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In Vivo Techniques for Assessing Internal Dental Anatomy: A Comprehensive Review

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ABSTRACT: The primary requirements for the successful treatment outcome are a thorough knowledge of the tooth morphology, careful interpretation of radiographs, proper access preparation and a detailed exploration of the interior of the tooth. We must be able to visualize the internal anatomic relationships of teeth before undertaking endodontic therapy. It is often said that "access is success," which means optimal endodontic results cannot be achieved if access cavity is not properly planned and prepared. Various aids must be utilized to achieve this goal. So the aim of this review is to summarize the various *invivo* aids available to visualize the internal anatomy of the teeth.

KEYWORDS: Cone beam computed tomography, Dental operating microscope, Exploration, Internal anatomy, Magnetic resonance imaging (MRI), Radiography

I. INTRODUCTION

The root canal morphology of teeth is often extremely complex and highly variable. Even the incidence of the various anomalous root anatomy forms within the adult human dentition can be quiet variable. For each tooth in the permanent dentition, there is a wide range of variation reported in the literature with respect to the frequency of occurrence of the number and the shape of the canals in each root, the number of roots, and the incidence of molar root fusion.

The primary requirements for the successful treatment outcome are a thorough knowledge of the tooth morphology, careful interpretation of radiographs, proper access preparation and a detailed exploration of the interior of the tooth. They must be able to visualize the internal anatomic relationships of teeth before undertaking endodontic therapy. It is often said that "access is success," which means optimal endodontic results cannot be achieved if access cavity is not properly planned and prepared. So various aids must be utilized to achieve this goal.

METHODS OF DETERMINING PULPAL ANATOMY

1. Clinical methods

a. Evidence based knowledge
b. Radiography
c. Cone beam computed tomography (CBCT)
d.Exploration
e.Visualization endogram
f.Fiberoptic endoscope
g.Magnetic resonance imaging (MRI)
h.Dental operating microscope

e. *In vitro* methods

a. Clearing and staining
b. Scanning electron microscope (SEM)
c. Sectioning
d.Microcomputed tomography

CLINICAL METHODS

a) Evidence Based Knowledge

Many researchers have conducted extensive studies using various methods to study the internal anatomy of teeth and on this basis their findings have been published. This knowledge of the work done is very

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useful and important as the basic anatomy of the teeth and the frequent variations should be understood by the clinician before starting endodontic procedure.

Coronal, Midroot and Apical Considerations for Determining the Root Canal Anatomy

Coronal considerations

Examination of the pulp chamber floor can reveal clues to the location of orifices and to the type of canal system present. It is important to note that if only one canal is present, it usually is located in the center of the access cavity preparation. If only one orifice is found and it is not in the center of the root, another orifice probably exists, and the clinician should search for it on the opposite side. [1]

The relationship of the two orifices to each other is also significant. The closer they are, the greater the chance the two canals join at some point in the body of the root. As the distance between orifices in a root increases, the greater is the chance the canals will remain separate. The more separation between orifices, the less the degree of canal curvature. [1]

Midroot considerations

As the canal leaves the coronal portion of the root and blends into the midroot portion, many changes can occur, including fins, webs, cul-de-sac, and isthmuses (also called anastomoses).

Another change that often occurs in the midroot portion is the splitting of a single canal into two or more canals, along with a wide variation in canal morphology. Likewise, canals often join in this area, starting as coronally two separate canals. Whenever a root contains two canals that join to form one, the lingual/palatal canal generally is the one with direct access to the apex, although this may require radiographic verification. When one canal separates into two, the division is buccal and palatal/lingual, and the lingual canal generally splits from the main canal at a sharp angle, sometimes nearly a right angle. [1]

Apical considerations

Kuttler"s description of the anatomy of the root apex has the root canal tapering from the canal orifice to the apical constriction, which generally is 0.5 to 1.5 mm coronal to the apical foramen. The apical constriction generally is considered the part of the root canal with the smallest diameter; it also is the reference point clinicians use most often as the apical termination for enlarging, shaping, cleaning, disinfecting, and filling. Violation of this area with instruments or filling materials is not recommended for long-term, successful outcomes. [2]

The morphology of the apical third of the root reflects multiple anatomic variations, including numerous accessory canals; areas of resorption; attached, embedded, and free pulp stones; varying amounts of reparative dentin; and varying root canal diameters.

b) Endodontic Radiography

Radiographs are the "eyes" of the dentists when performing many procedures. In 1895, Wilhelm Konard Roentgen discovered the cathode rays, which have contributed greatly to improve the dental health. Radiography is one of the most common methods of analyzing the pulp space by a clinician, but one must remember that this is only a two-dimensional image of a 3D object hence the clinician should analyze the pulp space, three-dimensionally, and this comes through experience. [3]

In endodontics, radiographs have several essential functions:

1. Aid in diagnosis of hard tissue alterations of the teeth and periradicular structures.
2. Determine the number, location, shape, size, and direction of roots and root canals.
3. Estimate and confirm the length of canals.
4. Localize hard-to-find, or disclose unsuspected, pulp canals by examining the position of an instrument within the root.
5. Aid in locating a pulp space markedly calcified and/or receded.
6. Determine the relative position of structures in the facial–lingual dimension.
7. Confirm the position and adaptation of master cones.
8. Aid in the evaluation of obturation.

Two basic type of X-ray machines are used in the dental office. One has a range of kilo voltage with 2 milliampere settings with which the long 16 inch cone is frequently used. The other type offers only one kilo voltage and milliampere setting and only the short 8 inch cone.

Overlying canals may be separated using the "Clark rule" or the "SLOB" rule - it states that the object that moves in the same direction as the cone is located toward the lingual and the object that moves

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in the opposite direction of the cone lies in the buccal side. When extra canal is suspected, radiograph should be taken in mesial or distal 15° angulations. When a radiograph shows that the canal suddenly stops in the radicular region the assumption is that it has bifurcated or trifurcated into much finer diameters. To confirm this, a second radiograph is taken from a mesial angulation of 10-30°. In the radiograph, lateral radiolucency might suggest the presence of lateral canals. Knob like image may indicate apex that curves toward or away from the beam of the X-ray machine. Multiple vertical lines indicate the possibility of a thin root. [4,5]

Limitations of radiographs

Radiographs are two-dimensional shadows on a single film. They are suggestive only and are not the single final evidence in judging a clinical problem. There must be correlation with other subjective and objective findings. The greatest fault with the radiograph relates to its physical state. As with any shadow, these dimensions are easily distorted through improper technique, anatomic limitations, or processing errors. [5]

c) Cone Beam Computed Tomography

The wide acceptance of the 3D imaging technique in the dental community started with the development of the cone beam computed tomography (CBCT) during the 1990s. This technology became so user-friendly that it was rapidly spread worldwide. CBCT scans offer increased accuracy for the identification of root canals and their location, prior to endodontic therapy. When compared with 2-dimensional digital radiographs, CBCT enables clinicians to identify more canals in multicanal teeth that can then be instrumented and obturated, thereby increasing the likelihood of a successful outcome. [6]

A CBCT scan may only be considered after a comprehensive clinical examination has been carried out, and appropriate conventional radiographs have been taken and assessed. As with any device emitting ionizing radiation, the benefits of the CBCT scan must outweigh the risks. This is particularly important in children and adolescents who are more radiosensitive to the potential effects of ionizing radiation. The ALARA principle ("as low as reasonable achievable") has to be considered in all cases. A request for a CBCT scan should only be considered if the additional information from reconstructed three-dimensional images will potentially aid formulating a diagnosis and/or enhance the management of a tooth with an endodontic problem(s). [7]

Radiation dose varies but can be comparable to that of a panoramic dental x-ray and much less than that of a medical CT scan. Smaller FOV, fewer projections, and a bigger voxel size can limit the dose. Number of projections may not affect image quality, but FOV and number of projections may significantly affect root canal visibility. In addition, using a big voxel size to acquire an image, then reconstructing it at smaller voxel sizes can reduce radiation dose but obtain an image of similar quality. [8]

Advantages:

- Provides accurate cross-sectional information.
- Short scanning time.
- No superimposed tomographic blurring.
- Multiplanar views and 3D reconstruction possible.
- Uniform magnification

Disadvantages:

- Imaging of entire jaw rather than site of interest in the majority of scanners.
- Relatively expensive.
- Metal restorations, metal posts and root fillings and to some extent adjacent dental implants typically cause artefacts to the reconstructed images .The potentially deleterious impact this may have on reconstructed images should be considered before considering a CBCT scan.
- The scan time of CBCT devices can be as long as 20 s and is therefore significantly longer compared with that of an intra-oral radiograph. Therefore, even the slightest movement of a patient during the scan may render the resulting reconstructed images of minimal diagnostic use. Therefore, this may be a problem with children, elderly patients and those with neurological disturbances, for example Parkinson"s disease. The spatial resolution of even the smallest voxel size may be too low to identify small objects, such as fractured instruments, or diagnostically challenging problems, for example incomplete vertical root fractures. [9]

Assessment of root canal anatomy with CBCT

Anatomical variations exist with each type of tooth.

The two dimensional nature of radiographs means that they do not consistently reveal the actual number of canals present in teeth. This may potentially lead to the inability to identify all the roots present, potentially resulting in incomplete disinfection of the root canal system, which may ultimately lead to a poorer outcome of root canal treatment.

d) Exploration

During pulp space preparation, it is very important to at least have the basic knowledge of pulp space anatomy. Exploration is one useful method for analyzing the anatomy in the hands of an experienced clinician. Once the pulpal floor is reached dark lines connecting the orifices and the grooves can be seen and it is called the "dental map". Careful exploration of these grooves helps in identifying the orifices easily.

e) Visualization Endogram

Visualizing endogram is a technique that utilizes a intracanal irrigant that has been formulated to provide a breakthrough in clinical endodontic treatment called Ruddle‟s solution. It consists of 17% EDTA, 5% sodium hypochlorite and Hypaque which is an aqueous solution of iodized salts, viz. ditrizoate and sodium iodide .
Mechanism of action
Hypaque was used to visualize root canal system anatomy because it is water soluble and radiopaque contrast solution. Sodium hypochlorite acts as a solvent. Hypaque acts as a radiopaque medium, and it is as radiopaque as gutta percha. The improved penetration of Ruddles solution is due to EDTA. After the access cavity preparation, the Ruddle‟s solution should be injected passively into the root canal system as shown in figure 17. The sodium hypochlorite dissolves the pulp and eliminates the bacteria and other irritants within the root canal system. The iodine portion of the Ruddle‟s solution flows into the vacated spaces which are cleared by the solvent action of the solution. [3]
After injecting the solution a radiograph should be taken. The solvent action of sodium hypochlorite clears the contents of root canal system and thus the it can flow into everynook and corner of the canal system such as fracture, missed canals and defective restoration. So Ruddles solution can be helpful for improving diagnostic accuracy, treatment planning, management of procedural accidents.

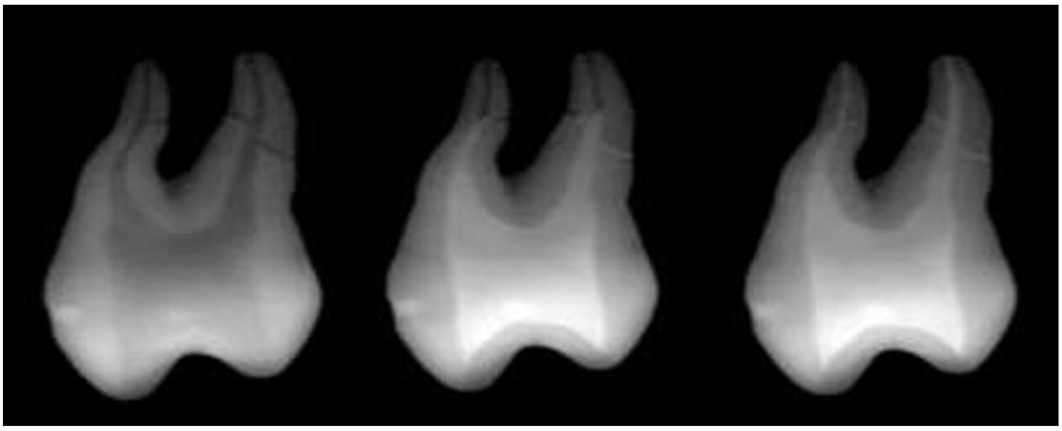

Figure 17: Radiograph after injecting Ruddle's solution. [3]

f) Fiberoptic Endoscope

It is a new method of magnified intra - canal visualization using fibro-optic endoscope (orascope) or rod lens endoscope. The option of a printer or a digital recorder can be added to the system for documentation of the procedure. Fiberoptics are transparent fibers made up of glass or plastics and therefore are small, light in weight, and very flexible.
Orascopic endodontics is the use of orascopy for visualization in conventional or surgical endodontic treatment. A 0.8 mm lens diameter, 0°, 15 mm in length, 10 K fiber optic orascope and a 4 mm lens diameter, 30°, 4 cm rod-lens in length endoscope are used for visualization in conventional endodontics. The 2.7 mm lens diameter, 70°, 3 cm long rod-lens endoscope is used for visualization in surgical endodontics. Each probe consists of a flexible fiber optic bundle with fibers that emit light generated by the metal halide light source and others that transmit the image. The digital signal processing unit filters the image to produce an enhanced, consistent image. Storage and retrieval of images can be accomplished

with connection to the clinical chair side workstation. Infection control is provided by placing disposable, optical-grade, plastic sheaths over the distal end of the probe. [3]

The difference between an endoscope and orascope is that an orascope is made of fibre optics, where as an endoscope is made up of glass rods. The use of the 0.7 mm fiberoptic probe in conventional endodontic treatment allows the clinician to easily visualize canal morphology and determine how well a canal is prepared iodide.

In addition this probe can help identify fractures, accessory canals, remnant pulpal tissue, and the location of broken instruments. Such intracanal visualization is made possible because the 0.7 mm probe has a uniform diameter (not tapered), a flexible 30-degree tip, and lenses that allow for a depth of field from 1 mm to infinity. The clinician must adequately prepare and dry the canal before probe insertion. If the canal has been under instrumented, a wedging of the probe may damage some of the fiberoptic bundles within the probe. The canal should be dry because sodium hypochlorite has a high refractory index and will reflect the fiberoptic light. Also the fiberoptic probe will not visualize properly in a canal filled with blood or exudate. Even though the 0.7 mm probe can visualize within canals, the probe must be withdrawn to the orifice of most canals in order to observe instrumentation within the canal. Also the difference in temperature between the operatory and the mouth can cause condensation on the probe lens. Placing an antifogging solution on the lens can prevent this condensation. [11]

g) Magnetic Resonance Imaging:

Its a non-destructive method, which does not use ionizing radiation. Computer processing of the data from the MRI permits creation of two and three-dimensional (3D) reconstructions. The spatial reconstruction of an individual canal configuration would be of great enlightenment for endodontic treatment. Since teeth are MR-invisible, the basic principle of this technique is that the teeth and jaw can be observed indirectly through contrast with a surrounding MR-visible medium. For this purpose, the oral cavity is filled with a nontoxic substance, such as water or MR contrast media, which gives a high MR signal. [12]

Compared to CT, MRI is superior for imaging soft-tissue structures, but for the detection of osseous structures, CT- or CBCT-scans are usually performed. MRI can be performed by using T1- and T2-weighted imaging techniques, as well as for imaging different structures or processes by the administration of contrast enhancing substances. [12]

More recently newer tomographs with a magnetic field strength of 3T (3T) have become available. In contrast with computed tomographic imaging, dental MRI can give insight into chemical, vascular, and edematous properties of a lesion; soft tissue processes like inflammations could be accurately visualized. Enamel and dentin usually appear black because of the lack of unbound protons; on the contrary, the dental pulp chamber, which contains nerves, blood vessels, and connective tissue, appears white or gray. Surrounding structures were well visualized; cortical bone can be identified as a black zone outlined by a moderate signal from external soft tissues. The root of a nonvital tooth produces a different signal when compared with a vital one. The signal is attenuated or absent because of the presence of necrotic tissues that are not more perfused or the presence of root canal obturation. The monitoring of the internal and external root canal morphology is very important for planning a successful endodontic treatment. Many studies attempted to reconstruct the internal and external morphology of human extracted and endodontically treated teeth using MRI.[13]

h) Dental operating microscope

The Operating Microscope emerges as a tool that offers many benefits such as better lighting, magnification and visualization of the operative field. The high magnification helps coronary access and the location of channels to identify isthmuses, to interpret the complexities of root canal system anatomy, the removal of fractured instruments, to minimize trauma of surgeries in soft and hard tissues, and detect fractures and microfractures. In addition, their use gives the dental surgeon a working position more comfortable and ergonomic, reducing fatigue and stress, and consequently, increasing work efficiency.[14]

CONCLUSION

The pulp space is complex; root canals may divide and rejoin, and possess forms that are considerably more involved than commonly implied. Many roots have additional canals and a variety of canal configurations. So a thorough knowledge of both root and root canal morphology is a fundamental prerequisite for successful root canal treatment. This knowledge includes pre- and intra-operative awareness of landmarks associated with normal morphology as well as any aberrant anatomy of the root and root canal system encountered in daily practice. A good understanding of the external and internal anatomical features of the root would minimize the number of missed roots and root canals during treatment, thus increasing the rate of clinical success.

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