

8.2.2.1 The primary beam

Personnel should never stand in the path of the primary beam. Under no circumstances should the dentist or other persons hold a film relative to the dentition, nor the X-ray cone, during an exposure. Such practice over a period of years, may have disastrous consequences.

8.2.2.2 Distance and operator position

The inverse square law states that the intensity of radiation varies inversely with the square of the distance (Figure 51). The greater the distance from the radiation source therefore, that the operator can be, then the less the radiation exposure will be (Lichtenstein et al, 1980). The recommended distance that an operator should stand from the radiation source is six feet (Frommer, 1981, Goaz and White, 1982 and the Eastman Kodak Company, 1985), in the absence of an effective barrier.

If the radiographic setup within the morgue or other examination facility is such that the operator is unable to be effectively shielded from radiation other than by distance, the position of the operator in relation to the X-ray source must be considered. The safest areas to stand in relation to minimum radiation scatter, are at right angles to the X-ray beam and toward the back of the body being examined (Figure 52).

8.2.2.3 Protective barriers

Physical barriers are the most effective form of protection against radiation for personnel (Lichtenstein et al, 1980 and Morlang, 1982).

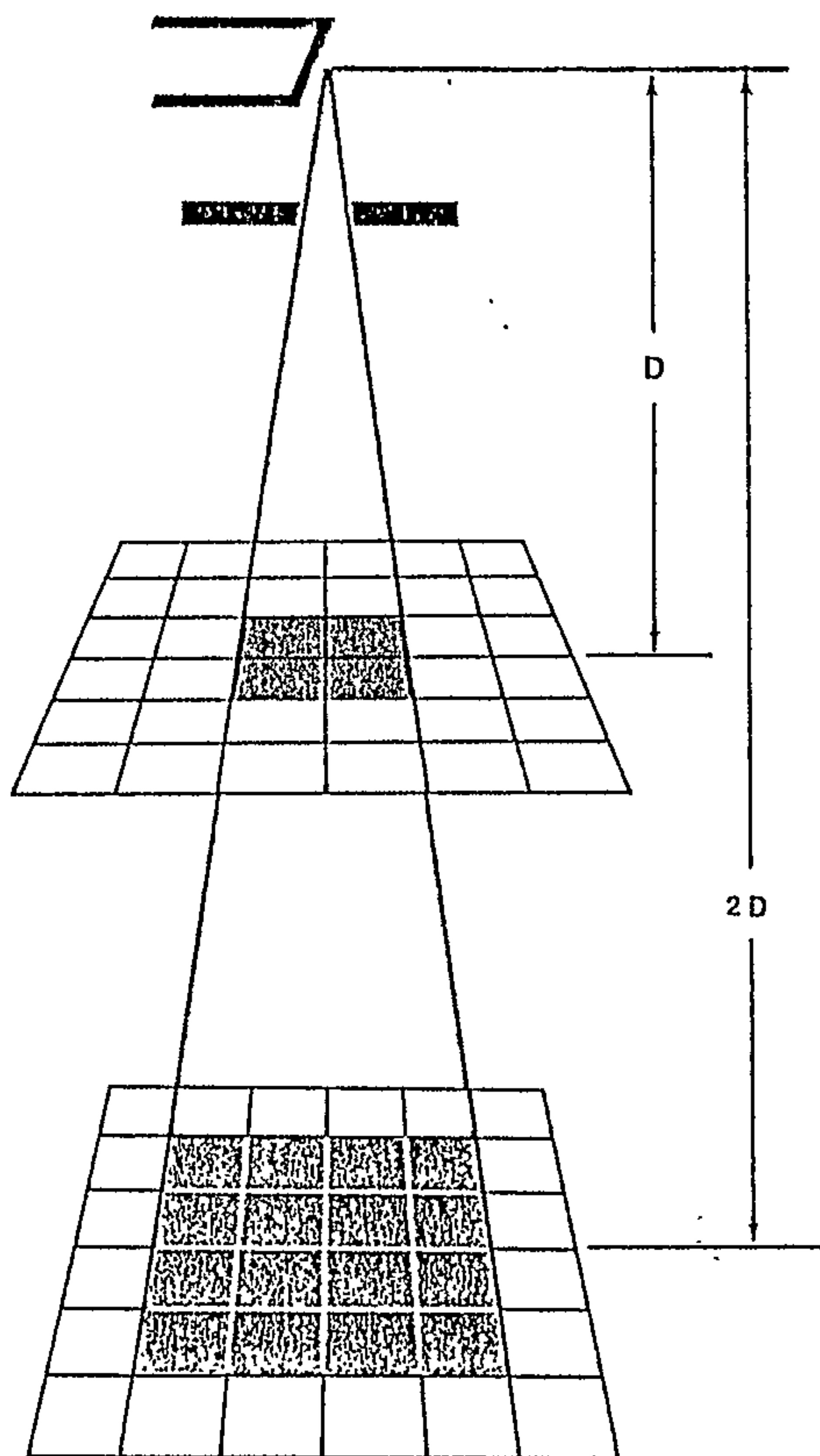


Figure 51. Illustration of the principles of the Inverse Square Law (Eastman Kodak Company, 1985).

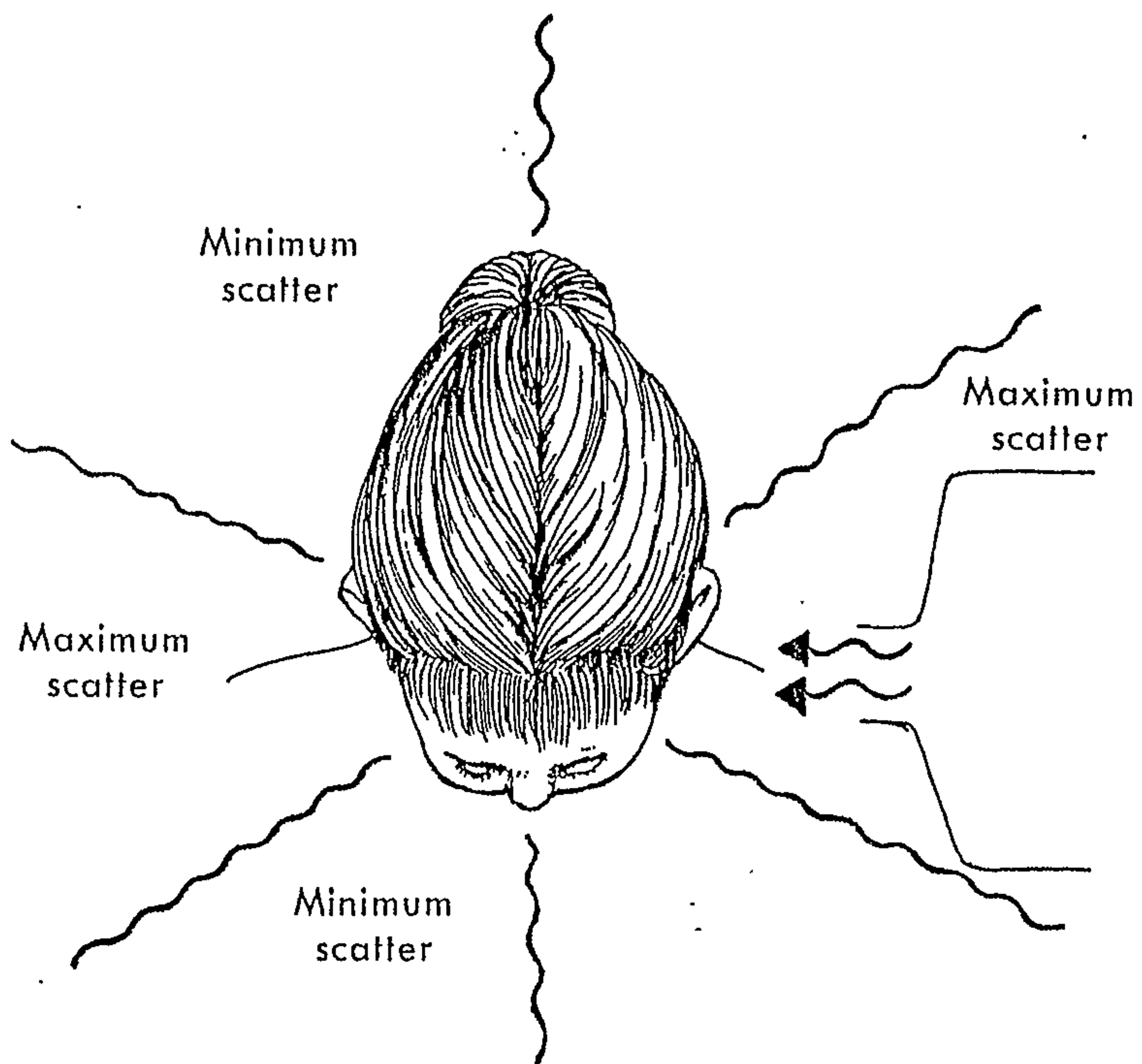


Figure 52.

Areas of minimum and maximum scatter during dental x-ray exposure.
(Frommer, 1981)

Barriers may take the form of mobile, lead-lined shields or structures, such as walls that have sufficient shielding, inherent in the construction materials.

Where radiographic equipment must be brought into an examination facility, placing the equipment in a corner of the building will provide adequate protection for personnel from radiation, on two sides. Operator protection is then facilitated by mobile screens or distance and position in relation to the X-ray beam.

8.2.2.4 Film speed and processing

The American National Standards Institute has recommended that only film with an ANSI speed classification of D or higher should be used for dental radiography (Frommer, 1981 and Goaz and White, 1982). This recommendation is important as exposure times with such films can be decreased.

Goaz and White (1982), claim that "the biggest single problem in radiation protection is gross over-exposure of the film, that is in turn compensated for by under-development." In other words, inferior image quality is often the result of using excessive radiation exposure, often requiring films to be retaken.

All films should be exposed adequately and processed according to the time-temperature technique, as recommended by the various film manufacturers. In the absence of proper darkroom facilities, an automatic processing machine, such as the Philips 810, or the

Durr Periomat may be used. Such machines usually operate at increased temperatures for developing, fixing and drying and, if incorrectly maintained, may result in poor image quality, with the need to retake films.

Processing machines such as the Procomat, may also indirectly result in an increased radiation exposure. In this machine, the developing solution is heated to a specified temperature, but the developing and fixing times for the film are the same. Often, even after adequate washing and drying, in the author's experience, films may develop a yellow or brown stain, indicating inadequate fixing and therefore requiring the film to be retaken. The use of the Procomat requires that the film be put through the fixing cycle twice, before washing and drying.

8.2.3 Radiation Monitoring

Lichtenstein et al (1980) and Morlang (1982), advise the monitoring of radiation exposure for personnel employed in the use of ionising radiation. This is most easily and economically achieved with personal X-ray dose film badges.

In forensic dentistry, the monitoring of radiation exposure has its greatest application in disaster situations, where many bodies are to be examined and numerous radiographs taken.

The film badge contains X-ray sensitive film in a light-proof packet and is usually the size of a dental X-ray film. The badge is worn

on the operator's clothing for a specified period and then returned to a radiation monitoring laboratory for reading (in New South Wales, this is carried out by the Department of Health, Radiation Health Services, at Lidcombe). The laboratory processes the film and measures the density as compared with standards, to determine exposure. Ideally, the recorded radiation levels from such badges should be zero, if recommended protection procedures are used (Frommer, 1981 and Goaz and White, 1982). The laboratory is also able to organise radiation surveys of work places and check the reliability of X-ray machines, with the use of ionisation chambers.

8.3 FILM IDENTIFICATION

In forensic dentistry, especially in the disaster situation, the need to permanently mark radiographs, quickly and simply, is apparent. Radiographs must also be mounted for viewing and a convention of relating the anatomical left and right of structures on the radiograph adopted.

Antemortem radiographs remain the property of the submitting dentist and, therefore, to maintain accurate records, duplication of radiographs is often necessary.

8.3.1 Permanent Marking of Radiographs

Radiographs may be marked simply and indelibly on a non-diagnostic part of a radiograph, with a felt-tipped pen. This method is useful when only a few radiographs need to be taken. In situations where many bodies are to be radiographed and numerous dental films taken,

confusion may arise as to which radiographs belong to which specimen, unless film racks and specimens have been carefully marked. Even so, radiographs cannot be marked with the above method until they are thoroughly dry. The chance of mis-labelling a radiograph in such circumstances is high.

Kogon and Reid (1974), advocate a simple and permanent method of film identification, that may be used effectively on both periapical and occlusal size films, at the time of the radiographic examination.

The method involves inscribing or typing an identification number or name, on a lead foil sheet, obtained from a film packet. The identification marking is then cut to a 5mm width and secured with tape to an area on the tube side of the unexposed film that will be free of anatomical structures. The film is exposed and processed in the normal manner, producing a radiograph incorporating the previously recorded data.

8.3.2 Mounting Radiographs

There are many methods of mounting radiographs, for viewing and filing. Radiographs may be mounted on plastic sheets or inserted in the pockets of commercially available film mounts. The purpose of the film mount is to protect the film, to arrange consecutive films in correct anatomical order and to conveniently file the films (Goaz and White, 1982). Opaque, light-diffusing mounts are preferable to clear plastic mounts, as they prevent stray light

from the view box reaching the examiner's eyes.

There are two ways in which periapical, bitewing or occlusal radiographs may be positioned for viewing. The preferred method is to arrange the films so that the images of the teeth are in correct anatomical position and in the same relationship to the examiner as when he is facing the body or specimen. The orientation dot of the film is so placed, that the convexity of the dot faces the examiner. Radiographs so mounted correspond to the odontogram on many dental treatment charts. The second way is to arrange the films with the concavity of the orientation dot facing the examiner (Sopher, 1976). In this way, the morphologic features of the teeth and anatomical landmarks are presented, as if the examiner were viewing the body or specimen from behind (Goaz and White, 1982 and Eastman Kodak Company, 1985). Anatomical landmarks are used to identify the right and left aspects of the dental arches.

8.3.3 Duplication of Radiographs

Radiographs may need to be duplicated for a variety of reasons, the submitting dentist may wish to maintain them in his records; the examiner may require duplicates to send to colleagues for opinions, or to use for teaching purposes and to present to the coroner with his written report regarding the identification of a body (Luntz and Luntz, 1973, Stimson, 1977, and De Vore, 1977).

The simplest method of obtaining a duplicate film of a postmortem specimen is to use a double film packet to produce two originals

Morlang, 1982 and Eastman Kodak Company, 1985). When further copies are required or duplicates of antemortem films need to be made, then the original may be duplicated either by photographic means (Luntz and Luntz, 1973, De Vore, 1977 and Brannon, 1983), or by the use of a copying film such as the Kodak X-OMAT duplicating film (Luntz and Luntz, 1973, Stimson, 1977, Frommer, 1981, Goaz and White, 1982 and Eastman Kodak Company, 1985).

De Vore (1977), suggests that with any duplicating technique, significant detail may be lost. The Eastman Kodak Company (1985), however, indicates that most radiographs are reproduced with excellent fidelity, using the Kodak X-OMAT duplicating film. The technique for duplicating radiographs with copying film, as advocated by Luntz and Luntz (1973), Stimson (1977) and Frommer (1981), is as follows :-

- (i) Under safelight conditions, the copying film is placed on a felt covered board, with the emulsion side up.
- (ii) The radiographs to be copied are placed on the film.
- (iii) The film and radiographs are covered with a glass sheet to stabilise them and to achieve close contact between them (this will preserve the detail of the original radiograph in the copy).
- (iv) The film is exposed to a white light source of about 40-60 watts, for 4 to 7 seconds,

at a distance of about 2 feet. Trial exposures may need to be made, to standardise time, light source and distance, for best results.

(v) After the exposure is made, the film is processed either by the time-temperature method, or in an automatic processing machine.

(vi) The copied radiographs are marked for identification purposes and lettered left and right for anatomic orientation. The radiographs may then be mounted as required.

Duplication of radiographs using copying film, has the advantage of being able to enhance the image of the original. Less exposure time is used, if a darker film is desired and more exposure time, if a lighter film is desired.

8.4 THE ANGLE OF PROJECTION OF THE X-RAY BEAM

Lichtenstein et al (1980), state that postmortem dental radiographs should be obtained in standard projections. This is in accord with the criteria for obtaining diagnostically acceptable radiographs as outlined by Frommer (1981) and mentioned previously. Radiographs of the dentition taken in standard projection must be considered in all postmortem examinations where antemortem radiographs are not readily available.

Crandell (1958), Jensen (1978), Fortier (1979) and Nysether and Hansen (1983), report the results of surveys of the diagnostic quality of radiographs and indicate that up to 75.5% are unsatisfactory. In many instances, this is attributed to errors in the angle of projection of the X-ray beam, which produce illusions or misrepresent dental anatomy on the radiographs (Thunty, 1978).

When direct comparisons can be made with antemortem radiographs, every effort should be made to obtain postmortem radiographs that are similar to the original. This is achieved by duplicating film placement relative to the dentition and the angulation of the X-ray tube to the film (Sopher, 1976, De Vore, 1977, Cottone and Standish, 1982, and Brannon, 1983). Duplication of angles of projection in the postmortem film will avoid possible confusion and conflicting information that may arise, if comparisons are undertaken using radiographs obtained with standard angles of projection.

8.4.1 Errors Associated with the Angle of Projection

Faulty angles of projection of the X-ray beam, either horizontal and/or vertical, can result in illusions on dental radiographs. These illusions are created by the superimposition of anatomic structures, which produce an incorrect or confusing anatomic image (Thunty, 1978 and 1980).

Some common radiographic illusions caused by faulty vertical and/or horizontal angulations of the X-ray beam, which can be significant in postmortem investigations, may be listed and described as :-

- (i) Vertical angulation and the number of restorations; a tooth may be seen as having a single large amalgam restoration. By decreasing the vertical angulation, occlusal and buccal restorations may be seen to be separate (Figure 53).
- (ii) Vertical angulation and restoration retentive pins; excessive vertical angulation may throw the shadow of retentive pins within the body of an amalgam restoration. Decreasing the vertical angulation will reveal the pins (Figure 54).
- (iii) Vertical angulation and the relationship of dental caries and restorations to the pulp; excessive vertical angulation may show dental caries to have caused a pulp exposure or show a restoration to be significantly close to the pulp. Too little vertical angulation may sometimes mask the presence of secondary caries under an amalgam restoration.
- (iv) Vertical angulation and the level of interproximal crestal bone; excessive vertical angulation may suggest that the level of interproximal crestal bone extends beyond the cervical margins of the teeth towards the occlusal surfaces. A reduction



Figure 53. Angle of projection and the number of restorations (Thunty, 1978)

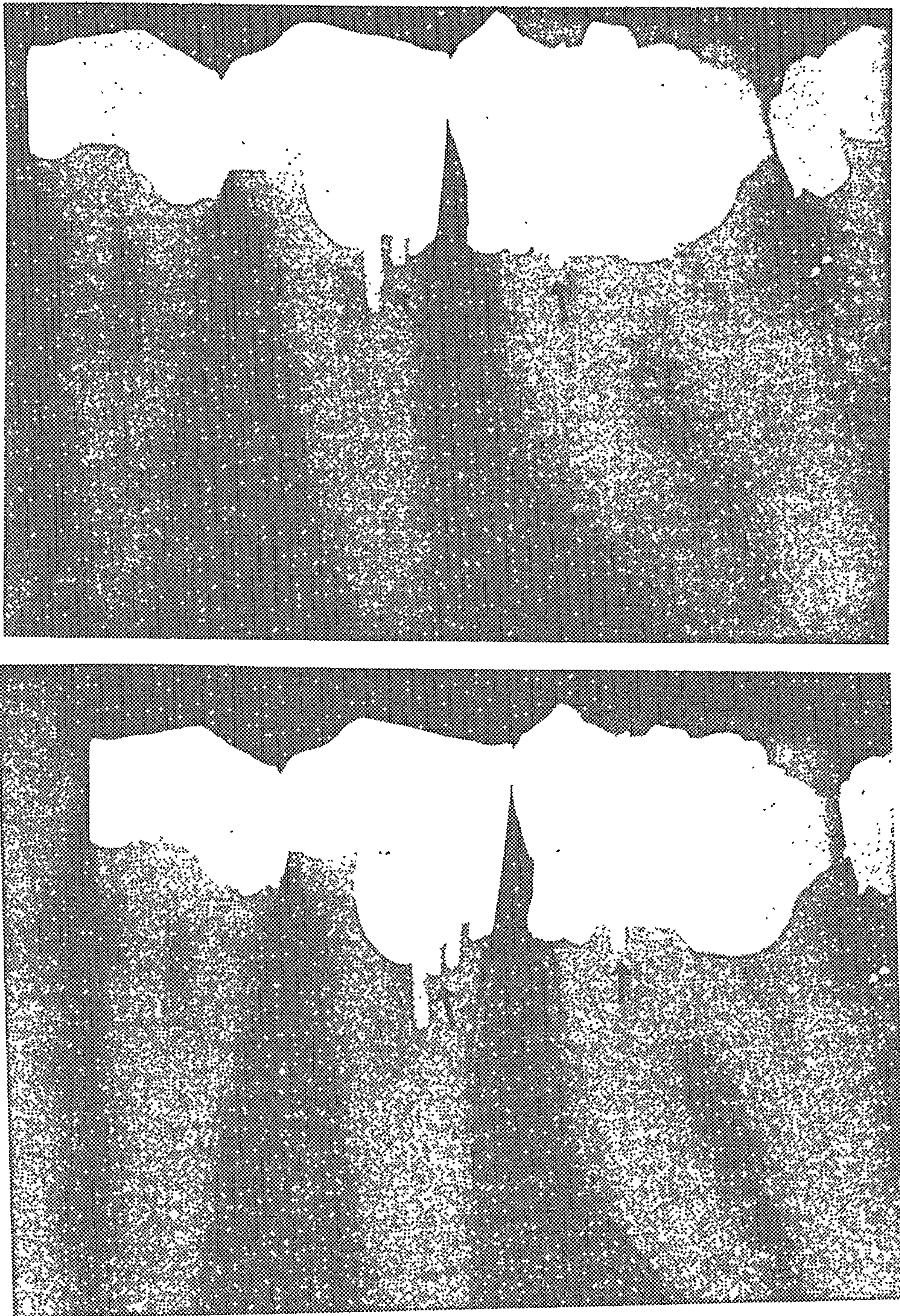


Figure 54. Angle of projection and restorative pins - two radiographs

in angulation will restore the correct relationships and also show an alteration in the bony trabecular pattern (Figure 55).

- (v) Vertical angulation and the mental ridge; excessive vertical angulation in the mandibular anterior region may cause the shadow of the mental ridge to be thrown over the apices of the anterior teeth.
- (vi) Vertical angulation and elongation and foreshortening; an excessive increase or decrease in vertical angulation produces a foreshortening or an elongation of the teeth respectively.
- (vii) Horizontal angulation and tooth size; the curvature of the dental arch, especially in the maxillary molar region combined with variations in horizontal angulation may show a significant increase or decrease in the mesiodistal dimensions of a tooth.
- (viii) Horizontal angulation and cusp numbers; the curvature of the dental arch in the first premolar regions, combined with an incorrect horizontal angulation may show the premolar to have three cusps.
- (ix) Horizontal angulation and curved roots;

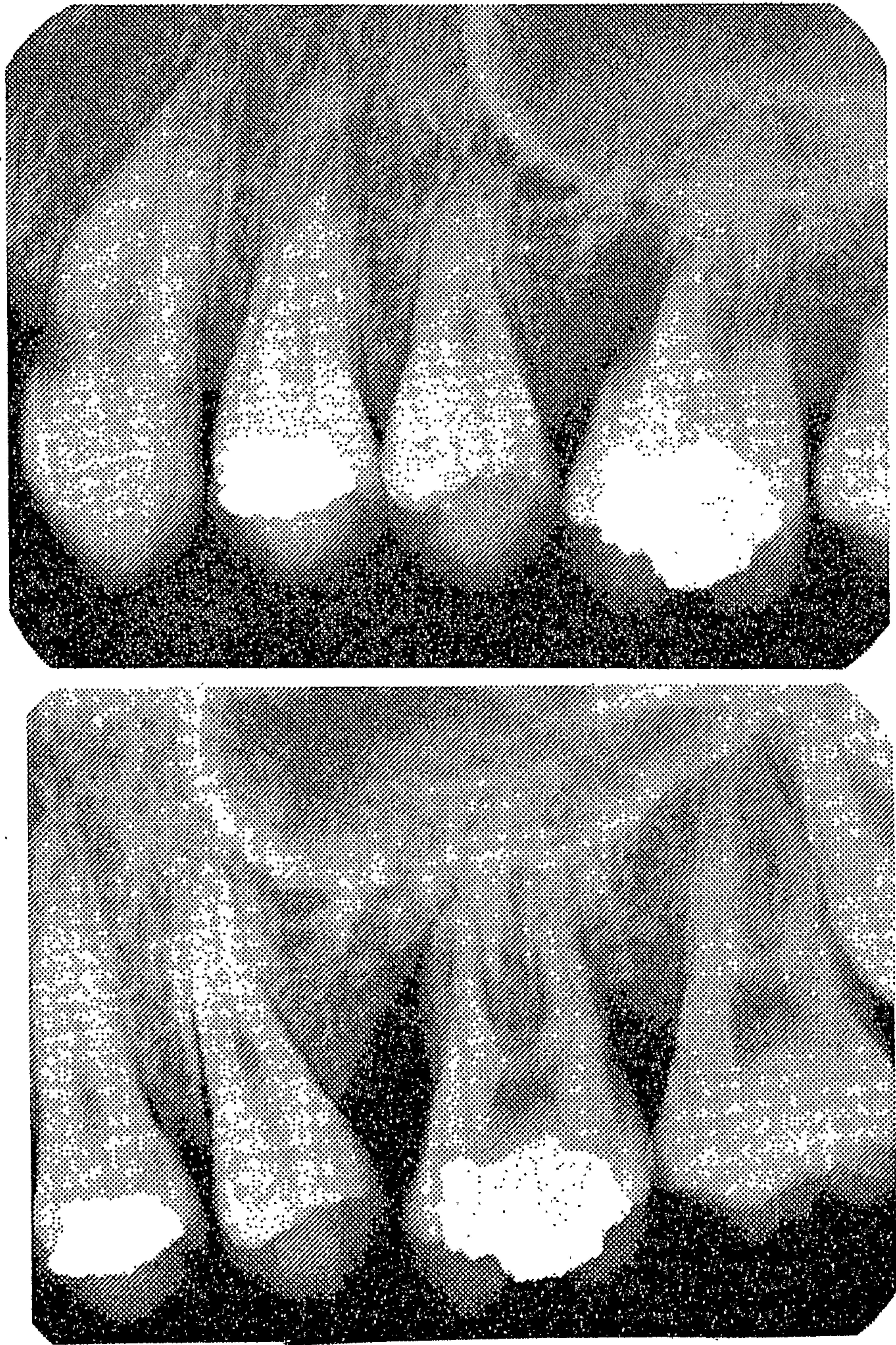


Figure 55. Angle of projection and level of interproximal bone.

a radiograph taken in standard projection may show a tooth to have straight roots, by altering the horizontal angulation, the effect of superimposition may be removed and the roots of the teeth revealed to be curved.

- (x) Horizontal angulation and tooth contact; teeth with interproximal restorations may show closed contacts on PA or bite-wing radiographs, a change in horizontal angulation may show these contacts to be open.
- (xi) Horizontal angulation and the number of restorations; often radiographs will reveal a single large amalgam restoration on the occlusal of a tooth, altering the horizontal angulation may reveal two separate restorations (Figure 56).
- (xii) Horizontal angulation and the position of restorations near tooth surfaces; as mentioned above, the curvature of the dental arches in the first premolar regions may show variations in anatomic images, when combined with changes in horizontal angulation. The relative position of a restoration to the mesial or distal surface of a premolar or canine may be seen to move markedly with a change in horizontal angulation.

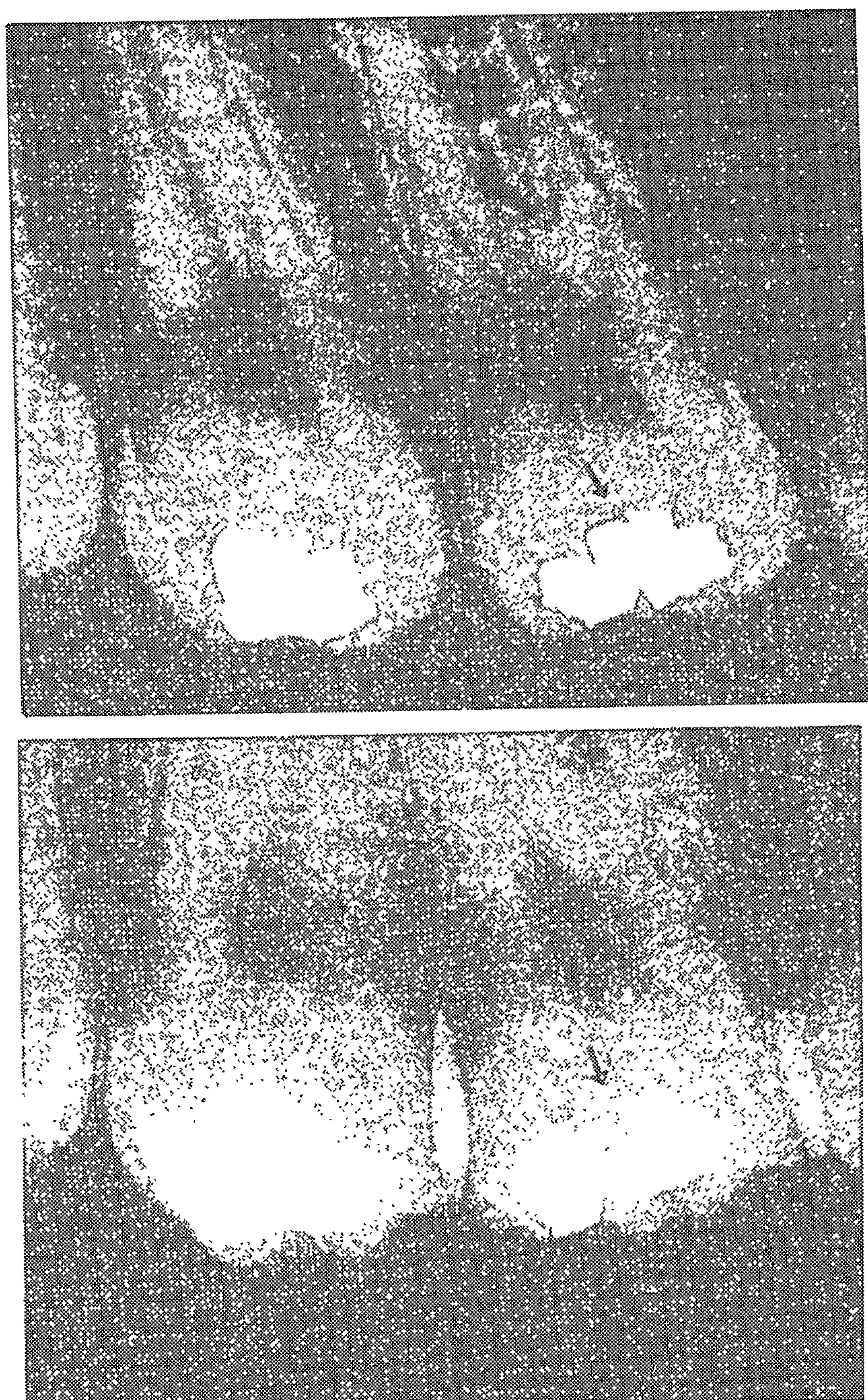


Figure 56. Altering the angle of projection may vary the number of restorations visible on a radiograph (Thunty, 1978).

- (xiii) Horizontal angulation and root canal fillings; a radiograph of a molar or premolar tooth may show a root filling in a single canal, a change in horizontal angulation may reveal two canals with separate distinct root fillings.

The examples listed above are common illusions, but may present conflicting evidence in postmortem radiographic studies. The forensic dentist must be aware of the anomalies that may present as a result in changes of vertical and horizontal angulations, and be prepared to vary his techniques to produce desired results.

8.4.2 Reproducing Antemortem Angles of Projection in Postmortem Radiographs

Positive postmortem identification of unknown human remains often depends upon comparison of radiographic evidence. Antemortem dental radiographs as mentioned are, in many areas, not technically perfect (Keiser-Nielsen, Johansen and Solheim, 1981), with errors in the angle of projection being a significant problem (Crandell, 1958, Jensen, 1978, Fortier, 1979 and Nysether and Hansen, 1983). Radiographic comparison of anatomic structures and tooth and restoration morphology requires that those films being examined, are similar (De Vore, 1977 and Cottone and Standish, 1982).

Problems are encountered in trying to reproduce the antemortem angles of projection, especially in periapical radiographs. Several

films at various projections often need to be taken to obtain one from which a comparison can be made. Trial and error is the usual means of obtaining a satisfactory result (De Vore, 1977 and Brannon, 1983).

A consideration of the "buccal object rule", a technique of radiographic localisation, may enable antemortem angles of projection to be reproduced more easily.

8.4.2.1 The "buccal object rule"

The "buccal object rule" as described by Richards (1952), is an extension of the radiographic localisation principles reported by Clark in 1909. The "rule" is used to assess the spatial relationships of hidden objects in the oral region to specific landmarks or other objects (Langlais, Langland and Morris, 1979 and Lilienthal, 1983).

The "rule" states:

"When two different radiographs are made of a pair of objects, the image of the buccal object moves, relative to the image of the lingual object, in the same direction in which the X-ray beam is directed" (Richards, 1980).

Localisation is accomplished using standard periapical technique and is simply explained by Frommer (1981) :

"To define the buccolingual relationship between two structures that appear radiographically superimposed, a second radiograph is taken. All factors remain the same for the second except that the tube is shifted in either the vertical or horizontal angulation about 20 degrees. When the two

radiographs are compared, the buccal object will appear to have moved on the film in the opposite direction that the tube has been shifted (Figure 57 and 58). If the tube is moved mesially by a change in horizontal angulation, the buccal object will move distally. In the mandible for example, if the vertical angulation is changed in moving the beam down by increasing the vertical angulation, the buccal object will appear to have moved superiorly on the film."

Lilienthal (1983), indicates that the direction of vertical and horizontal angulation changes, as observed in radiographic images of the teeth, may be determined from radiographs, using one or more of the following factors described by Richards (1980):

- (i) The vertical angulation of the X-ray beam determines the length of the radiographic image of a tooth when the "bisecting angle" technique is used. Increasing positive vertical angulation in the maxilla or negative vertical angulation in the mandible will shorten images of the teeth, whereas by decreasing the positive vertical angulation in the maxilla or negative vertical angulation in the mandible, the images of the teeth will be lengthened.
- (ii) Vertical angulation changes cause buccal cusp images to move vertically, in the same direction in which the X-ray beam is directed, relative to the lingual cusps.
- (iii) Vertical angulation changes cause the images of buccal root apices to move vertically, in the same direction in which the X-ray beam is directed,

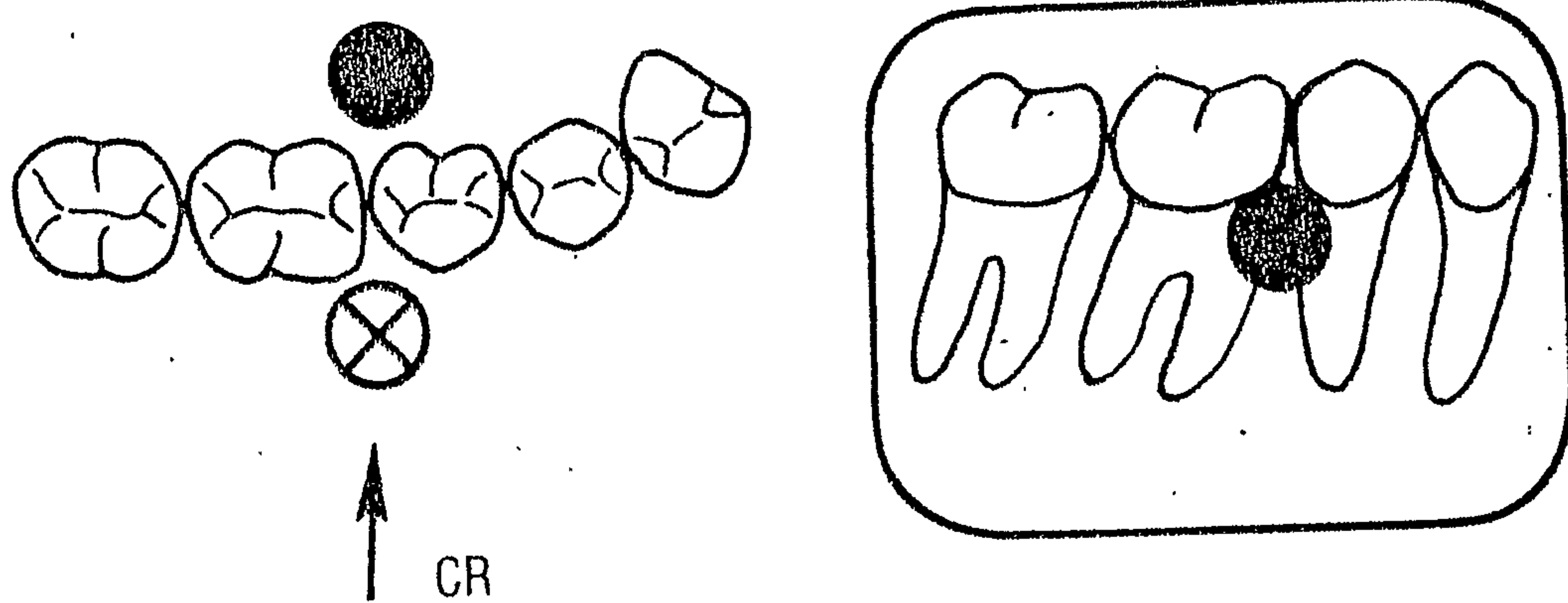


Figure 57. Illustration of the Buccal Object Rule (Langlais, Langland and Morris, 1975).

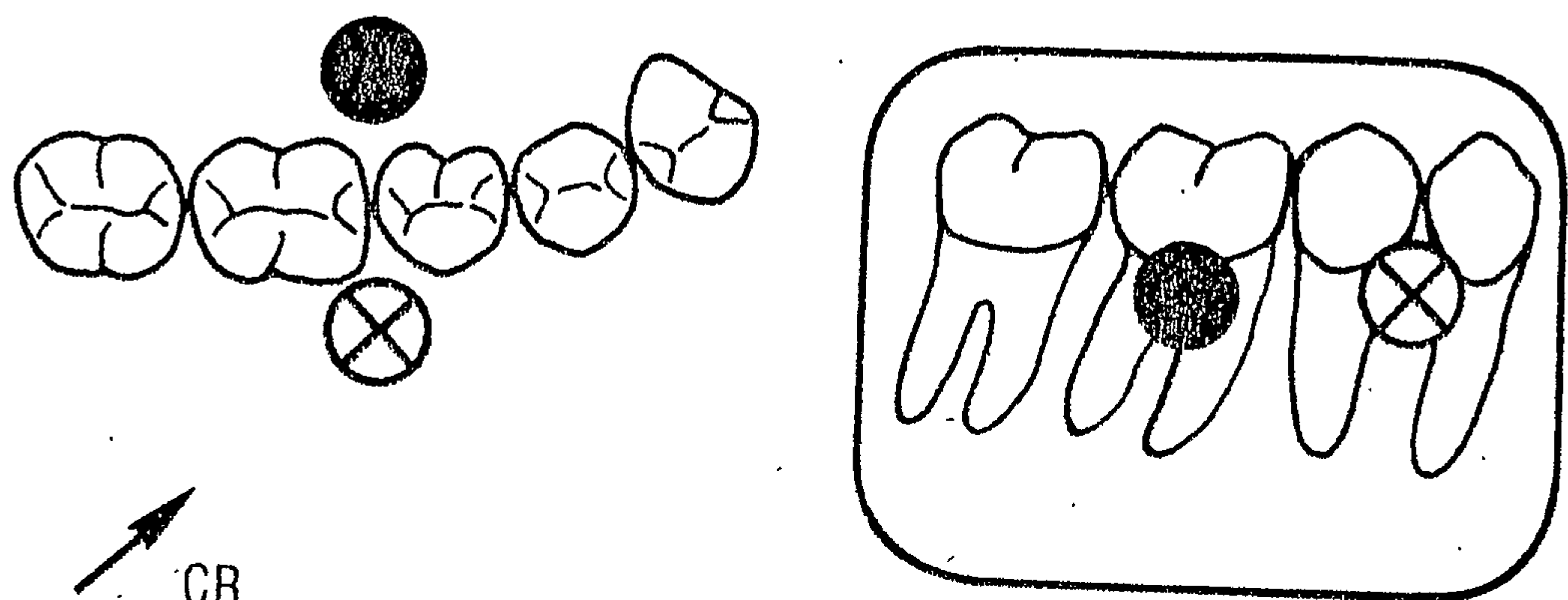


Figure 58. Illustration of the Buccal Object Rule (Langlais, Langland and Morris, 1975).

relative to the lingual root apices.

- (iv) Vertical angulation changes shift vertically the U-shaped image of the zygomatic process of the maxilla, in the same direction in which the X-ray beam is directed, relative to the maxillary molar root images.
- (v) Vertical angulation changes cause the image of the anterior border of the ramus (external oblique ridge) to move vertically, in the same direction in which the X-ray beam is directed, relative to the images of the mandibular molar teeth.
- (vi) Vertical angulation changes occur whenever a given area is radiographed using two different methods, e.g. periapical and bitewing methods or periapical and occlusal methods, etc.
- (vii) Horizontal angulation changes cause the images of roots to tilt in the same direction in which the X-ray beam is directed.
- (viii) Horizontal angulation changes cause the images of buccal cusps to move horizontally, in the same direction in which the X-ray beam is directed, relative to the lingual cusps.
- (ix) Horizontal angulation changes cause the images of buccal root apices to move horizontally, in the same direction in which the X-ray beam is directed, relative to the lingual root apices.
- (x) Horizontal angulation changes cause the image of

the U-shaped zygomatic process of the maxilla to move horizontally, in the same direction in which the X-ray beam is directed, relative to the maxillary molar teeth.

- (xi) Horizontal angulation changes cause the image of the anterior border of the ramus (external oblique ridge) to move horizontally, in the same direction in which the X-ray beam is directed, relative to the mandibular molar teeth.
- (xii) When a routine periapical examination is made, the horizontal angulation is changed mesially for each exposure, to direct the X-ray beam through the interproximal spaces, starting with the central incisor region and progressing posteriorly, to the left and right.

A consideration of the above factors in postmortem radiographic examinations will enable the forensic dentist to determine the direction of vertical or horizontal angulation change in antemortem radiographs, when compared to standard projections taken postmortem. This information, once interpreted, will allow the dentist to so vary the direction of the X-ray beam in relation to the dentition, to give views that more closely resemble the antemortem radiograph. Several exposures, however, may still need to be taken before a satisfactory radiograph is obtained.

8.4.2.2 Tooth length and angle of projection

In clinical dental practice as has been mentioned, the most commonly taken radiographs for diagnostic purposes are bitewing projections. As such, these radiographs are likely to be presented for postmortem comparison and, in the majority of cases, are easily able to be reproduced.

In an investigation of unknown human remains, the suggested radiographic survey that should be taken of the dentition, for comparison with records that may become available at a later date, are periapical projections of the upper anterior teeth, bitewings of the posterior teeth (at standard angles of projection) and oblique lateral projections of the lower molar teeth.

Some postmortem investigations may require the comparison of a single periapical projection, for specific minute detail, that may have been taken of the maxillary anterior region, or of the maxillary or mandibular premolar/molar regions. In such cases, it would be helpful to the forensic dentist, if the angle of projection of the antemortem periapical radiograph could be determined. This would enable a postmortem radiograph to be produced that closely resembles the antemortem radiograph, with a minimum number of exposures having to be made.

The principles of the "buccal object rule", when applied to a postmortem periapical projection, taken of a particular region for comparison purposes, are able to determine the direction of vertical

and/or horizontal angulation changes required to be made, to produce a radiograph that more closely resembles the antemortem film. The degree of angulation change, however, cannot be determined from these principles, nor has the problem been addressed in the literature.

In an effort to determine a correlation between angle of projection and tooth length, a series of radiographs of postmortem specimens were taken and various measurements recorded.

Method

It was assumed that the majority of periapical radiographs taken in clinical practice are based upon the "bisecting angle" technique.

Periapical radiographs were taken of the maxillary anterior region and the maxillary and mandibular premolar/molar regions of clean, dry postmortem specimens, using the principles of the "bisecting angle" technique (Figure 59).

Specimens were arranged such that the sagittal plane was vertical and the occlusal plane horizontal (Figure 60). Film was positioned (and supported with plasticine or adhesive tape) in relation to the dentition, as it would be in the living patient. Radiographs were taken of each area at standard angles of projection.

The length of a selected tooth on the processed radiographs at the standard angle of projection, was measured with Vernier calipers

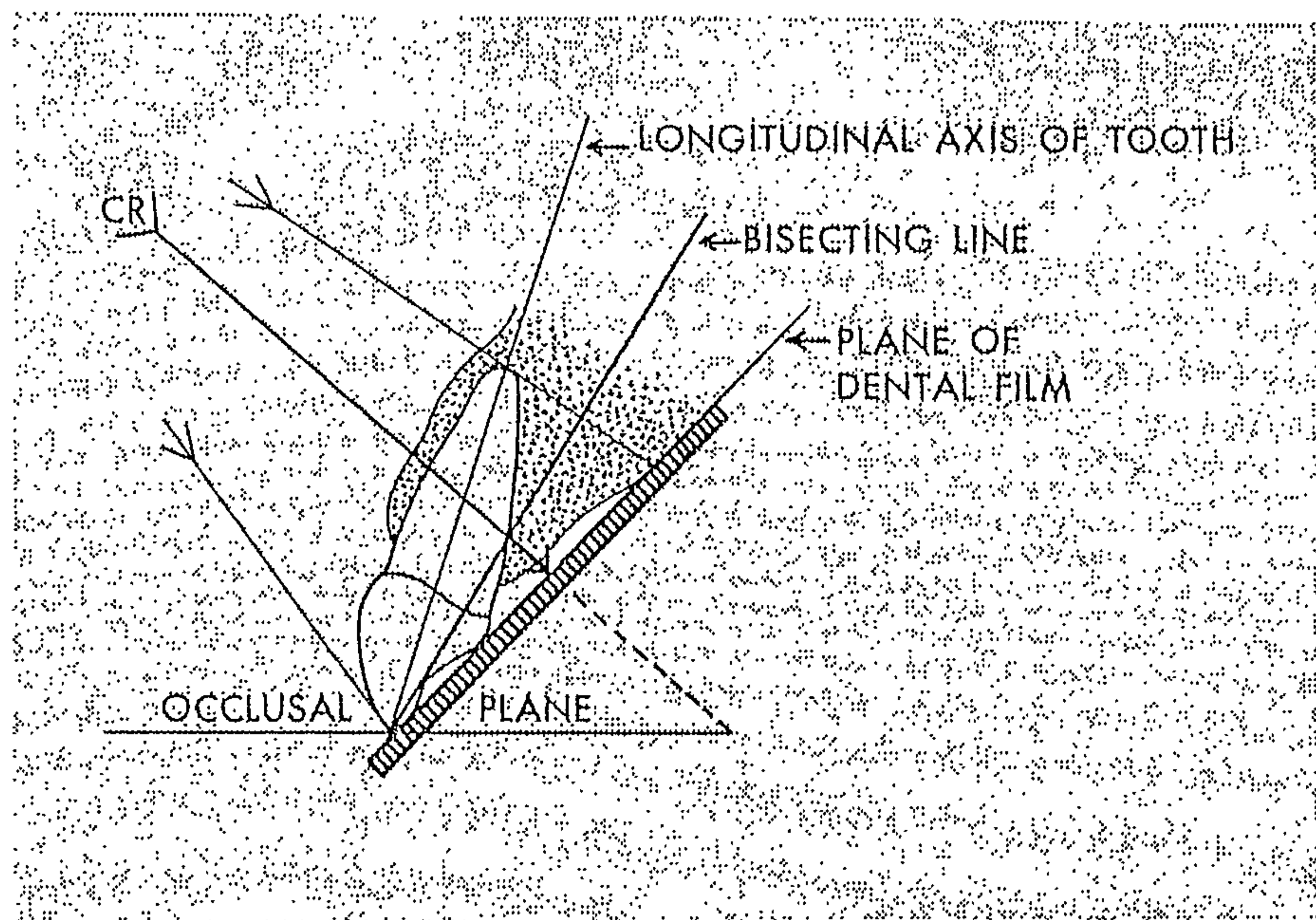


Figure 59. The Bisecting Angle Technique
(Eastman Kodak Company, 1985).



Figure 60. Positioning resected specimens
for radiography.

and recorded. The same tooth was also measured for each angulation change and that measurement recorded, as well as the change in length from the standard.

The data obtained was applied to determine whether there was a reproducible correlation between changes in tooth length and angles of projection.

For each area previously examined, a periapical radiograph (antemortem radiograph) was taken at an unknown angle of projection and the length of the same tooth as measured in the first series of radiographs was recorded. Periapical radiographs (postmortem radiographs) of the same regions were then taken at standard angles of projection and the same teeth measured. The difference in tooth length between the antemortem and postmortem radiographs was obtained and compared with the recorded data.

Further periapical radiographs were then taken using angles of projection from the data, that most closely reflected the changes in tooth length between the antemortem and postmortem films, and compared with the tooth length of the antemortem radiographs.

Results

Tables 4, 5, 6, 7 and 8 tabulate angles of projection and tooth length for each area examined, as well as the length variation for each angle of projection, from that of the recorded length at standard angle of projection.

RADIOGRAPHIC LENGTH CHANGES

Table 4

UPPER CENTRAL INCISORS

S.A.P. +40°

ANGLE	TOOTH LENGTH	LENGTH CHANGE	*
25°	30.0 mm	3.5	
30°	29.2	2.7	
35°	28.1	1.6	
40°	26.5	0	
45°	26.0	0.5	
50°	23.8	2.7	
55°	23.1	3.4	

* Length change from standard angle of projection

Key: S.A.P. = Standard Angle of Projection

Table 5

UPPER PREMOLARS

S.A.P. +30°

ANGLE	TOOTH LENGTH	LENGTH CHANGE	*
15°	25.3 mm	3.8	
20°	24.0	2.5	
25°	22.2	0.7	
30°	21.5	0	
35°	21.3	0.2	
40°	21.7	0.2	
45°	21.4	0.1	

* Length change from standard angle of projection

Table 6

UPPER MOLARS

S.A.P. +20°

ANGLE	TOOTH LENGTH	LENGTH CHANGE	*
5°	26.2 mm	1.6	
10°	25.4	0.8	
15°	24.5	0.1	
20°	24.6	0	
25°	23.7	0.9	
30°	23.5	1.1	
35°	23.3	1.3	

* Length change from standard angle of projection

Table 7

LOWER PREMOLARS

S.A.P. -10°

ANGLE	TOOTH LENGTH	LENGTH CHANGE	*
5°	25.0 mm	0.2	
0°	24.8	0.4	
- 5°	25.3	0.1	
-10°	25.2	0	
-15°	25.0	0.2	
-20°	24.7	0.5	
-25°	24.2	1.0	

* Length change from standard angle of projection

Table 8

LOWER MOLARS

S.A.P. -5°

ANGLE	TOOTH LENGTH	LENGTH CHANGE *
10°	23.8 mm	0.3
5°	23.9	0.4
0°	24.2	0.7
- 5°	23.5	0
-10°	23.5	0
-15°	22.8	0.7
-20°	22.3	1.2

* Length change from standard angle of projection

Discussion

A change in the tooth length does occur from that length recorded on a radiograph taken at standard angle of projection, when the angle of projection is either increased or decreased. There is not a proportional linear relationship between length change and angle of projection, but it is possible to demonstrate that these length changes are reproducible according to the angle of projection.

Certain variations in tooth length between antemortem and postmortem radiographs, taken at similar angles of projection, are to be expected. It is not possible from the data to exactly reproduce an angle of projection, with its corresponding exact tooth length change, but it is possible to achieve results that will enable positive postmortem identification, based upon antemortem and postmortem radiographs, to be made.

Variables such as :-

- (i) film position relative to the dentition;
- (ii) film curvature relative to the dentition, and
- (iii) film angulation relative to the dentition, will influence tooth length at any given angle of projection.

Further, variables such as :-

- (iv) short or long cone "bisecting angle" technique
or
- (v) radiographs that have been taken using the "paralleling" technique add to the problem of exact reproduction of angle of projection and tooth length.

Tables 9, 10, 11, 12 and 13 record measurements of changes in tooth length for various angles of projection as measured from drawings of teeth of average length, and Tables 14, 15, 16, 17 and 18 are a composite of the measurements of Tables 4 to 8 and Tables 9 to 13.

The measurements indicate that there is not a proportional linear relationship that can be demonstrated between tooth length and angle of projection, for any area that was examined.

Table 19 tabulates tooth length from the antemortem radiographs, the postmortem radiographs at standard angle of projection, the length variation between the two, the suggested angle of projection of the antemortem film from the recorded data and the tooth length from the postmortem radiographs taken at the angle of projection determined from the recorded data.

Table 19 suggests that there is a reproducible correlation between tooth length and angle of projection, as demonstrated in the radiographs taken. The data recorded in Tables 4 to 8 can therefore be used to produce postmortem radiographs that closely resemble antemortem radiographs for the areas under consideration. Figure 61 illustrates the radiographic results of a postmortem investigation using the above method.

There does not appear to be a significant change in the width of a tooth, with minor variations in the horizontal angle of projection.

CALCULATED LENGTH CHANGES

Table 9

UPPER CENTRAL INCISORS

S.A.P. +40°

ANGLE	TOOTH LENGTH	LENGTH CHANGE *
25°	31.7 mm	1.7 mm
30°	31.0	1.0
35°	30.5	0.5
40°	30.0	0
45°	29.9	0.1
50°	29.0	1.0
55°	28.7	1.3

* Length change from standard angle of projection

Table 10

UPPER PREMOLARS

S.A.P. +30°

ANGLE	TOOTH LENGTH	LENGTH CHANGE *
15°	24.9 mm	1.3
20°	24.1	0.5
25°	24.0	0.4
30°	23.6	0
35°	23.2	0.4
40°	23.0	0.6
45°	22.5	1.1

* Length change from standard angle of projection

Table 11

UPPER MOLARS

S.A.P. +20°

ANGLE	TOOTH LENGTH	LENGTH CHANGE *
5°	24.6 mm	0.5 mm
10°	24.7	0.3
15°	24.8	0.2
20°	25.0	0
25°	25.2	0.2
30°	25.5	0.5
35°	25.6	0.6

* Length change from standard angle of projection

Table 12

LOWER PREMOLARS

S.A.P. -10°

ANGLE	TOOTH LENGTH	LENGTH CHANGE *
5°	25.4 mm	0.4 mm
0°	25.1	0.1
- 5°	25.0	0
-10°	25.0	0
-15°	24.8	0.2
-20°	24.7	0.3
-25°	24.5	0.5

* Length change from standard angle of projection

Table 13

LOWER MOLARS

S.A.P. -5°

ANGLE	TOOTH LENGTH	LENGTH CHANGE *
10°	24.9 mm	0.5 mm
5°	24.6	0.2
0°	24.4	0
- 5°	24.4	0
-10°	24.4	0
-15°	24.3	0.1
-20°	24.3	0.1

* Length change from standard angle of projection

COMPOSITE CHARTS

AVERAGE OF CALCULATED & RADIOGRAPHIC LENGTH CHANGES

Table 14

UPPER INCISORS

S.A.P. +40°

ANGLE	TOOTH LENGTH	LENGTH CHANGE *
25°	30.8 mm	2.6
30°	30.1	1.9
35°	29.3	1.1
40°	28.2	0
45°	27.9	0.3
50°	26.4	1.8
55°	25.9	2.3

* Length change from standard angle of projection

Table 15

UPPER PREMOLARS

S.A.P. +30°

ANGLE	TOOTH LENGTH	LENGTH CHANGE *
15°	25.1 mm	2.6
20°	24.0	1.5
25°	23.1	0.6
30°	22.5	0
35°	22.2	0.3
40°	22.3	0.2
45°	21.8	0.7

* Length change from standard angle of projection

Table 16

UPPER MOLARS

S.A.P. +20°

ANGLE	TOOTH LENGTH	LENGTH CHANGE	*
5°	25.4 mm	0.6	
10°	25.0	0.2	
15°	24.6	0.2	
20°	24.8	0	
25°	24.4	0.4	
30°	24.5	0.3	
35°	24.4	0.4	

* Length change from standard angle of projection

Table 17

LOWER PREMOLARS

S.A.P. -10°

ANGLE	TOOTH LENGTH	LENGTH CHANGE	*
5°	25.2 mm	0.1	
0°	24.8	0.3	
- 5°	25.1	0	
-10°	25.1	0	
-15°	24.9	0.2	
-20°	24.7	0.4	
-25°	24.3	0.8	

* Length change from standard angle of
 projection

Table 18

LOWER MOLARS

S.A.P. -5°

ANGLE	TOOTH LENGTH	LENGTH CHANGE *
10°	24.3 mm	0.5
5°	24.2	0.4
0°	24.3	0.5
- 5°	23.8	0
-10°	23.8	0
-15°	23.5	0.3
-20°	23.3	0.5

* Length change from standard angle of projection

Table 19

COMPARISON OF ANTEMORTEM RADIOGRAPHS WITH
POSTMORTEM RADIOGRAPHS TAKEN AT A
SUGGESTED ANGLE OF PROJECTION DETERMINED
FROM THE DATA

TOOTH	A.M. LENGTH	P.M. LENGTH AT S.A.P.	LENGTH CHANGE FROM S.A.P.	SUGGESTED ANGLE OF PROJECTION	P.M. TOOTH LENGTH AT SUGGESTED A.P.
UPPER CENTRAL INCISOR	29.3 mm	26.5 mm	2.8 mm	30°	29.1 mm
UPPER PREMOLAR	22.4	21.5	0.9	25°	22.8
UPPER MOLAR	24.0	24.6	0.6	25°	24.1
LOWER PREMOLARS	23.5	25.2	1.7	> -25°	23.2
LOWER MOLARS	23.0	23.5	0.5	-15°	22.5

Key: A.M. = Antemortem
 P.M. = Postmortem
 A.P. = Angle of projection

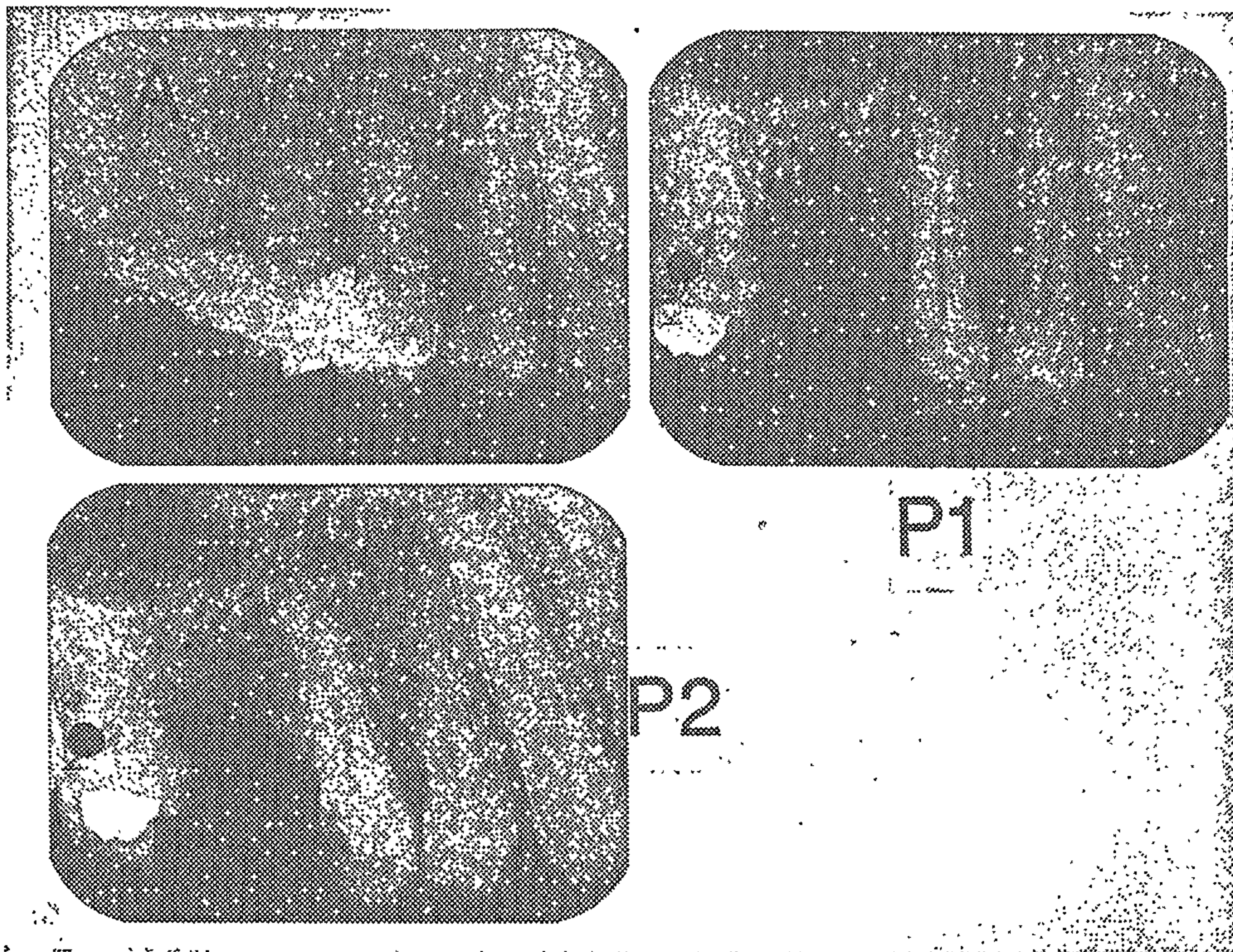


Figure 61. Antemortem/postmortem radiographs
(Recent postmortem investigation).

Figure 62 illustrates the difference in tooth length obtained from that of the standard angle of projection and demonstrates that there is not a proportional linear increase or decrease in tooth length, according to the angle of projection. It is seen that the radiation source, when the "bisecting angle" technique is used, rotates about the apex of the tooth being radiographed (the crown being in contact with the film), and as the vertical angle of projection is varied, it can be seen that :

- (i) increasing the angle of projection produces a small change in tooth length, and
- (ii) decreasing the angle of projection produces a correspondingly large change in tooth length.

As the angle of film placement varies in relation to the longitudinal axis of the tooth (i.e. as the apex of the tooth either moves further away from or closer to the film), then it can be seen that:

- (iii) increasing the angle of film placement relative to the longitudinal axis of the tooth produces a larger change in tooth length, and
- (iv) decreasing the angle of film placement relative to the longitudinal axis of the tooth, produces a smaller change in tooth length, according to the angle of projection of the X-ray beam.

Tables 14 to 18, being averages of recorded radiographic tooth lengths and tooth lengths determined theoretically, illustrate the variability in tooth lengths that may be obtained in practice, because of film angulation differences.

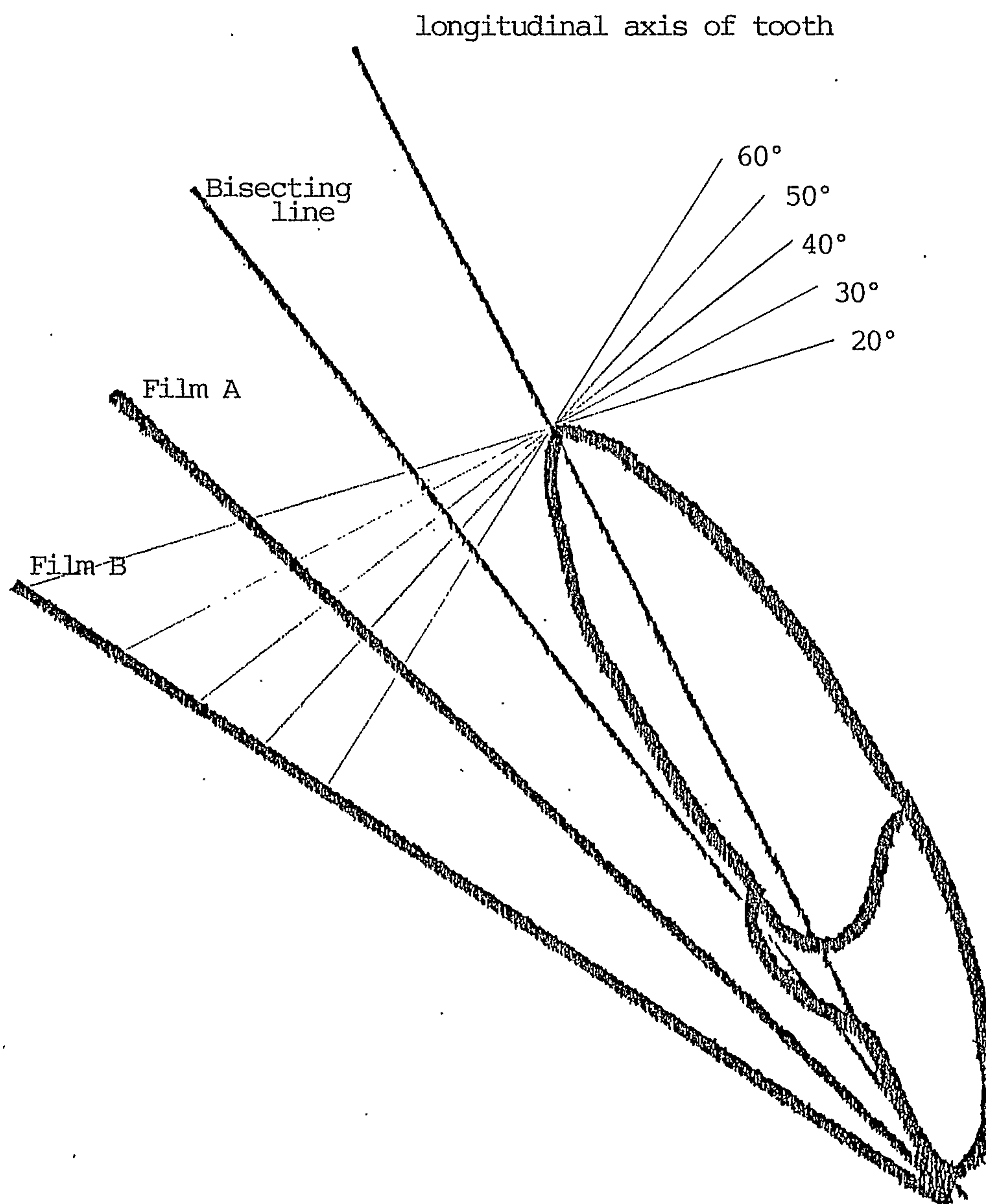


Figure 62. Bisecting Technique

Recorded tooth length increases significantly when angle of projection is decreased and also when angulation of film relative to longitudinal axis of tooth increases.

A proportional linear relationship according to tooth length and angle of projection does exist, when periapical radiographs are taken using the paralleling technique (Figure 63). This is reflected in part, in the changes in tooth length recorded for lower premolars and molars, where film placement relative to the longitudinal axis of the tooth concerned, approaches parallelism.

The principles of the "buccal object" rule and the data recorded in the Tables above, enable postmortem radiographs to be produced, that closely resemble given antemortem radiographs, more easily and with a minimum number of exposures, than is usually the case, with the "trial and error" techniques that are presently employed in forensic dentistry.

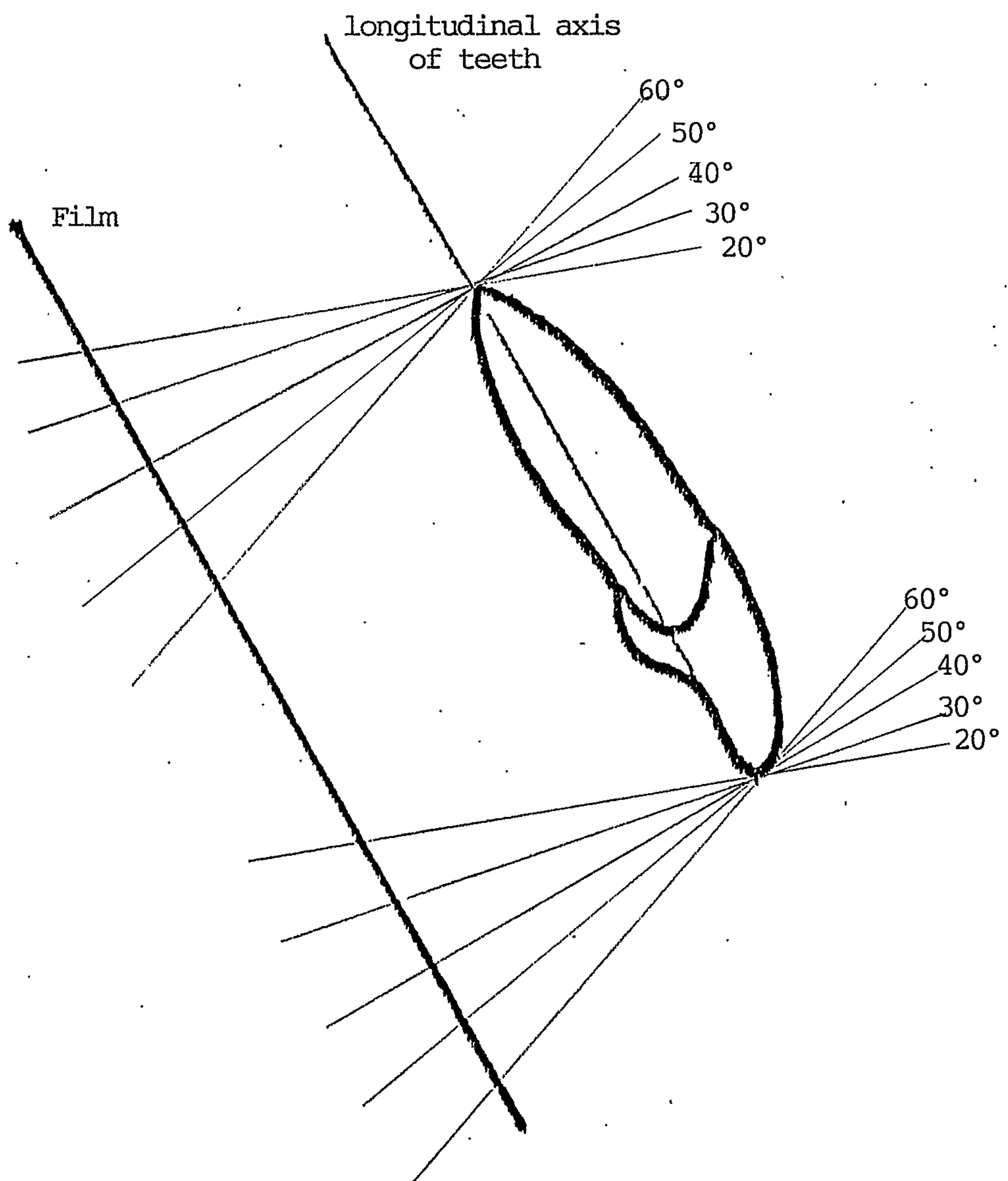


Figure 63.

Paralleling Technique

Tooth length does not vary with angle of projection. A proportional linear relationship exists between tooth length and angle of projection.

8.5 RADIOGRAPHIC IMAGE DIGITISATION IN FORENSIC DENTISTRY

Computerised storage, retrieval and transmission of radiographic images, has application in forensic dentistry (Southard and Pierce, 1986). The system allows for radiographic images to be electronically processed and also to be remotely viewed and stored.

Southard and Pierce (1986), suggest that such a system has application in archiving antemortem dental data of military personnel. In the event of a mass disaster, information could be transmitted to the investigation site, to a compatible computer via telephone modem.

The Eastman Kodak Company (1985), describe the image transmission system as consisting of a lightbox assembly, with an attached high-quality, electronically controlled zoom-lens video camera, a video monitor console, a key-board and joystick controls for image processing and a personal computer. Built into the system is a special image-digitising "frame grabber" and a telephone modem with bit preserving data compression.

The system scans, digitises and stores a radiographic image and has the capacity for improved visualisation of small areas of interest, by providing close up images, by means of adjusting the video camera's zoom-lens until the area of interest fills up the monitor screen. This optical magnification increases effective resolution, therefore providing additional detail for study.

Southard and Pierce (1986), consider that the images most helpful in postmortem identifications, and therefore those that should be digitised from the antemortem records, are bitewing, periapical and panoramic radiographs.

The transmission of digitised radiographic images by telephone modem, to a compatible computer system, has been judged to be of sufficient resolution (Southard and Pierce, 1986) for use in forensic comparison.

Dr. Ken Brown, of the Dental Department of the University of Adelaide, has recently begun to study the forensic dental applications of radiographic image digitisation. A programme currently in use by Dr. Brown, enables an image to be enhanced, manipulated and rotated through various co-ordinates, to facilitate comparison with postmortem radiographs. That is, the angle of projection of a radiograph can be duplicated electronically on a computer screen, without the need to take several postmortem radiographs of a specific area.

Digitised image transmission systems are widely used in medical radiology and could be of great value in forensic investigations, especially when combined with a computerised dental examination/treatment record system.

9. SUMMARY

The primary intention of forensic dentistry is to identify people, either known or unknown, whether they are living or dead, by examining the dentition and supporting structures. Forensic dentistry is of special importance in the identification of victims of disasters.

The certification of death is a legal requirement in most western countries and is based upon the identification of a body. Serious legal, financial and social complications may arise if identification, for whatever reason, cannot be carried out.

Positive identification is determined by the concordance of post-mortem and antemortem data, gathered from a variety of sources, e.g. family and medical and dental records. Data should be collected by authorities as soon as a person is reported missing or as soon as possible following accidents or disasters.

A variety of methods are used to establish identity, however, fingerprints and the dental condition provide the most scientifically reliable means of identification.

In forensic dentistry the oral examination is an essential part of any examination. The method of examination of the dental structures is determined by the condition of the remains. In many cases, access to the oral cavity is obtained by performing an oral autopsy. Examination may then be carried out with the jaws in situ, or the jaws may be removed, cleaned and examined under ideal conditions.

The postmortem data obtained from the oral examination must be as accurate as possible. It must include all potentially identifying characteristics of the dentition. Comparisons with antemortem data may not be possible for some time after the investigation, or even until after the remains have been disposed of.

Important dental characteristics, such as dentures, the teeth, tooth sockets, dental caries, restorations and materials used, the occlusion, anomalies in the shape and number of the teeth and oral pathology, all provide valuable information upon which to establish identity. Photographs, radiographs and study models may also need to be obtained to complete the postmortem investigation.

Antemortem dental data must be as complete and as accurate as possible, to minimise unnecessary delays in establishing identity. Unfortunately, many dental records are incomplete, lack radiographs and often record financial details of treatment, without specifying either the tooth treated or treatment given. Radiographs, if available, provide the most positive data and accurate means of establishing identity, when compared with postmortem radiographs.

The assessment of age of human remains may represent a critical aspect of identification, especially in cases of incineration, gross decomposition or skeletonisation.

The radiographic examination of the stages of formation and the progress of development of the teeth, represent the most reliable

means of assessing chronologic age, from about five months in utero to fifteen years. During this period there is continual growth, development and intermixture of the primary dental follicle, through the various stages of tooth mineralisation, ending in mature root formation with the closure of the apical foramen.

From fifteen to twenty years of age, the radiographic assessment of dental age is confined to the development of the roots of the second and third molar teeth. The variable development of these teeth makes age assessment in this period less reliable.

Radiographs of the dentition compared with standard charts developed from radiographic data, such as those of Schour and Massler, and Moorrees, Fanning and Hunt, or Gustafson and Koch, help determine the age of a victim.

With regard to forensic examinations, the radiological examination can be performed without tissue removal. It should be carried out early in an investigation, and not as an after-thought. The radiographic appearance of the teeth and the bones of the face, is a permanent record of these tissues and is available for reference even when teeth and sections of bone have to be removed for histopathological examination.

Radiographic apparatus generally available in mortuaries is unsuitable for dental procedures, because of the size and limited angulation of the tube head. A variety of portable radiographic apparatus

is available and can be used in remote sites if necessary, however, it is often preferable to remove the jaws and complete the dental examination and radiography in a dental facility, under ideal conditions.

Cottone and Standish (1982) state that, for identification purposes, properly exposed, developed and mounted radiographs are as good, if not better, than fingerprints.

Radiographic features noted by the forensic dentist in comparison exercises include: the size and shape of the pulp chamber, the relationship of the cemento-enamel junction to the alveolar crest, root shape and angulation, periodontal membrane width, the lamina dura, the root apex and the relationship of both periodontal membranes and lamina dura to the apex of the tooth.

In the absence of restorations or teeth, bony trabecular patterns may be distinctive and give added weight to dental identification. Radiographs show a certain regularity of trabecular pattern, with specific width, density and arrangement, which are stable unless surgical interference has occurred.

The skull itself, apart from the teeth and jaws, is the most helpful area of the body for comparison radiography. Extra-oral radiography is able to show many highly individualistic features, which can be compared with postmortem radiographs. Some of these factors may be listed as :-

- (i) the position of the mandibular foramen;
- (ii) the length and thickness of the styloid process;
- (iii) the shape of the coronoid process;
- (iv) the length, size and shape of the head of the condyle;
- (v) the depth of the glenoid fossa;
- (vi) pneumatization of the maxillary sinuses;
- (vii) the position of the incisive and mental foramina;
- (viii) size and shape of the nasal cavity;
- (ix) size and shape of the frontal sinus;
- (x) the size and shape of the sella turcica, and
- (xi) various features of bony pathology.

On some occasions, when the comparison techniques cannot be used because of the lack of suitable antemortem data, radiographic or photographic superimposition techniques may be employed to gain additional information in the identification of unknown human remains.

In clinical practice, the maintenance of radiographic standards by individual practitioners may often be a problem and is reflected in the quality of antemortem radiographs submitted for postmortem comparison. Practitioners must be encouraged to adopt criteria for diagnostically acceptable radiographs as a service to their patients and the practice of dentistry.

Radiographic techniques employed in forensic dentistry differ from those used in clinical practice, with respect to head position

and support, film placement and support and exposure times. In the non-visually identifiable body, radiographs ideally are taken on resected specimens, using techniques that position the specimens as they would be in the living patient, with respect to occlusal and sagittal plane positioning. Film placement and support, however, and exposure times will vary.

Exposure times are generally reduced in postmortem radiography and may vary from between one-third to two-thirds the normal exposure times, depending upon the thickness of the tissues being radiographed.

It must be remembered that in the decomposed or skeletonised specimen, teeth loosen in their sockets and must therefore be firmly pushed into position before radiographs are taken.

If antemortem radiographs are available at the time of the postmortem radiographic examination, the forensic dentist must endeavour to duplicate film placement relative to the dentition and the angulation of the X-ray tube to the film, of the original radiographs, to enable positive comparison.

Radiation safety in forensic dentistry may not always be fully considered. Radiation safety must be directed towards the dentist and personnel working within the vicinity of radiographic equipment, using such measures as distance from the radiation source, position in relation to the radiation source, the use of protective barriers, and the use of radiation monitoring devices such as badges.

Radiographs may be marked permanently by a variety of methods, the prime requisites being that this is done at either the time of exposure or of processing, that the radiographs be accurately marked according to the specimen being radiographed and that marking is placed in a position on the radiograph, free of anatomic structures.

Duplicating antemortem angles of projection is often a problem in postmortem radiography, especially so far as periapical radiographs are concerned. Several films at various angles of projection often need to be taken to obtain one from which a comparison can be made. Trial and error is the usual means of obtaining a satisfactory result.

A consideration of the "buccal object rule", a technique of radiographic localisation, may enable antemortem angles of projection to be reproduced more easily than is usually the case, especially when these techniques are used in conjunction with data derived from the correlation of both length and angle of projection, as described.

The capture, storage and transmission of radiographic images by computer digitisation is being applied to forensic dentistry.

The system allows radiographic images to be enhanced and manipulated to simulate changes in angles of projection and also to record detail from previously unusable "poor quality" radiographs. Such systems are expensive and unlikely to be readily available for

general use in forensic dentistry, but add to the possibilities of establishing identity in difficult cases.

CONCLUSIONS

- (1) The certification of death based upon the identification of a body is a legal requirement.
- (2) Forensic dentistry provides a scientifically proven method of establishing identity, using the condition of the dentition and supporting structures, in an otherwise unidentifiable body.
- (3) The teeth, jaws and skull are valuable sources of information from which radiographic comparisons can establish identity.
- (4) Postmortem dental radiography provides the most accurate information upon which to establish identity, when compared with antemortem radiographic data.
- (5) Postmortem dental radiography can accurately determine the age of an individual, from five months in utero to fifteen years, by the comparison of radiographs with standard tooth development charts.
- (6) There are certain problems associated with postmortem dental radiography. These may be listed as :-
 - (i) the availability of radiographic and processing equipment at the site of the investigation;
 - (ii) access to the oral cavity for intraoral radiography;

- (iii) the need to vary angles of projection in relation to the head position in the supine body;
- (iv) the need to resect jaws in many cases, to facilitate radiographic examination;
- (v) film placement and support relative to the dentition;
- (vi) the need to vary exposure times to produce an acceptable image, depending upon the thickness of the material being radiographed;
- (vii) the need to duplicate angles of projection in the postmortem radiograph to produce an image similar to the one on an antemortem radiograph.

This treatise has described the current status of forensic dentistry with reference to dental radiographic identification and has provided suggestions and solutions to a variety of problems encountered during the postmortem radiographic examination.

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