Endodontic Radiology

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Radiology is an indispensable tool in the clinical practice of endodontics because most structures harboring disease are not visible to the naked eye. As a result, radiographs are needed during several aspects of the treatment and their proper interpretation and analysis is crucial to the establishment of a favorable outcome.

Standard two dimensional radiographs used for the management of endodontic problems yield limited information because the images produced often are accompanied by geometric distortion and anatomical noise. Goldman[2], in his classic paper, mentioned that radiographs are not so much read as interpreted and that this process can be ambiguous and inconsistent. Dentists are always asking: is there an area of radiolucency? How large is the area? Where is the apex of the tooth?

In endodontics, radiographs are essential in diagnosis, treatment planning, treatment procedures, prognosis, follow up, legal documentation, and education. In this article, the art of interpreting everyday radiographs will be explained in detail.

Diagnosis:

Radiographs are an important if not the most important tool available to the clinician and helps in identifying the problem, the tooth and in developing the treatment plan. At least one current preoperative radiograph taken using the paralleling technique is mandatory in identifying the presence and nature of pathosis.

Some common rules are important to follow when radiographs are used to assess diagnosis: If the tooth in question is fully mature and vital and your diagnostic testing reveals an irreversible pulpitis, no significant changes may be apparent on the radiograph. Teeth with necrotic pulps do not routinely have rarefactions associated with their roots and apical rarefactions of pulpal origin will routinely demonstrate the loss of the apical lamina dura in association with the rarefaction[3].

From the clinical point of view, it is important to remember that necrosis can sometimes be seen with naked eye, in other words, when a crown that we “see” is discolored, it may be an indication of pulpal necrosis; or when we “see “a sinus track on the gingiva, it may indicate

the presence of infection originating from a necrotic pulp. By the same standard, an apical rarefaction that we “see” radiographically may indicate necrosis. While patients demonstrating the clinical signs of irreversible pulpitis may not show demonstrable radiographic changes, the radiograph does have the potential to show etiological contributing factors, such as caries or a deep restoration. Establishing a diagnosis in cases such as this can at times be more challenging.

Radiographs are also helpful in assessing and in explaining to the patient the risks and benefits of the proposed treatment.

The preoperative (or diagnostic) radiograph should also be used to assess the root canal anatomy and “the difficulty of the case” should be evaluated. A supplemental bitewing radiograph is useful to detect caries, to determine the depth of a calcified pulp chamber or to reveal a pulp chamber obscured by a by a large radiopaque restoration. A second periapical radiograph taken at a different horizontal projection is also helpful in determining the number and shape of the roots when multirooted teeth are involved.

When a sinus track or fistula is present, it can sometimes be traced back to an area of pathosis. This is accomplished by threading a new gutta-percha cone (size 30 or 40) through the track and exposing a periapical radiograph. Generally, it is not necessary to anaesthetize during this step. If the sinus track cannot be penetrated with a gutta-percha point, it may be necessary to reopen it with an explorer tip or periodontal probe and then introduce a new cone.

The clinician must realize that periradicular pathosis and/ or bone destruction may be present, but not radiographically visible. Radiographic bone loss is not evident until there is significant erosion of the cortical plate[4].

Clinicians must be trained to radiographically identify normal anatomical landmarks as well as anatomical variations that can mimic pathosis and to be aware that considerable distortion of radiographic images can occur when irradiation geometry is not ideal[5-8].

As previously stated, it may be necessary to take more than one radiograph in order to obtain maximum diagnostic information. It is best to have one normal, standard (direct) one standard radiographic projection, so that the central ray strikes the receptor at a right angle and the other with an altered horizontal angulation that produces a shift in overlapping structures when the image is “read”. In endodontics such changes in angulation are useful to:

• determine the number, location, shape, size and direction of curvature of roots and canals;

• identify superimposed roots and canals;

• establish the position and degree of root curvatures;

• identify the position of root apices in relation to anatomical landmarks;

• distinguish between anatomical structures and radiolucent apical pathology;

• establish the position of iatrogenic errors (perforations, fractured instruments etc.);

• distinguish between internal and external root resorption;

• locate foreign bodies following trauma;

• establish the position of root fractures or apical resorption9

Limitations of conventional and digital radiography for endodontic diagnosis[10]

Conventional images yield limited information for several reasons. These include:

- *Loss of three-dimensional anatomy:* Conventional images compress three-dimensional anatomy into a two-dimensional image or shadowgraph, greatly limiting diagnostic performance11. Important features of the tooth and its surrounding tissues are visualized in the mesio-distal (proximal) direction only. Similar features presenting in the bucco-lingual plane (i.e. the third dimension) may not be fully appreciated.

- *Missing third dimension:* The spatial relationship of the root(s) to their surrounding anatomical structures and associated periradicular lesions cannot always be truly assessed with conventional radiographs. In addition, the location, nature and shape of structures within the root under investigation (for example, root resorption) may be difficult to assess[12]. Diagnostic information in this missing 'third dimension' is of particular relevance in surgical planning, where the angulation of the root to the cortical plate, the thickness of the cortical plate and the relationship of the root to key adjacent anatomical structures such as the inferior alveolar nerve, mental foramen or maxillary sinus should be understood[13].

On occasion, deliberate and controlled alteration of the radiation geometry can be beneficial and provide additional information not always visible on receptors taken with standard angulations (Application of the buccal object rule). For example:

> *Separation of anatomical features and periapical radiolucencies:* Changing the horizontal angulation alters the relationship of anatomical landmarks and root apices. This effect can be used to dissociate the incisive foramen and mental foramen from adjacent tooth apices[9]. Increasing the vertical angulation also alters the vertical relationship of anatomical landmarks and root apices. This effect can be used to determine whether anatomical landmarks lay buccally or lingually, an assessment which has benefit during endodontic surgery[9]

Distinguishing of lingual roots and apical pathology: Changes in the vertical angulation are useful in many aspects of endodontics because it allows for more accurate visualization of lingual roots and their apices. However, it must be appreciated that increases in vertical angulation will lead to a shortening in the length of tooth images, with buccal roots appearing shorter than lingual roots in multirooted teeth and buccal cusps looking longer than lingual cusps in the teeth with multiple cusps because they are further from the receptor[9].

Treatment:

Radiograph for verification of the working length:

Working radiographs are taken with the rubber dam in place. The desired working length for the biomechanical preparation and resultant obturation of the root canal system is one of the most important phases of endodontic therapy[14]. Although, electronic apex locators (EAL) are very accurate in determining the working length, it is recommended that a working length periapical radiograph be taken to verify this measurement and to confirm the tooth anatomy. This radiograph, taken with a small file placed in the canal, will be the first indicator of the real anatomy of the root. The presence of sharp or double curvatures needs to be taken into consideration when the method of root canal enlargement is chosen.

The technique used to take this radiograph is as follows: After measuring the pre-operative radiograph to estimate the length of the canal, and confirming this length with an EAL, a file is selected, carried to the estimated working length, and a periapical radiograph is taken with the file in place. A file smaller than #15 is not recommended because it will not be visible in the radiograph. This radiograph will show the relationship between the file and the apex of the tooth. If the file is seen trespassing the apex by more than two millimeters, a new radiograph with an adjusted measurement should be taken before proceeding with canal enlargement.

An angulated radiograph can be taken if more than one canal per root is suspected (Clark technique). When treating teeth with buccal and lingual canals, application of the Buccal Object Rule is essential to properly determine the correct working length of all canals.

The beam angulation will affect the appearance of the image of the rubber dam clamp on the radiograph. The lingual arm of the rubber dam clamp that it is closer to the film (or receptor) will always appear closer to the apex and it will move in the same direction as the central ray.

In cases where the roots of mandibular molars are short, superimposition of the clamp can interfere with the image of the roots. In these cases, an angulated radiograph is recommended. A more negative vertical angulation will elongate the radiographic appearance of the roots helping to provide an unobstructed view.

Inserting the receptor with the rubber dam in place and the files in the canals is not an easy task. Specially designed holders are available for this purpose. In some cases, hemostat pliers can be used to properly place the receptor.

The decision of when to take the working length radiograph may vary and it is dependent upon factors such as: root canal diagnosis (vital vs. necrotic pulp), the degree of the root development, and the technique selected for root canal instrumentation (crown down or step back).

It is recommended that measurements of the working length be taken after the coronal third of the root canal is enlarged, so that files used in apical preparation have better straight line access to the apex, and so that the working length measurement remains constant in the future. In addition, if cusps are going to be reduced, this should be done before the working length determination radiograph is taken.

Once the radiograph is taken, it is important to analyze the following two aspects:

1) Is the real length (RL) the same that the estimate length (EL)? (RL=EL) or

2) Is real length greater or less than the estimate length? (RL> or< than EL)

Some modification in the beam angulation during radiographic acquisition can be used to enhance the information obtained from the radiograph during treatment. On many occasions, and particularly when using the bisecting angle technique, superimposition of the zygomatic process of the maxilla over the root apices of molar teeth occurs, resulting in the characteristic arch-like radiopacity which hinders radiographic interpretation. To lessen this imaging difficulty, modification by decreasing the vertical angulation can be considered. In addition when using the bisecting angle technique the vertical orientation of the receptor is dictated by the local anatomy. So in situations where the receptor forms an angle with the long axis of the teeth, most commonly occurring in the palatal arch of the maxilla, placement of a cotton roll so that it lies against the lingual surfaces of the teeth, produces a more desirable parallel orientation between receptor and teeth. This allows the reduction of the vertical angulation, thus giving rise to improved visualization of the roots and surrounding bone decreasing zygomatic superimposition. Alternatively, a film holder that positions the receptor in a parallel orientation to the teeth and guides the x-ray beam (eg. RINN holder) can be used to minimize this anatomical obstruction.

Another alteration that can be done is changing the horizontal angulation, also known as applying “the buccal object rule”[16]. This rule dictates that with an alteration to the horizontal angulation of the beam images of objects furthest from the source will move in the same direction as the beam. Thus, mesial angulation of the beam will appear to move lingual objects (more distant from the beam) to the mesial and buccal objects (more distant from the film) to the distal. Conversely, distal angulation will move the lingual objects to the distal and buccal objects to the mesial.

Modifications in imaging initiated by an alteration in horizontal angulation are extremely useful in endodontics for a number of reasons:

Identification of multiple roots

Roots that are superimposed on a standard radiograph can be visualized when a mesial or distal view is taken. In general, the degree of horizontal angulation change necessary to achieve a clear image will depend on the separation of the roots; the more parallel the roots (closer), the greater the alteration should be, whilst roots with a considerable divergence will require only a modest degree of horizontal angulation modification.

The three roots of a maxillary molar are normally visible on the standard view. However, when fusion of the palatal and either the mesiobuccal or distobuccal root occurs, visualization can be difficult. This problem also occurs when the palatal root is placed mesially or distally, so that superimposition over one or other of the buccal roots is difficult to avoid. Changing the horizontal angulation will separate the root images on the radiograph; a distal angulation will dissociate the mesiobuccal root, while a mesial angulation will dissociate the distobuccal root.

Identification of multiple canals

When canals lie buccally and lingually within the same root, they become superimposed on the standard radiograph. Changing the horizontal angulation separates the canals and allows their identification.

Separation of anatomical features and periapical radiolucencies

Changing the horizontal angulation alters the relationship of anatomical landmarks and root apices. This effect can be used to dissociate the incisive foramen and mental foramen from adjacent tooth apices.

Identification of apical root curvature

Buccal or lingual root curvature is not visible on the standard (direct) view. Increasing the horizontal angulation will allow this common occurrence to be identified, although such images are often poorly defined. Buccal curves move in the opposite direction to the angulation of the beam; a mesial angulation will produce a movement of the image of the root apex towards the distal aspect. Lingual curves will move in the same direction as the beam angulation.

When identification of root curvature is critical, such as when surgery is planned, or when the precise location of canal irregularities or fractured instruments is required, the use of the triangular scanning technique can be beneficial.

The triangular scanning technique[17]

This technique can be used to detect the exact position of root curvatures as well as iatrogenic errors such as ledges, creation of false channels during canal and post space preparation and lateral perforations. The technique involves the exposure of three films, one using the standard angulation and the others using mesial and distal angulations.

Underlying the use of the technique is the fact that visualization of curvatures or defects is impossible when they are superimposed over the canal space; in these circumstances the problem cannot be identified. For example, a file which is caught on a ledge will simply appear short of the apex if the ledge is in the same plane as the canal, because the image of the instrument tip is superimposed over the image of the canal.

To interpret the data available from the three films correctly, it is necessary for each view to draw a diagram with two concentric circles where the outer circle represents the root contour and the inner circle the outline of the canal. Each cross-sectional representation of the root is then divided into quadrants by two lines, one vertical dividing the root into mesial and distal halves, the other horizontal dividing the root into buccal and lingual halves.

Clearly, a mesial angulation will superimpose the mesiobuccal (MB) and distolingual (DL) quadrants, whilst a distal angulation will superimpose the distobuccal (DB) and mesiolingual (ML) quadrants. Data obtained from the three radiographs are transferred to the diagrams to produce a simple representation of the complex three dimensional architecture of the tooth, surrounding bone and associated anatomical landmarks and apical pathology.

Customized periapical technique for third molars[18]

This technique is useful for mandibular third molars when the anatomical features or low patient tolerance preclude normal placement of the film. To overcome these problems, the film is placed at a slight inclination to the tooth with the inferior border gently curved in the direction of the tongue; on occasions, it can also be beneficial if the superior border is folded towards the buccal so that the patient can bite onto the film during exposure. The resultant film provides an image of the whole length of the tooth and surrounding bone.

Two images of the same tooth on one film[19]

In a substantial number of cases, a periapical radiograph is used to visualize only one tooth, with a large area of the film being unnecessary. The technique of Almeida (1953) allows two images of the same tooth, taken at different angulations, to be included on the same film, a technique referred to as dicotomography.

The technique is simple and uses a conventional film which is folded in two with lead foil secured between the two halves. With careful positioning of the (narrower) film and thoughtful beam angulation the first image is exposed, the film is then turned so that the

unexposed side is adjacent to the tooth and a second exposure taken at a different angulation. Following conventional processing, the two images of the same tooth appear side by side on the same film.

Identification of the images can be facilitated by reference to the identification dot on the film; for example, all mesioangular exposures could be taken on the side of the dot.

When this technique is used, it must be appreciated that the effective size of the film is reduced on each exposure, requiring careful film placement and beam angulation. When the beam direction is altered to the mesial or distal, it is wise to move the film a small distance in the opposite direction. To maintain a perpendicular relationship with the beam, a cotton wool roll can be attached to the film. This is placed between the film and the tooth on the mesial side for a mesioangular exposure and on the distal side for distoangular exposure.

The importance of obtaining acceptable quality radiographs was emphasized by Schwartz,' who stated that the sophistication of endodontic treatment closely parallels the sophistication of endodontic radiographic techniques. When radiographs are inaccurate and have to be retaken, endodontic treatment becomes less efficient, and patients are exposed to additional radiation9.

Canal preparation:

Once working length is established, cleaning and shaping of the apical portion can be started. Different systems and techniques are available to clean and shape the root canal system.

Usually no radiographs are needed at this stage. However, if a mishap occurs during this phase, a radiograph is mandatory to diagnose the problem and evaluate the possible outcome of the tooth. The errors that most often occur during canal preparation include: loss of working length (blockage), deviation from normal canal anatomy (ledge, zip, and elbow), and inadequate canal preparation, perforation and/or separation of root canal instrument.

Radiograph for Verification of Master Apical File:

Once the canal preparation has been completed, a radiograph is taken with the Master Apical File (MAF) in place. The MAF is the largest file that achieves the working length. This radiograph is vital to confirm (one more time) that the length of the MAF is to WL and the shapes of the canals are adequately tapered.

Intracanal Medication:

If the root canal will be performed in more than one appointment, the use of intracanal medication is recommended. The most commonly used intracanal dressing is Calcium Hydroxide (Ca(OH)2). Calcium Hydroxide has similar radiopacity to the dentin. Therefore, if a

radiograph is taken with Ca (OH) 2 in place, interpretation of these images needs to be done carefully, because the canal can appear calcified but actually is filled with the temporary filling material.

Cone fit radiograph:

This radiograph is taken by placing the master cone in the prepared canal just before obturation. An accurate cone fit picture assures that the tooth will be properly obturated if the clinician has achieved an ideal tapered preparation. This radiograph should reveal a cone which is not kinked or deformed in any way.

Postoperative radiograph:

Postoperative radiographs should be taken with the same technique as the preoperative radiograph. It should be taken with the access cavity sealed and the rubber dam off. It is used to assess the length density, configuration and the general quality of the obturation in each root canal. This final radiograph will be the one that the clinician uses to assess healing during follow up appointments.

Recall:

The same principles used for diagnostic and postoperative radiographs apply to recall radiographs. The traditional method of assessing the success of endodontic therapy involves clinical examination and the use of recall radiographs taken with the same exposure factors as the immediate post-operative radiograph. At some time following the completion of endodontic therapy, a radiograph of the treated tooth is taken and compared with the radiographs taken at the time of treatment. On the basis of changes in radiographic images of periapical bone, dentists seek to determine from such radiographs whether the tooth is healed, or is still in the healing process or there are signs of persistent infection. The dentist’s decision regarding this success or failure is important because it may determine the subsequent disposition of the case. Additional angled radiographs are often required to assess diagnosis[20].

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