to problems of overenlargement of the apical foramen as opposed to the presence of excess material itself.[3,6]

These two schools of thought suggest a different approach to endodontics. The success rates published by the advocates of each technique are based on the totality of the concept, not a combination of both. Of course, the two concepts may be combined by shaping a canal with a small foramen and a regular conical shape and, at the same time, stopping the preparation two millimetres short of the radiographic apex. This would allow one to take advantage of

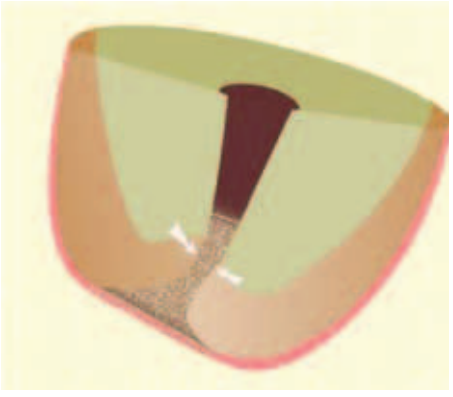

Figure 6. In the American concept, shaping stops 0.5 mm before the foramen.

Figure 7. A patency file is worked beyond the foramen to make sure that the canal has been cleared, and to allow the irrigating solution to flow into this non-instrumented area.

Figure 8. When the canal is prepared according to the American school, the sealer's puff is unavoidable.

the biological approach, and at the same time reduce the problems related to the instrument's stiffness. However, such an approach would be at variance with the original concepts and the outcome may be compromised as the canal preparation is comparatively underinstrumented in either length or width.

It is not possible to determine if either concept is superior to the other. Each operator will strive to justify his/her approach, but may be unable to prove that the other leads to less success in the long term. A compromise seems to be accepted by most practitioners, one in which the foramen is located at 'canal length' (L) the 'working length' will be L – 0.5 mm (Figure 6). The patency of the canal is checked frequently with small files (06, 08, 10), in order to allow disinfection of the non-instrumented area, and ensure that canal patency is maintained (Figure 7). The canal is prepared to the working length, apical patency is ensured by passing an 06/08 file to the canal length. If patency is maintained throughout the entire procedure, pressure induced by the filling techniques will force cement and gutta-percha to flow into recesses of the canal (including accessory canals) but, at the same time, it will induce a protrusion of sealer into the periapical tissues, thus forming puffs (Figure 8). By working this way, Schilder's principles are respected and shaping is performed exclusively in the intra-radicular portion of the canal, with only small patency files extruding beyond the terminus of the canal (patent to the radiographic terminus shape inside). Whichever technique is used, the limit of the canal must be determined prior to selecting the desired working length for the files used to shape the apical portion.

The apical anatomy

Kuttler's observation and description of the apical area has led to a precise description of the anatomical and histological structures forming the apical few millimetres of a root.[7] This paper clearly described the following areas (Figure 9):

- Dentinocemental junction;
- Anatomical apex (vertex of the tooth);
- Foramen;
- Apical constriction.

One should add the radiographic apex, as it is the only feature that can be determined clinically.

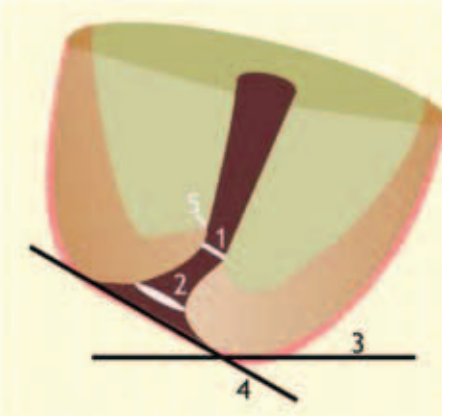

Figure 9. Anatomical and histological apical structures by Y Kuttler. 1. Apical constriction. 2. Foramen. 3. Radiographic apex (area that is projected on the film if the picture is taken with a beam aiming device. 4. Anatomical apex of the tooth. 5. Dentinocemental junction.

Dentinocemental junction

This is considered by a majority of schools as the ideal end point for the preparation, being considered as the transition from endodontium to periodontium (presence of cementum). This junction is strictly histological and is impossible to locate clinically.

Anatomical apex

This is the 'end' point of the root; the vertex of the tooth.

Foramen

This is the the porthole of exit on the root surface. Often considered as being at the centre of the apex, numerous studies clearly show that the foramen is generally not in the centre and may even be situated on the lateral side of the root (Figure 10).

Apical constriction

This is the naturally narrowest area of the canal located in its last few millimetres. Some clinicians assume that the periodontium starts here, and consider any instrument or filling material beyond this point as overinstrumentation/overfilling. For others, the transition to the periodontium is at the level of the foramen. They regard the last few millimetres or tenths of millimetres covered with cementum as a part of the canal which has to be disinfected and filled. For those clinicians, overinstrumentation/

a b

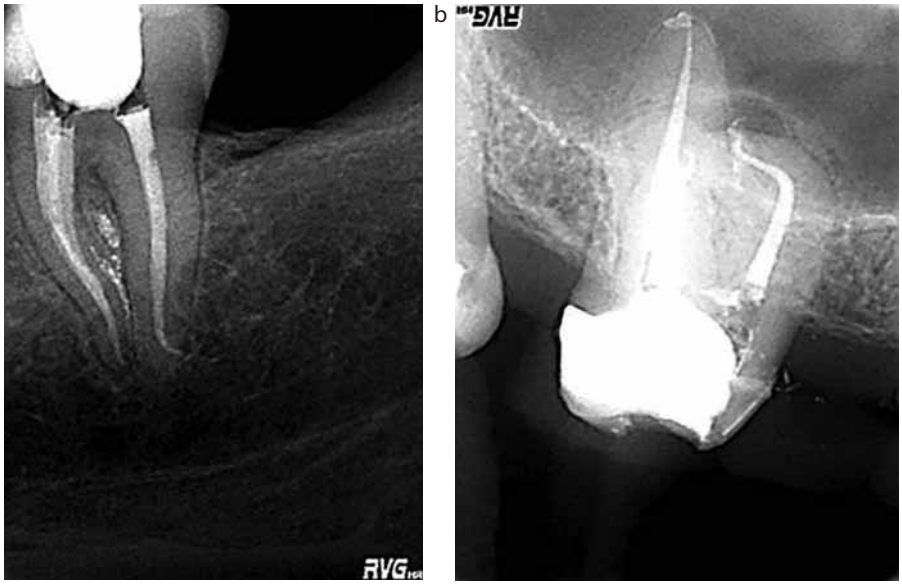

Figure 10. (a, b) The foramen is not always at the centre of the radiographic apex, but may be laterally displaced.

Figure 11. The Root ZX new model.

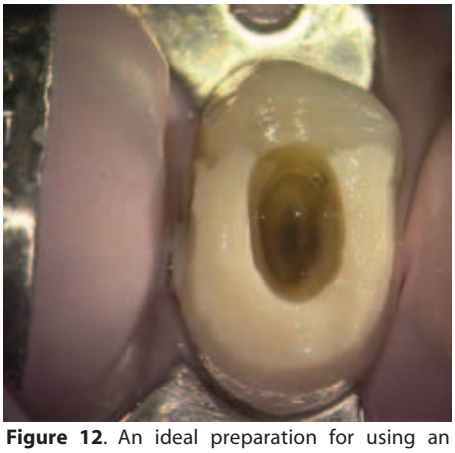

Figure 12. An ideal preparation for using an electronic apex locator; the metallic filling has been removed, and the tooth filled with a non-conductive material. The operative field is dry. Any shunting of the current is thus avoided.

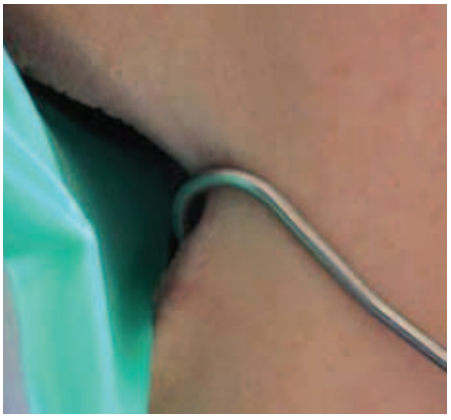

Figure 13. The labial clip is placed on the corner of the patient's mouth, under the rubber dam.

overfilling starts beyond the anatomical apex.

The apical constriction is an interesting anatomical element because, as Inoue states, it has an electronic specificity, ie resistance, of 650 ohms. This specificity was used in the first generation of electronic apex locators.

For a long time, the apical constriction and dentinocemental junction were viewed as a single area, and located at an average of 1 mm from the root apex. These estimations have led clinicians to teach that the working length is 1 mm from the radiographic apex. The preparation was thus considered, on a statistical basis, as being in the region of the dentinocemental junction.

Numerous studies of this complex area of the root show that this technique is no longer reliable, for three main reasons:

- The dentinocemental junction is very rarely located at the apical constriction.
- The thickness of the cementum varies greatly from one tooth to another and between patients.
- The thickness of the cementum changes with physiology (increases with ageing) and pathology (apical resorption related to canal infection).

The technique of determining the working length from a single radiograph remains empirical, and apex locators should be considered an essential aid in establishing working length.

The electronic apex locators

Clinical use

All electronic apex locators on the market are 4th (RootZX®, Morita, France) (Figure 11) or 5th generation (Raypex 5®, VDW, Allemagne), Apex Pointer+® (Micro mega, France), Propex II® (Dentsply Maillefer, France), Novapex® (VDW, Munich).

They are simple to use, but several precautions must be taken to ensure accuracy and reproducibility.

- Remove any metallic parts from the crown of the tooth (amalgam, crown, etc) that could shunt the current, and isolate the tooth with a dry operating field (Figure 12).
- Assess the root length by superimposing a file on the pre-operative radiograph taken using a paralleling technique.
- Prepare the access cavity, relocate the canal openings, and clear the content from the pulp chamber (sodium hypochlorite irrigation).
- Place the lip hook under the rubber dam, making sure the mucous membranes are damp (Figure 13).
- Clip the second electrode of the locator on the hand instrument (Figure 14). Start the device.
- Place the file in the canal and slowly advance toward the apex, using alternating 1/4 turns (watch winding motion).
- Stop advancing when the locator displays '0' (Figure 15).
- Check and confirm the measurement three times.
- Confirm the working length during the procedure using digital or conventional radiography.

Additional precautions:

- In the case of curved roots, it is recommended to check the working length before shaping the apical third. Relocating the canal following the shaping of the coronal 2/3 may change this working length markedly, by up to 1 mm.
- The diameter of the tip of the instrument must be in accordance with that of the canal. The instrument must not 'float' and should be in contact with the walls of the canal.
- Apex locators work in a so-called 'damp' environment; their reliability is increased by leaving a minimal amount of irrigating solution in the canal and the access cavity should be free of irrigant. Avoid any shunting of the current by fluids, gingiva, saliva, etc.
- If, in spite of all these precautions, the determined length differs consistently from the estimation on the pre-operative radiograph, the device should be turned off and the steps followed again.

In the case of repeated wrong readings, the batteries should be checked as low voltage causes electronic errors.

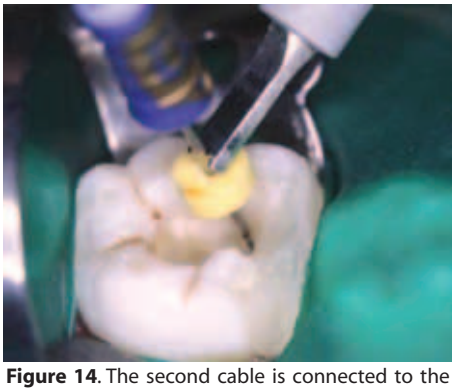

Figure 14. The second cable is connected to the instrument either with a flat contactor or with a claw.

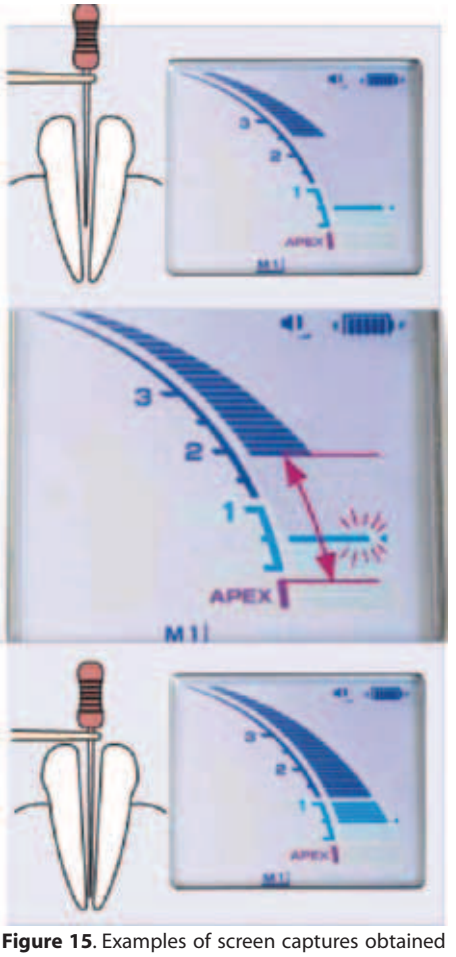

Figure 15. Examples of screen captures obtained while advancing the file in the canal toward the final apical millimetre Dentaport ZX® (Morita).

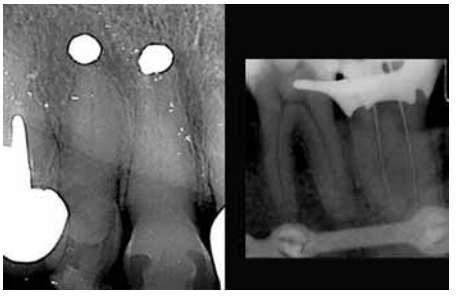

Figure 16. Two cases where the apex locator is unavoidable.

How do apex locators work?[8]

The apical constriction is an interesting anatomical landmark because, as Sunada states 'it has a specific electronic characteristic: a resistance of 650 ohms'.[9] This finding was used to develop the first generation electronic apex locators.

Based on Ohm's law (V = R x I), these devices are generators that deliver a direct current of a known voltage (V), and include an ammeter that measures the intensity (I) of the current after its passage through the file and being recaptured by the labial hook. An electronic component calculates the ratio V/I and deducts the resistance at the level of the canal where the instrument is located. When the resistance is 650 ohms, the screen displays a '0' and the clinician then estimates that the tip of his instrument is at the apical constriction.

Electronic apex locators were a great advance in endodontics, however, there were limits to their use. As they functioned with direct current, any interference, mainly from fluids, led to errors. They have recently progressed, and are now replaced by devices from the 4th and 5th generations. The use of alternating current has allowed the design of an electronic system, including the tooth, supporting tissues, and liquids that may possibly be present in the canal (eg sodium hypochlorite, EDTA, blood). More reliable results are obtained with more complex electronic principles, where factors such as resistance (R), inductance (L) and capacity (C) of the system are taken into account. Two frequencies of current, carefully chosen by each manufacturer, are employed. The impedances Z1 and Z2 of currents with a corresponding frequency of N1 and N2 are permanently calculated by the device. When the two impedances are equal, the device displays a signal on the screen, indicating that the end of the instrument is in the desired region.

Although apex locators work with the same principle, manufacturers do not agree with the area that is detected by their device. Whereas most owner's manuals assure that they detect the apical constriction, Morita (Dentaport ZX®) suggests that their device detects the apical foramen and not the constriction.[10,11] They also advise that the operator should stop advancing the file when the reading shows 0.5 on the screen in order to locate the constriction.

The clinical reliability of contemporary electronic apex locators is excellent. However, we acknowledge that their limits must be recognized. The most reliable value regardless of device is the '0' reading. Most apex locators have a numeric display as the file progresses towards the apex; the operator may be tempted to consider these values as millimetres from the file tip to the desired area, which is not the case. These devices are not root canal length 'calculators', rather they are apical area locators (constriction or foramen) and this feature can be particularly helpful when the apex is superimposed on anatomical structures, thus making it impossible to use a radiograph in order to determine the

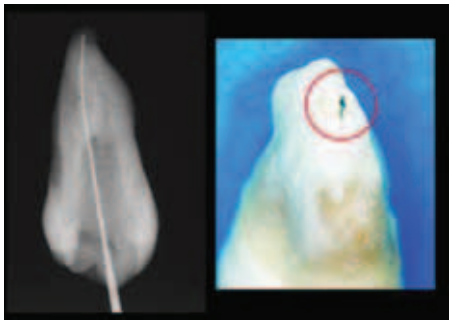

Figure 17. Radiography is an important adjunct to the use of a locator. However, it has been confirmed to be less reliable than an apex locator as the foramen may not end at the radiographic apex.

working length (Figure 16).

The place for radiography

Radiography remains the best choice to determine the working length when an apex locator is not available. The radiographic apex is used as the reference with the working length being deducted.

Digital radiography allows easy and fast determination of the working length with a picture of the file in position. The imaging software programs used with these devices allow modification of colour, contrast and magnification, which can be very helpful in choosing the apical limit. The radiograph is a two-dimensional picture of a three-dimensional object and curvature in the buccal to palatal/lingual plane can remain undetected. Frequently, the file appears to be superimposed on the radiographic apex, whereas it is actually beyond the foramen (Figure 17).

According to the literature, the reliability of apex locators is close to 95%, with the Dentaport ZX® being the most reliable.[12,13,14] In spite of this reliability, it is highly recommended to confirm the working length with a radiograph with an instrument placed in the canal, and/or just before filling with a gutta-percha point in the canal. This check is mandatory if the determined length is doubted, or inconsistent with the estimated length on the preoperative radiograph. A radiograph can also be kept as proof in the patient's record and is an objective element to assist in evaluating the next steps of the treatment as it may demonstrate previously unrecognized curvatures or show a file to be off-centre, thereby suggesting the presence of a previously unidentified canal.

The paper point technique

A third method used for length determination is the paper point measurement technique. This technique is particularly useful towards the end of preparation, or on roots with a very wide canal in which the apex locator can sometimes be unreliable. This method consists of placing a feathered tip paper point in the prepared canal, knowing that the canal has been cleared of all its contents. A minute amount of blood or tissue fluid at the end of the point is an indication that it has been inserted beyond the foramen. Repeated points are used to determine the wet/dry point and the working length can therefore be determined before final refinement of the apical preparation or filling of the canal.

Conclusion

Establishing the working length is an important step in endodontic treatment as inaccurate length determination may lead to failure. The working length, however, is not static, particularly in curved canals as preparation shortens the length from coronal access point to foramen. Neither of the two approaches to endodontic treatment (Scandinavian or North American) has been deliberately favoured in this article. Reliable determination of the constriction or the foramen with an electronic locator allows the clinician to choose working length by deciding on the position of the apical limit for themselves. Almost all the devices now available work on the same principle. The only two differences are ergonomics and 'user friendliness'. The Dentaport ZX® works slightly differently and is the only one to locate the foramen and not the constriction (according to the manufacturer). This is a great advantage because, in the case of apical resorption related to an inflammatory process, the natural constriction of a canal can disappear but the foramen will remain. Manufacturers recommend using 0.5 and constriction.

The reliability of these devices has been proven; the price is moderate and apex locators are now part of the basic armamentarium in the achievement of quality and predictable endodontic treatment.

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