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Periapical radiographic techniques during endodontic diagnosis and treatment

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Summary

The objective of this article is to describe various radiographic projections which can be used during endodontic therapy. Changes to the angulation of the X-ray beam in relation to the teeth and film can help diagnosis and treatment by producing images which provide additional information not always visible on radiographs taken with standard angulations. For example, changes in angulation can be useful to determine the number and curvature of roots and canals, to identify superimposed roots and to distinguish between anatomical landmarks and apical pathology. Although use of such techniques increases the diagnostic yield of films, it must be appreciated that such views lead to images that are less distinct because of inherent image distortion. Nevertheless, use of the various techniques during endodontics can provide substantial benefit for clinicians in their daily practice.

Keywords: **diagnosis, endodontics, horizontal angulation, periapical radiographs, radiation geometry, vertical angulation.**

Introduction

Success of root canal treatment depends on a number of factors but, in particular, diagnosis of the pulp and periapical condition, root canal anatomy, canal preparation and obturation. Use of periapical radiographs before, during and after treatment is essential in order that anatomical details, canal length, quality of obturation and tooth and bone pathology can be identified and monitored. Clearly, clinicians must be trained to identify normal anatomical landmarks as well as variations due to pathology and to be aware that considerable distortion of radiographic images can occur when irradiation geometry is not ideal (Sewerin 1981, Sewerin *et al.* 1987, Jenkins *et al.* 1992, Bishop *et al.* 1995).

Under normal circumstances, the optimal relationship of the beam, tooth and film occurs when the tooth and film are parallel and at right angles to the X-ray beam. This provides an image which is free from distortion (alteration in shape and size) apart from the effect that occurs as a result of the unavoidable increase in circumference of the X-ray beam which can be minimized, but not entirely eliminated, by using a long-cone technique. The routine use of film holders and beam aiming devices will facilitate the creation of accurate radiographs which are free from distortion and it is essential that such films are taken as a routine for diagnosis and during endodontic procedures.

Unfortunately, although free from distortion, images created by the standard angulations can result in superimposition of adjacent anatomical landmarks or pathological features leading to difficulties during interpretation. On occasions, deliberate and controlled alteration of radiation geometry can be beneficial and provide additional information not always visible on films taken with standard angulations. The purpose of this article is to review the various radiographic techniques which can be applied in endodontics and describe how substantial benefits can be gained by clinicians in their daily practice.

Angulation of X-ray beam

The head of a dental X-ray machine can be moved in two planes. When the head is moved about a horizontal axis, the beam can be directed upwards or downwards and thus alter the vertical angulation. This movement can be used to localize an object in relation to a horizontal line as with the buccal or lingual position of the inferior dental canal and the apices of mandibular teeth.

When the head is moved about a vertical axis, the

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beam can be directed mesially or distally and thus alter the horizontal angulation. This movement can be employed to localize objects in relation to a vertical line, as with the superimposed roots of a maxillary premolar tooth where a mesial or distal shift in angulation will reveal both roots.

Clearly, to obtain maximum information it is necessary to expose at least two radiographs of a tooth, one taken at the normal, standard (direct) angle and the other with an altered angulation. In endodontics such changes in angulation can be useful to:

- determine the number, location, shape, size and direction of curvature of roots and canals;
- identify superimposed roots and canals;
- establish the position of root curvatures;
- locate the position of root apices in relation to anatomical landmarks;
- distinguish between anatomical landmarks 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 resorptive processes.

Although having the potential to improve diagnosis, radiographs taken with eccentric beam angulations and altered film placement are inherently less distinct, as the images lose the normal sharpness expected from standard films. However, this is balanced by the increased diagnostic yield that is achieved.

Alteration in vertical angulation

Visualization of lingual roots and apical pathology

Changes in vertical angulation are useful in many aspects of endodontics. However, it must be appreciated that increases in vertical angulation will lead to a shortening in the length of tooth images (Fig. 1a), with buccal roots appearing shorter than lingual roots in multi-rooted teeth because they are further from the film. Thus, more accurate visualization of lingual roots and their apices can be achieved by increasing the vertical angulation. This effect is obvious in Fig. 1b, which shows the result of increased vertical angulation on the image of a maxillary tooth with two roots. The benefit of such a view can also be seen in Fig. 1c, where the shape and size of a periapical lesion on the lingual aspect of a root becomes clearer.

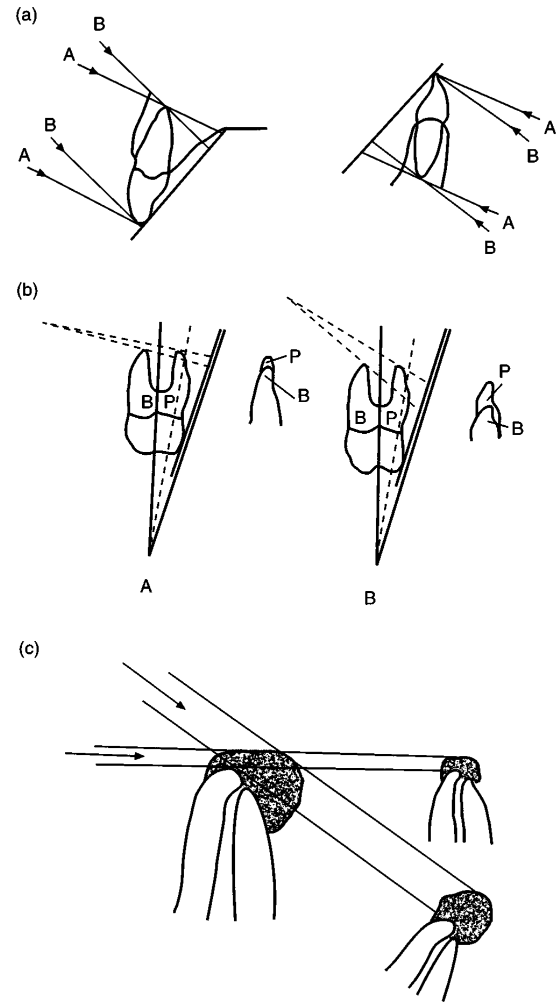

Fig. 1 (a) Diagrams of maxillary and mandibular incisors with periapical films positioned without film holders. On both examples, lines AA represent the standard bisecting angle technique which produces minimal distortion of tooth length on the resultant images. Lines BB represent an increased vertical angulation which produces a shortening of the tooth images (Richards 1980). (b) Diagrams of maxillary molars with periapical films positioned without film holders. The standard bisecting angle technique (A) tends to superimpose images of the buccal and lingual roots making interpretation difficult. Increasing the vertical angulation (B) tends to shorten both roots but the root furthest from the film, the buccal, is shortened more to produce a clearer image of the apices (Rosa & Tavares 1988). (c) Increasing the vertical angulation on a root apex with an endodontic lesion placed lingually will provide a more accurate image of the shape and dimensions of the bone loss (Holland *et al.* 1979).

Distinguishing normal landmarks from apical pathology

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 lie buccally or lingually, an assessment which has benefit during endodontic surgery. Figure 2

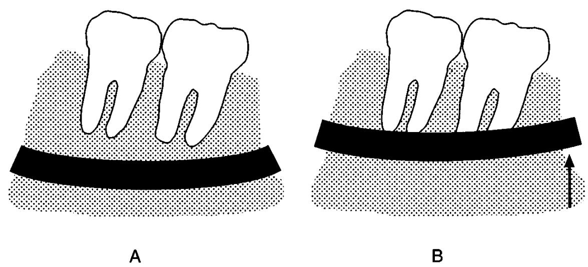

Fig. 2 A standard (direct) view of mandibular molars reveals that the root apices are above the inferior dental canal (A). Increasing the vertical angulation (B) has 'moved' the canal vertically upwards to lie over the apices, confirming that the canal was buccal to the roots (Morse 1974).

represents a standard view of mandibular molars with the root apices above the inferior dental canal (A) and a view taken with increased vertical angulation where the inferior dental canal has 'moved' vertically upwards to lie over the roots (B). This has occurred because the canal was buccal to the roots; if the canal was not superimposed on the roots in the second film taken with increased vertical angulation, then the canal would be lying on the lingual aspect of the roots.

Figure 3 demonstrates the use of increased vertical angulation in order to differentiate anatomical landmarks from periradicular lesions of endodontic origin in other regions of the mouth.

Reducing the effect of the zygomatic process

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 will occur (Fig. 4A), resulting in the characteristic radiopacity which renders interpretation difficult. If a cotton wool roll is attached to the surface of the film so that it lies against the lingual surfaces of the teeth, the desired parallelism between film and teeth is achieved, allowing the vertical angulation to be reduced, so giving rise to improved visualization of the roots and surrounding bone (Fig. 4B). This method is based on a modification of the bisecting angle technique and results in more parallelism between the teeth and film, thus allowing a reduction in vertical angulation which decreases the incidence of superimposition of the zygomatic process (Le Master 1924). Clearly, an alternative would be to use a film holder and beam aiming device.

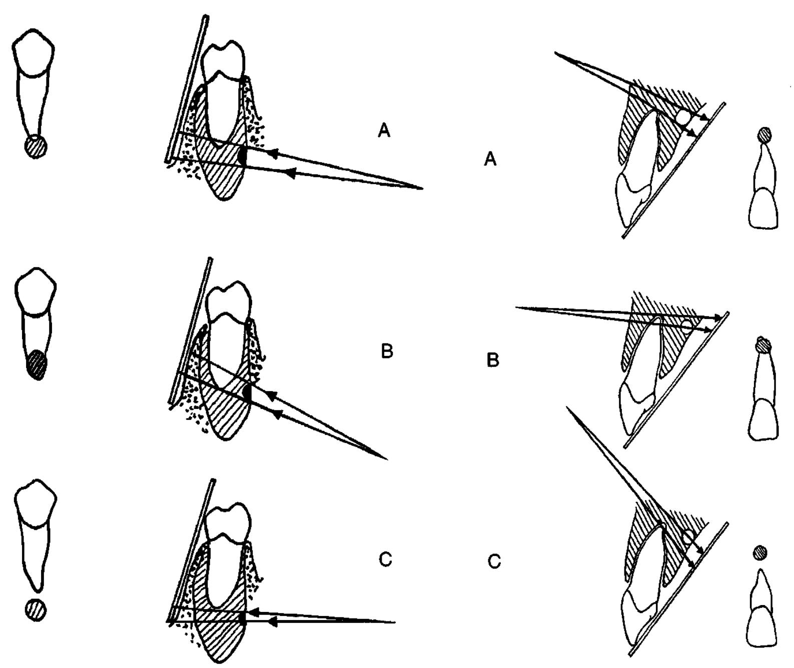

Fig. 3 (a) Diagram of the mandibular premolar region demonstrating the effect of altering the vertical angulation of the X-ray beam. In the standard bisecting angle technique (A), the mental foramen is superimposed over the root apex and could be interpreted as a lesion of endodontic origin. Increasing the vertical angulation moves the image of the foramen coronally (B) whilst reducing the vertical angulation moves the foramen away from the root apex (C). This effect is observed because the foramen is buccal relative to the tooth apex (Rosa & Tavares 1988). (b) Diagram of the maxillary incisor region demonstrating the effect of altering the vertical angulation of the X-ray beam. In the standard bisecting angle technique (A) the incisive foramen is superimposed over the root apex and could be interpreted as a lesion of endodontic origin. Reducing the vertical angulation moves the image of the foramen coronally (B) whilst increasing the vertical angulation moves the foramen away from the root apex (C). This effect is observed because the foramen is lingual relative to the tooth apex (Rosa & Tavares 1988).

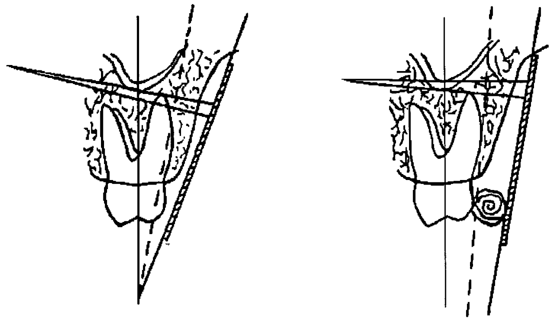

Fig. 4 When exposing films of maxillary molars, the standard bisecting angle technique (A) often produces superimposition of the zygomatic process over root apices. Placing a cotton wool roll on the inferior border of the film produces a more parallel relationship between teeth and film, allowing a reduction in the vertical angulation (B), so decreasing the incidence of superimposition (Rosa & Tavares 1988). Alternatively, a film holder and beam aiming device can be used.

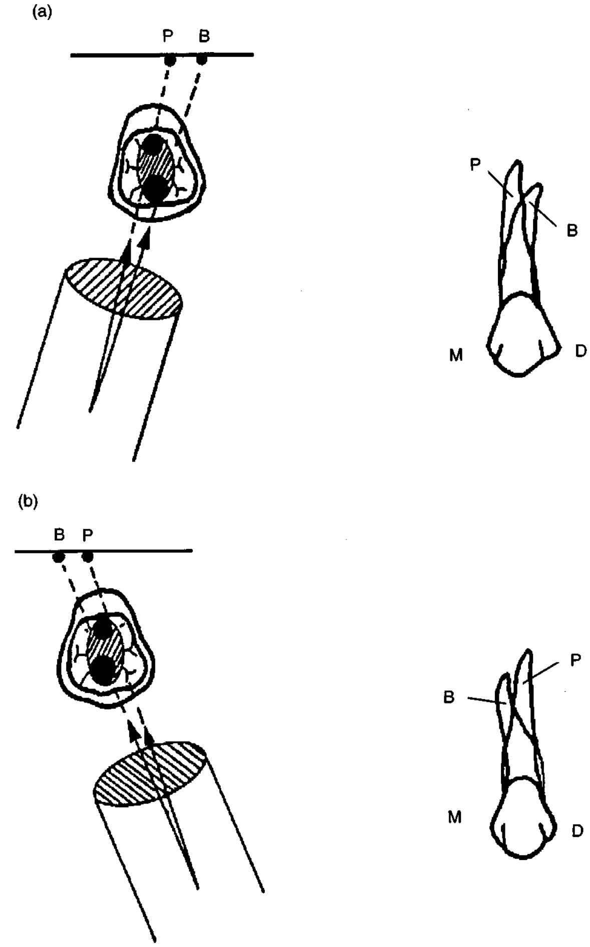

Fig. 5 (a) Diagram of a maxillary premolar demonstrating the effect of altering the horizontal angulation of the X-ray beam. Changing the horizontal angulation of the beam so that it approaches the tooth from a mesial direction will move the palatal root towards the mesial and the buccal towards the distal (Rosa & Tavares 1988). (b) Changing the horizontal angulation of the beam so that it approaches the tooth from a distal direction will move the palatal root towards the distal and the buccal towards the mesial (Rosa & Tavares 1988).

Alteration in horizontal angulation

The buccal object rule (Clark 1916)

This technique is based on alterations to the horizontal angulation of the beam and the fact that objects furthest from the source will move towards the direction of 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 (Fig. 5a). Conversely, distal angulation will move the lingual object to the distal and buccal objects to the mesial (Fig. 5b).

Such alterations 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 (Fig 5a and b). In general, the degree of horizontal angulation 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. Figure 6 is a maxillary premolar with the two roots superimposed on the standard view (Fig. 6A) but separated on the angled view (Fig. 6B).

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. Increasing 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 (Fig. 7).

Identification of multiple canals

When canals lie buccally and lingually within the same root, they become superimposed on the standard radiograph. Increasing the horizontal angulation

Fig. 6 The standard view of this maxillary first premolar (a) produces superimposition of the buccal and lingual roots. A mesioangular view dissociates the two roots and highlights a buccal curve on the buccal root apex (b).

separates the canals and allows their identification (Fig. 8). Figure 9 provides an example of a radiograph of a maxillary left first molar taken from a distal angulation to highlight the two separate canals in the mesiobuccal root.

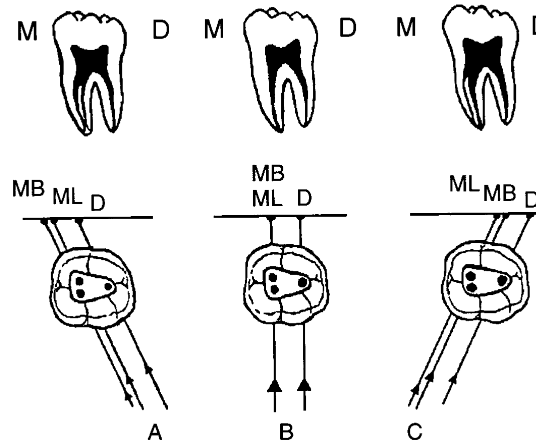

Fig. 8 Diagram of a mandibular left molar demonstrating how to improve the image of the two canals in the mesial root. The standard (direct view) (B) produces an image where the two mesial canals are superimposed. Altering the horizontal angulation will dissociate the mesiobuccal canal (MB) from the mesiolingual canal (ML) (A & C). For a left molar using a distal angulation (A) the canals are seen from left to right in the sequence mesiobuccal (MB), mesiolingual (ML) and distal (D). When using a mesial angulation the sequence is mesiolingual (ML), mesiobuccal (MB) and distal (D). In cases where the distal root contains two canals, a distal angulation (A) will produce an image where the distobuccal canal is left of the distolingual with the reverse being true for a mesial angulation (C) (Rosa & Tavares 1988).

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 (Fig. 10).

Identification of apical root curvature

Buccal or lingual root curvature is not visible on the standard (direct) view. Increasing the horizontal

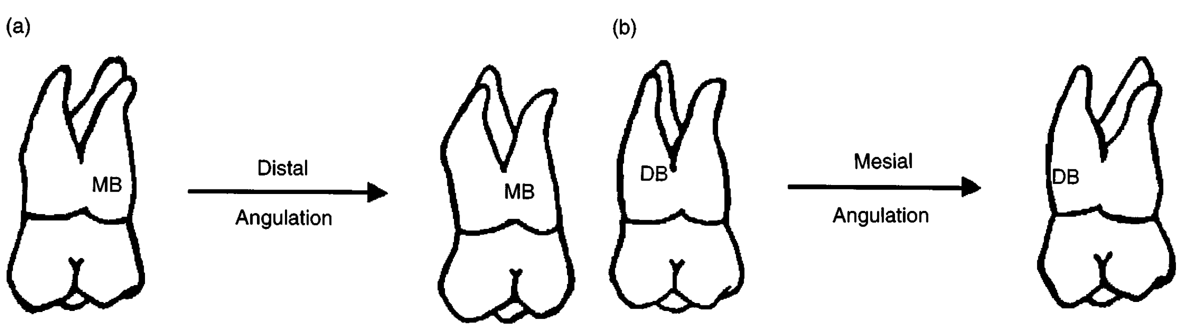

Fig. 7 (a) Diagram of a maxillary molar demonstrating how to improve the image of the mesiobuccal root. When the palatal root is superimposed over the mesiobuccal root, increasing the horizontal angulation by aligning the beam from the distal aspect of the tooth will separate the mesiobuccal root (Rosa & Tavares 1988). (b) Diagram of a maxillary molar, demonstrating how to improve the image of the distobuccal root. When the palatal root is superimposed over the distobuccal root, increasing the horizontal angulation by aligning the beam from the mesial aspect of the tooth will separate the distobuccal root (Rosa & Tavares 1988).

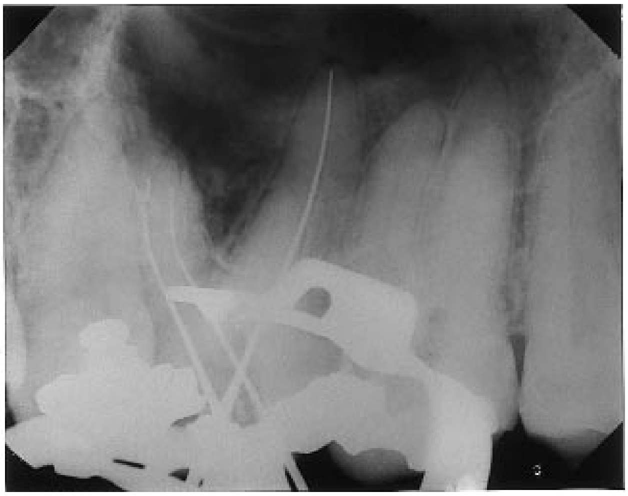

Fig. 9 Periapical view of a maxillary left first molar taken from a distal projection. Two separate canals in the mesiobuccal root are obvious.

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 root apex towards the distal aspect (Fig. 11). Lingual curves will move towards the direction of 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 (Bramante *et al.* 1980) can be beneficial.

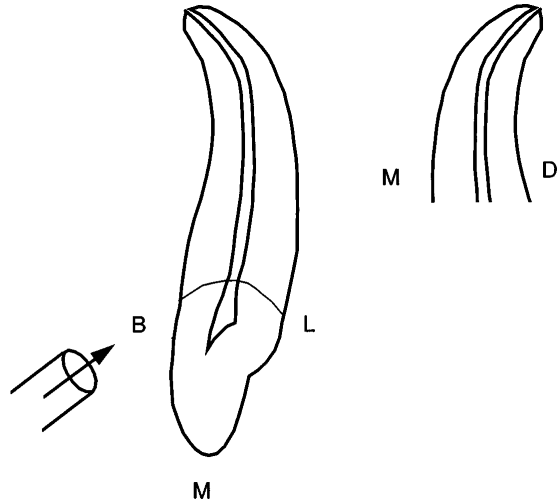

Fig. 11 Identification of buccal or lingual root curvature is not possible on a standard view whereas changing the horizontal angulation can help determine this common occurrence. Buccal curves move in the opposite direction to the angulation of the beam; lingual curves move towards the direction of angulation. In this example, a mesial angulation produces a root image which points distally – the root apex must curve towards the buccal. See Fig. 6 for an example of this phenomenon.

The triangular scanning technique (Bramante *et al.* 1980)

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

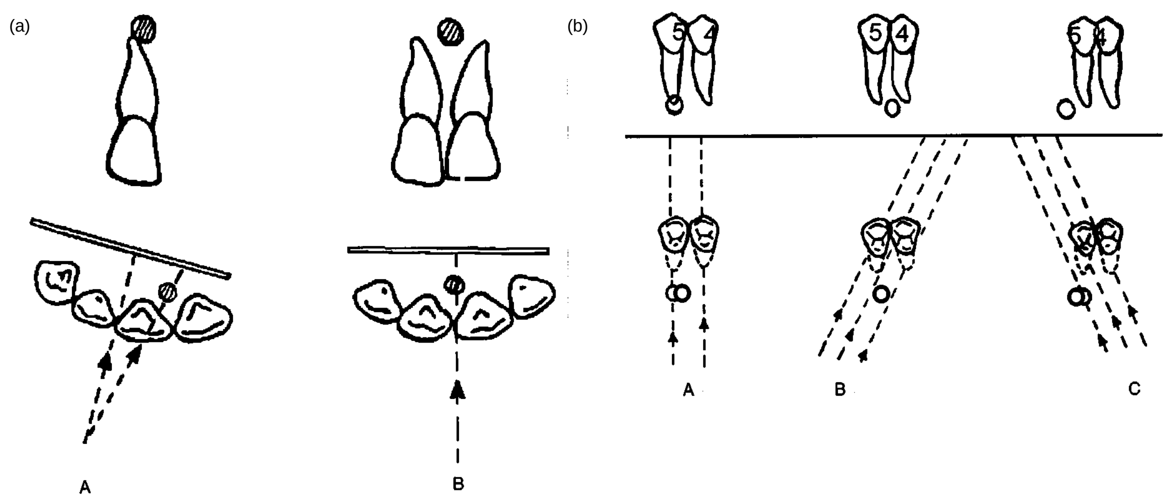

Fig. 10 (a) Diagram of the maxillary incisor region including the incisive foramen. When a standard film is taken of the central and lateral incisors (A), the foramen can become superimposed over the apex of the central incisor to create an image where the radiolucency appears to be of endodontic origin. Altering the horizontal angulation (B) dissociates the foramen from the root apices (Rosa & Tavares 1988). (b) Diagram of the mandibular premolar region including the mental foramen. When a standard film is taken of the premolars (A), the foramen can become superimposed over the apex of the second premolar to create an image where the radiolucency appears to be of endodontic origin. Altering the horizontal angulation (B & C) dissociates the foramen from the root apices (Rosa & Tavares 1988).

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 the outline of the canal (Fig. 12a). 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 (Fig. 12a). 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 (Fig. 12b). Data obtained from the three

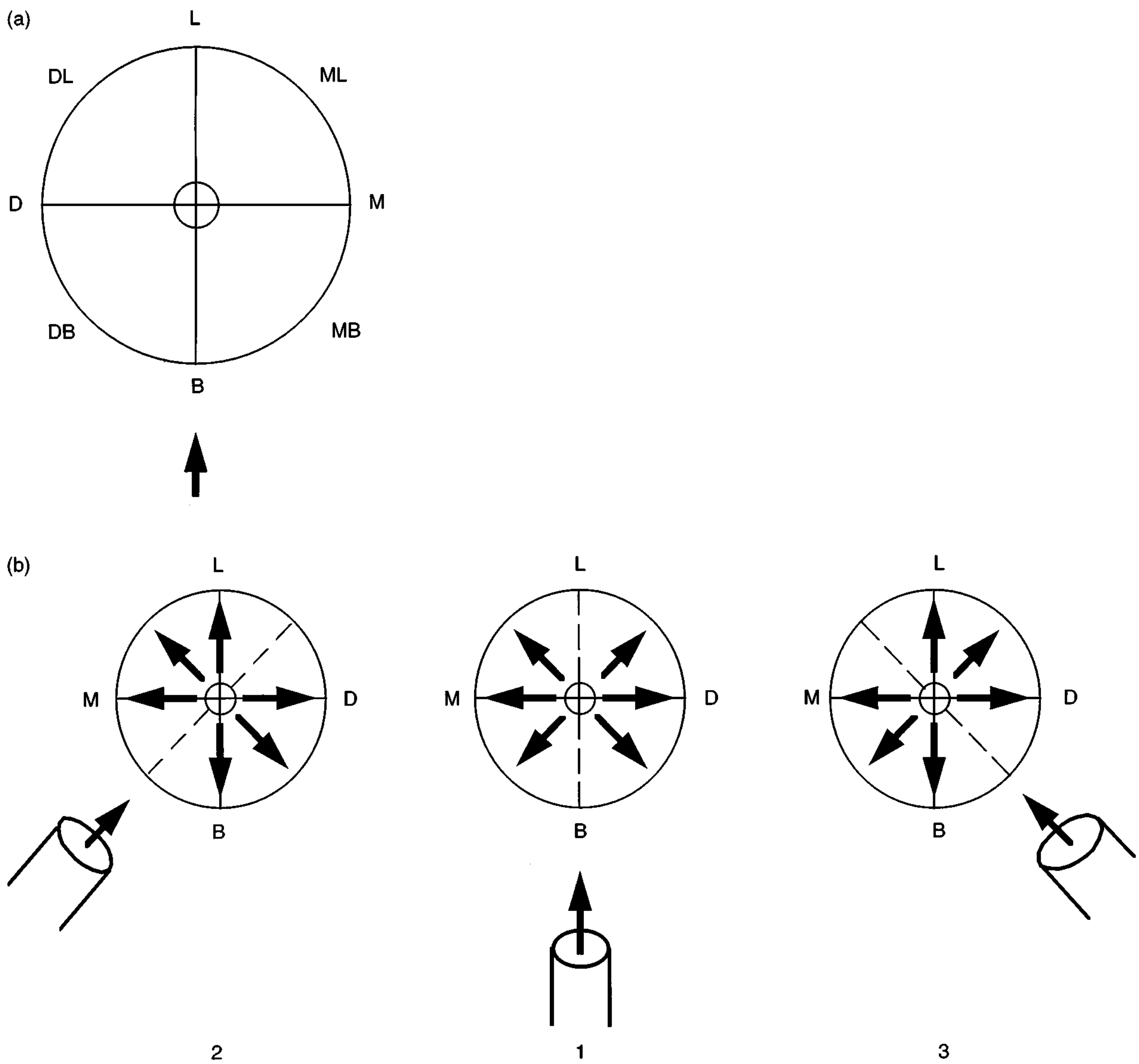

Fig. 12 (a) Diagrammatic cross-section of a root divided into four quadrants which is used to determine the exact direction of root curvatures, as well as the position of iatrogenic errors such as ledges, perforations and fractured instruments. The technique relies on the exposure of three radiographs and is called the triangular scanning technique. B=buccal, L=lingual, D=distal, M=mesial. (b) The triangular scanning diagram demonstrates that a mesial angulation (2) will superimpose the mesiobuccal (MB) and distolingual (DL) quadrants (broken line), whilst the distal angulation (3) will superimpose the distobuccal (DB) and mesiolingual (ML) quadrants (broken line). Data obtained from these two views, together with the standard view (1), will produce a simple representation of the complex three-dimensional architecture of the tooth.

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.

Use of the diagrams is demonstrated in the following example of a maxillary left lateral incisor with a distal curvature. Interpretation of a standard radiograph showing a root with such a curvature (Fig. 13a) will not provide precise details of the exact direction of curvature; in fact, the curvature could be to the distal (D), distolingual (DL) or distobuccal (DB) (Fig. 13b). If data from a film taken from a distal angle (Fig. 13c) still show a distal curvature, then the direction could be either distal (D) or distolingual (DL) (Fig. 13d). It could not be curving towards the distobuccal (DB), as such a root would appear straight since the direction of curvature would be in the same plane as the canal (Fig. 13d, broken line). By elimination, the film taken from the mesial angulation (Fig. 13e) will now precisely establish the exact direction of curvature. This third projection shows the root to be straight (Fig. 13f) because the root curvature is in the same plane as the canal (Fig. 13f, broken line). When these data are transferred to the diagram, it is clear that the precise direction of curvature of the root in this example is towards the distolingual (DL).

Using this technique, the location of perforations, ledges and fractured instruments and burs can be

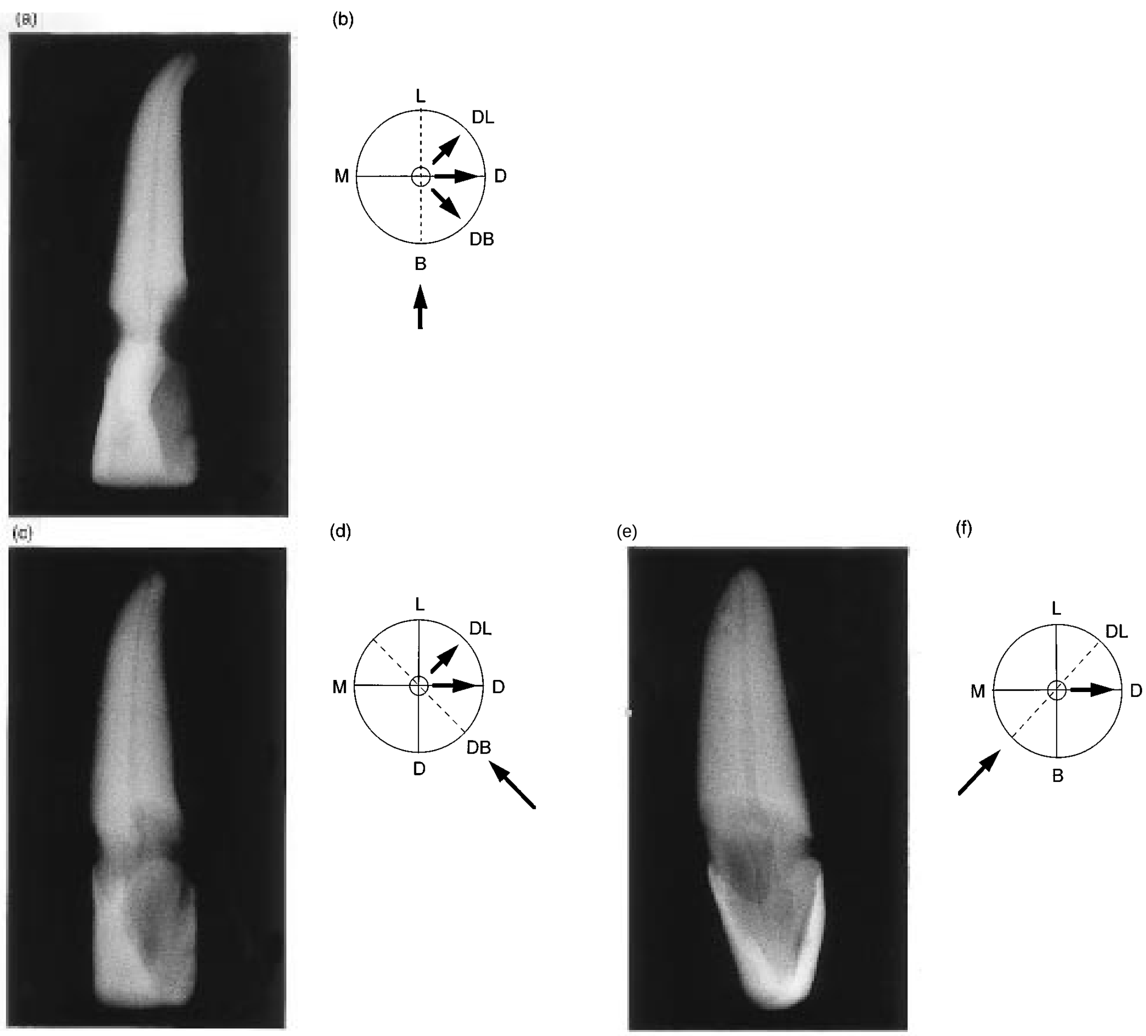

Fig. 13 Periapical radiographs (a, c, e) and triangular scanning diagrams (b, d, f) of a maxillary lateral incisor to demonstrate use of the technique to locate exactly the direction of root curvature (Bramante *et al.* 1980). The standard view (a and b) indicates that the curvature could be distobuccal (DB), distal (D) or distolingual (DL). The distal angulation (c and d) indicates that the curvature could be distal (D) or distolingual (DL). The curvature could not be distobuccal (DB) as the root would appear straight, i.e. in the same plane as the canal. The mesial angulation (e and f) indicates that the curvature must be towards the distolingual (DL), as the root curvature is in the plane of the canal.

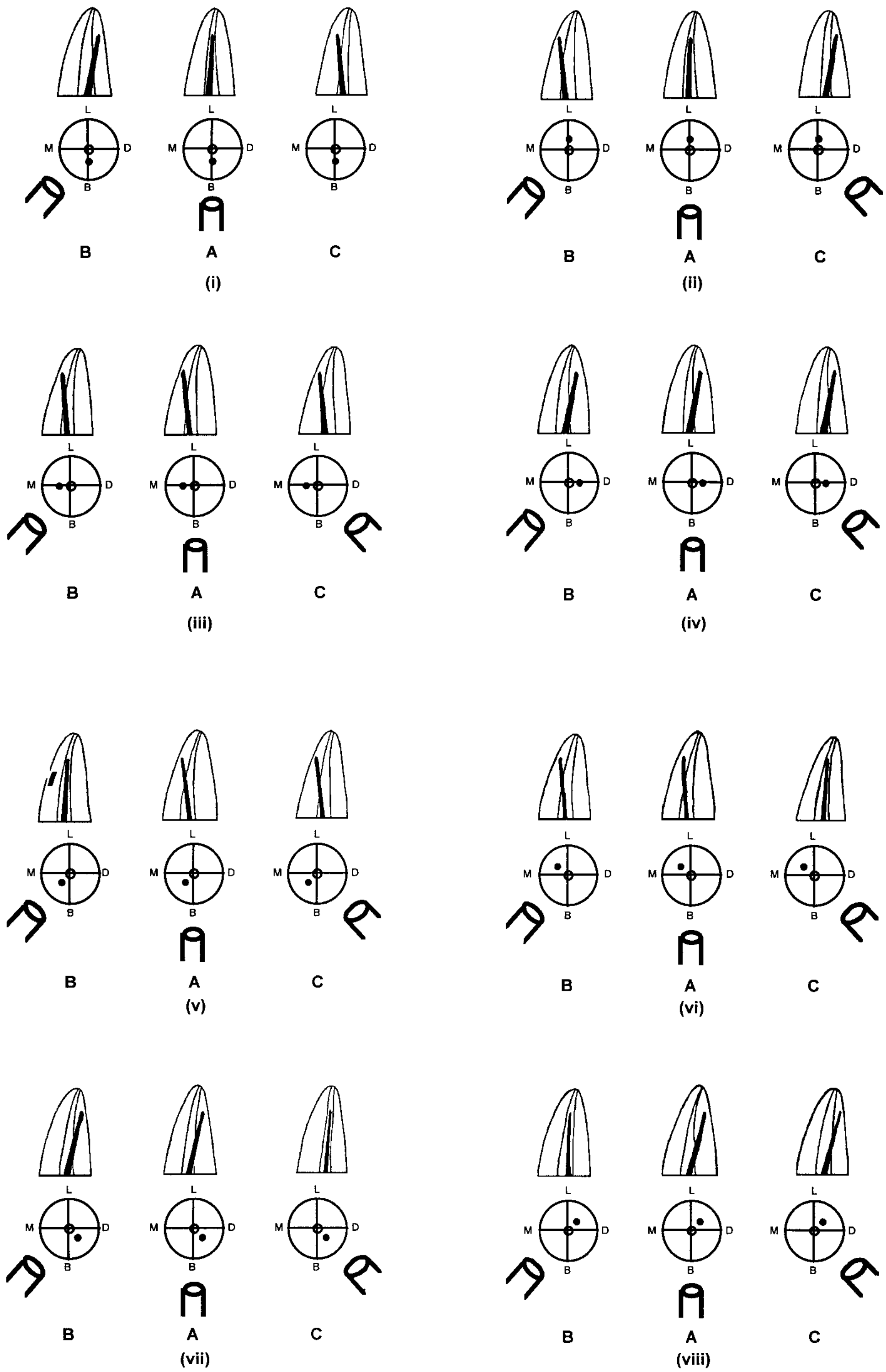

Fig. 14 Triangular scanning diagrams illustrating the deviation of an endodontic file from a canal in all possible directions. The information is summarized in Table 1. The file is represented by a shaded black circle lying in a buccal position (i), lingual position (ii), mesial position (iii), distal position (iv), mesiobuccal position (v), mesiolingual position (vi), distobuccal position (vii) and distolingual position (viii). The position of the file in relation to the canal can be seen in both cross-section and in longitudinal section. In all examples A is the standard exposure, B the mesial angulation and C the distal angulation.

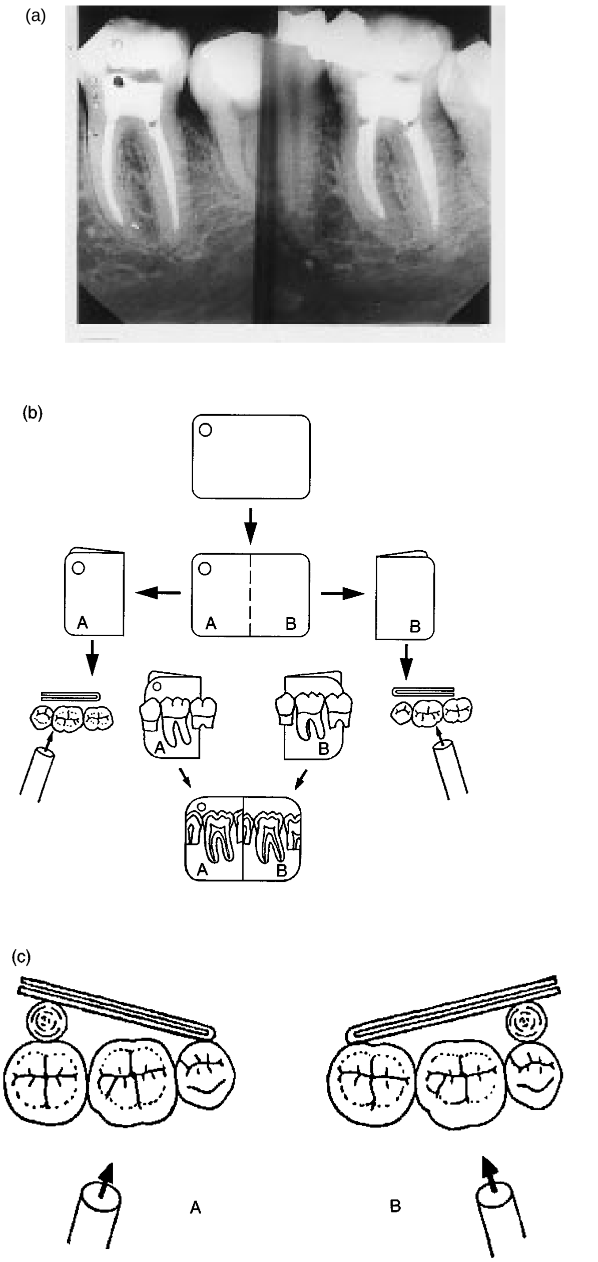

Fig. 15 (a) Radiograph of a mandibular molar with two images of the same tooth taken at different angulations. The technique is illustrated in Fig. 14. (b) Diagram of the technique used to obtain two images of the same tooth on one film (Almeida 1953). The film is folded in half so that side 'A' can be exposed to a mesial angulation and subsequently side 'B' to a distal angulation. Lead foil must be secured between the two halves during the two exposures. (c) When exposing two images on the one film a cotton wool roll can be used to maintain the position of the film in relation to the tooth and beam. In the distal angulation (A) the roll is placed on the distal side whereas in the mesial angulation the roll is place on the mesial side (B).

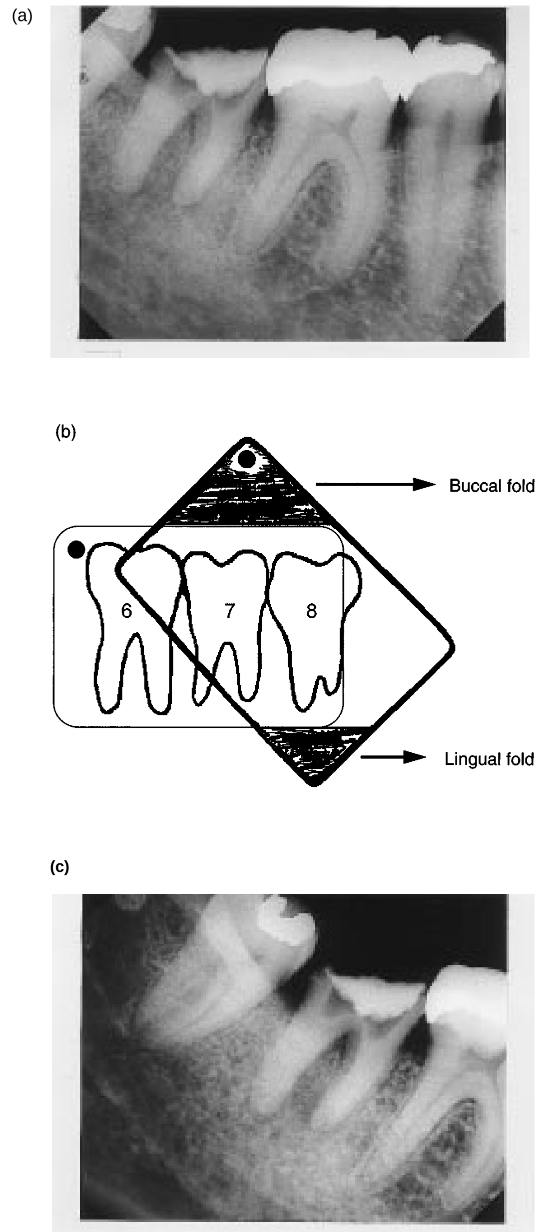

Fig. 16 (a) Conventional film placement when taking a radiograph of a mandibular third molar can be difficult and result in the tooth being missed on the image. (b) Customizing the position of the film by rotating it so that one corner protrudes below the tooth and the diagonal corner above the tooth ensures that the image of a mandibular third molar is captured (Parma 1956). (c) Customized film placement when taking a radiograph of a mandibular third molar results in a satisfactory image of the tooth and surrounding bone (Parma 1956).

Table 1 Summary of the various possibilities of the triangular scanning technique outlined in Fig. 14

Location	Angulation Standard (Direct) Fig. 14A	Mesial Fig. 14B	Distal Fig. 14C
Buccal [Fig. 14(i)]	X	D	M
Lingual [Fig. 14(ii)]	X	M	D
Mesial [Fig. 14(ii)]	M	M	M
Distal [Fig. 14(iv)]	D	D	D
Mesiobuccal [Fig. 14(v)]	M	X	M
Mesiolingual [Fig. 14(vi)]	M	M	X
Distobuccal [Fig. 14(vii)]	D	D	X
Distolingual [Fig. 14(viii)]	D	X	D

deduced making remedial treatment simpler and safer. Figure 14 demonstrates the deviation of an endodontic instrument in all possible directions using the triangular scanning technique (Bramante *et al.* 1980). Table 1 summarizes the data derived from the examples, where the first column (Location) defines the position of the deviating file whilst columns 2, 3 and 4 provide the findings from the three radiographic exposures, standard, mesial and distal angulations. M and D indicate the direction of curvature of the file whilst X represents the superimposition of the instrument over the canal space or that the curvature appears straight.

Thus, for an instrument placed buccally [Fig. 14(i)] the standard view (A) shows the file in the plane of the canal, the mesial view (B) shows the file in the distal half and the distal view (C) shows the file in the mesial half. This outcome could only occur when the instrument was placed buccally. Figures 14 (ii) to (viii) provide examples of instruments in the other regions of the root.

Two images of the same tooth on one film (Almeida 1953)

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 (Fig. 15a), 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 (Fig. 15b). Following conventional processing, the two images of the same tooth appear side by side on the same film (Fig. 15a). 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, with the result that careful film placement and beam angulation are essential. 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 (Fig. 15c). This is placed between the film and the tooth on the mesial side for a mesioangular exposure (B) and on the distal side for a distoangular exposure (A).

Customized periapical technique for third molars (Parma 1956)

This technique is useful for mandibular third molars when the anatomical features or low patient tolerance preclude normal placement of the film (Fig. 16a). To overcome these problems, the film is placed at a slight inclination to the tooth (Fig. 16b) with the inferior border folded 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 (Fig. 16b). The resultant film provides an image of the whole length of the tooth and surrounding bone (Fig. 16c).

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