Collection and Recording of Radiological Information for Forensic Purposes

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Key Words: Forensic, forensic odontology, radiology, dental radiology, forensic radiology
Abstract

Forensic odontology is the application of dental expertise to legal issues. Commonly, it involves the comparison of dental records of a missing person with a deceased individual for the purposes of forensic personal identification, either in a single case, or as part of the response to an event involving multiple simultaneous fatalities (Disaster Victim Identification, or DVI). It also may involve studies to determine the age of an individual, which may be required as part of a forensic identification process, or for another legal purpose such as the determination of legal responsibility, or in connection with immigration.

This report examines the types of radiological information currently used in such forensic studies, and discusses how this information may be accessed or recorded, as well as the techniques that are commonly applied to the radiological data to reach a satisfactory outcome for application in forensic casework.

Key Words: Dental Radiology, Forensic, Forensic Odontology, Forensic Radiology, Radiology
Introduction

A common task undertaken by forensic odontologists is comparison of dental records to investigate the identity of an individual, with subsequent preparation of a report to a coroner who will determine the question of identity based on this and other available evidence. This may be done as part of a routine coronial investigation, or following a mass disaster. It comprises the compilation of data about a missing individual and of a deceased person, and the subsequent comparison between the two. The findings may be expressed in the following internationally-accepted terms (1) where AM = ante-mortem (before death) and PM = post-mortem (after death):

- **Identification**: There is absolute certainty the PM and AM records are from the same person
- **Identity Probable**: specific characteristics correspond between PM and AM but either PM or AM data or both are minimal
- **Identity Possible**: there is nothing that excludes the identity but either PM or AM data or both are minimal
- **Identity excluded**: PM and AM records are from different persons
- **No comparison can be made**

While some variation in the expression of the categories used in different States and Territories in Australia has been documented (2), the Australian Society of Forensic Odontology suggests similar categories for identification in its Disaster Victim
Identification (DVI) Guide (3), but with one important difference; its definition of Identification includes a reference to radiographs:

- “Identity Established: The PM and AM data correspond in sufficient detail to establish that they are from the same individual. There is radiographic evidence in support of the identification, and there are no irreconcilable discrepancies.”

This underlines the importance that is placed on radiographic evidence, and for good reason.

Brown (4) discusses the importance of following appropriate protocols for retrieval of AM dental records. Such protocols help, among other things, to ensure that the records have not been tampered with or exchanged before they reach the forensic odontologist by documenting the chain of custody and ensuring the probative value of the records. Wood (5) points out that dental records may be the subject of fraud, and this has also been true in our experience. Written records, or elements within them, may be falsified. We have also noted a case of identity theft in recent times which would mean that, should the dental records apparently belonging to an individual be compared with the actual individual, exclusion would result. For this reason, statements relating to the conclusions reached should contain a caveat relating to this possibility.

Further, genuine mistakes may have been made in recording (5, 6). In other words, written dental records are subjective, interpreted records that do not derive directly from an individual, and which may be subject to errors, inaccuracies and deliberate falsifications.
Radiographic images, however, do derive directly from an individual and record exactly what is projected onto the image sensor during radiological examination. They are objective records that document detailed morphology of the dentition and surrounding bony structures (6). They may also record detailed morphological information about dental treatments including extractions, and restorations including root canal treatments, if they are present. This objectivity is of first importance in the determination of identity by comparison, and also in other forensic applications such as age determination.

In cases where dental radiographs are used for identification, distinctive features are sought and used for comparison between AM and PM images. These may include the specific individual morphology of dental restorations, evidence of past trauma and/or surgical treatment such as healed fractures, surgical plates, absent teeth and misaligned teeth. In the absence of restorations or evidence of other dental treatment (or together with them), anatomical features including tooth morphology (shapes, arrangement and relative sizes of teeth, roots, pulp chambers and root canals), pneumatic sinuses, and bone morphology including trabeculae, may be used, generally with a reduced degree of ease and frequently with a lesser degree of confidence. Richmond (7) reports that such comparisons may still be useful even in edentulous cases although a higher error rate is observed. The important issue is that the concordance between AM and PM images should be sufficiently high that there is no doubt that the two images derive from the same individual, and that any discrepancies noted should be explainable.

Adams (8, 9) attempted to lay a statistical groundwork for the use of comparisons of features of the dentition to determine human identity by surveying the patterns of
dental features of large numbers of American civilian and military subjects. However, the use of frequencies of observations is specific to a given population at a given time, and even then tends to fail when applied to individuals with few recorded dental features. A case in point is a missing person whose dental records indicate only a single amalgam restoration on the occlusal surface of, for example, 16, and a deceased person with a single amalgam restoration in the same place. The observation of the single filling in the deceased simply places that person into the category of persons of similar age and sex with that characteristic. Although it is consistent with the AM dental record, there are likely to be a number of matching individuals with the same dental pattern, and so it fails to identify conclusively. Since these papers were published, new dental materials and treatments have become common, and rates of caries and interventional dental treatment have changed in the US (10), worsening the odds considerably.

It is worth noting however, that even then, Adams recognised that “few forensic odontologists would question the validity of congruence of features in PM and AM radiographs” (9). An excellent review of forensic applications of maxillofacial radiology was provided by Wood (5).

Two basic types of radiographic imaging technology are commonly applied to forensic odontology investigations: plain-film radiographs and CT scans. These are considered in the sections below.

Specific techniques to be applied in any given case will depend crucially on the types and quality of the AM radiographs that are available to the forensic odontologist.
Plain Film Radiographs

Plain film radiographs are those taken without the aid of a contrast medium. Those
most commonly available as part of the AM dental record include the bitewing and
periapical radiographs, and the orthopantomogram (OPG)(11), although various other
views of the skull and portions of it may also be available. Bitewings, periapical and
OPG images are generally considered to be the most useful in forensic odontology
because they show clear images of the teeth and morphological detail of artefacts
resulting from trauma and dental treatment. Frontal sinus radiographs have also been
used to establish identity (12).

In Australia, most mortuaries are equipped to obtain bite-wing and periapical
radiographs of deceased persons but very few mortuaries are equipped with dedicated
machines for PM OPG radiographs. OPGs are problematic, positioning of the body of
the deceased may be difficult, and excision of the jaws may be required to obtain a
useable image. OPGs are therefore not commonly taken as part of the dental PM,
although more recently, simulated OPG –like images may be reconstructed from PM
CT (Computed Tomography) data for comparison with AM OPGs (13). PM bite-wing
radiographs may be very difficult to obtain and frequently, such images will be taken
of a single jaw, simulating the conditions for a bite-wing exposure as closely as
possible.

In cases of routine forensic identification where a police investigation has determined
a missing person whose records are to be compared with those of the deceased, it is
invariably better to wait until radiographs included in AM dental records are available
before taking corresponding PM images, as then one can duplicate as closely as
possible the geometry of the AM image to facilitate comparison. Small changes in
image geometry can result in significant changes in the way that the same items appear on different radiographs (5), and comparison using PM images taken without reference to AM radiographs may prove difficult for non-experts, including coroners (the identifying authority in Australia), to understand.

In DVI operations the aim of the dental radiological examination is to provide unambiguous documentation of the teeth and jaws of the deceased at the time of death (14). It is very rarely possible to obtain AM records for comparison prior to radiological examination of the deceased in such circumstances.

Sometimes, even when excellent AM images are available, the demands on the forensic odontologist’s radiographic skills may be extraordinary. A deceased person may exhibit a posture that may make radiographic access difficult, particularly when rigor mortis is present. This is also commonly encountered with incinerated victims, where heat-induced muscle contraction may cause the limbs to become friable and to move into extreme positions that cannot easily be altered without dissection, providing physical barriers to radiographic equipment (11). Rigor mortis may also limit the amount by which the mouth can be opened (15). While others have recommended jaw resection as a routine part of PM examination in DVI operations (16) or espoused its usefulness in routine PM dental imaging (11), we aim to resect jaws as rarely as humanly possible to prevent avoidable further mutilation out of basic human respect, and therefore most commonly have to work around such difficulties.

In Queensland, for example, Coroners now require a formal request and justification before approval will be given for any jaw resection. In such circumstances, it may be impossible to obtain PM images that closely duplicate an available AM image.
Matching of Plain Film Radiographs

Pairs of AM and PM plain-film dental radiographs may be compared, with common features being highlighted and commented upon, or they may be superimposed on each other to demonstrate the similarity between common elements. Less commonly, similarity between them may be demonstrated by subtraction imaging in various forms. The greatest weakness in rigorous comparison of corresponding radiographic images for forensic purposes is the lack of a certified external measurement scale against which different images can be demonstrated to be directly comparable. However, given that most AM radiographs are not taken for evidential purposes, this is a factor that is beyond our control.

Visual comparison of pairs of corresponding radiographs may be thought of as a pattern-matching exercise (17). The accuracy of comparison of dental bite wing radiographs of individuals with unrestored dentitions has been investigated recently in adults by Wenzel et. al. (17), and in children by Fridell and Ahlqvist (18). Both studies concluded that experts (maxillofacial radiologists, forensic odontologists) are generally better at matching than others, confirming the results of an earlier study (19), but in none of these cases was image geometry tightly controlled. Both of the more recent studies suggested that younger children would prove more difficult to identify by such comparison as a result of likely developmental changes between the taking of the AM and PM images and the fact that less information was likely to be present on them (17, 18), an issue brought into tight focus in the 2004-2005 Thailand Tsunami DVI operation. All of these studies relied on the most difficult of scenarios – unrestored dentitions - and two of them relied on simulated situations involving the use of dried skulls. Interestingly, all of them found a high degree of reliability in the
technique, particularly when applied by an expert forensic odontologist, but matching errors were seen in all studies. Some attempts have been made to remove subjectivity by automating the process (20).

An example of a forensic radiographic comparison is shown in Fig 1.

Some workers have reported standard methods for PM dental radiography that they suggest should be routinely used (for example Raitz et al. (21)), but these authors appear to miss the point that, when AM radiographs are available, the object of the exercise is to duplicate their geometry as accurately as possible rather than to take standard PM radiographs.

Duplicating image geometry may severely test the radiographic skill of even the most experienced forensic odontologist, but if corresponding images of sufficient similarity are obtained, then superimposition of the common elements of both may be possible to demonstrate the constellation of common elements. Wood (5) describes a variation on the superimposition technique where a strip showing anatomical features is digitally cut from one radiograph and placed over a corresponding image to show the similarity of the features. Besana and Rogers (12) emphasize the reliability of superimposition in using radiographs of the frontal sinus for forensic identification. It is possible to demonstrate simultaneous comparison of all of the corresponding features of two radiographs by digitally overlaying the PM radiograph on the corresponding AM image, aligning the common features of each, and showing the relationships by reducing the opacity of the overlying image to show the features of the underlying radiograph. The outcome can be seen in Fig 2.
Some workers have expressed the view that affine image transformations can be applied to one of a pair of corresponding radiographic images to show that they are of common origin (22), but there are dangers in presenting such complex evidence to a court where a lay jury needs to understand the evidence clearly to decide how it relates to the issue in question. It may be more appropriate to leave the aspect ratios of the original images unchanged, relying on recreating the geometry of the AM image by taking successive images until the effort is rewarded. Where the physical size of features shown on corresponding pairs of images is different due to differences in the distance between tissue and film at the time of image acquisition, only the size or resolution of the largest image should be altered to match the corresponding parameters of the smaller one. This is because, should the images require presentation in a court or similar tribunal, we believe it is permissible to lose information by shrinking the amount of data in an image, but we do not believe it is valid to have an imaging program “create” information by interpolation using a process not easily explained. Thus, assurance of the probity of the image can be given on that basis.

Because these two techniques (comparison or superimposition) provide a visual experience of similarity between two images, they are satisfying to undertake and are easy for lay persons to understand and interpret, but neither provides an estimation that would allow a Trier of Fact or a coroner to understand the degree of concordance expressed as a mathematical index. Attempts have been made to formulate a method where similarity of two images can be mathematically expressed in this way (23). This is a solution that indirectly attempts to address a fundamental question underlying the whole process of comparison of dentitions by any means whatever: what is the chance of two dentitions being so similar that a convincing match might occur by sheer chance?
The question of similarity between dentitions of different people has also been expressed in reverse: what is the degree of uniqueness of the human dentition? Unfortunately, most attention has focused on this question in the context of bite mark analysis and are well summarized by Bush et al. (24), who performed a rigorous analysis of this sort, and concluded that statements of dental uniqueness with respect to bite mark comparison in an open population were unsupportable. The problem is that these analyses considered statistical analyses of the spatial arrangement of the incisal edges of anterior teeth, and therefore did not address the range of individual elements visible in a radiograph. They do not therefore apply to radiographic dental comparisons.

One way of addressing this issue is to demonstrate the similarity between AM and PM pairs of corresponding dental radiographs in a way that demonstrates the differences between them. Subtraction imaging techniques have been applied in such circumstances (6, 23).

One method utilises commonly available digital imaging programs such as Adobe Photoshop ® or The Gimp. One of the radiographs is placed as a layer in a larger digital canvas, and the second is placed in a layer on top. Adjustments are made to the size and resolution of the larger image until it matches the smaller, and then the two are superimposed to maximise the concordance of similar features. The overlying layer is then rendered as a negative, and its opacity reduced until common features cancel out to the greatest extent to leave a neutral grey shadow. The result is shown in Figure 3, using the same case as illustrated in Fig 2.

An enlargement of the area of forensic interest (Figure 4) demonstrates that the common features of the two radiographs indeed cancel each other out. The mass of
amalgam fillings can clearly be seen to have the same shape in both images, and the minor misalignment can now be observed to be consistent with a slight difference in image acquisition geometry between the two radiographs. Given that the radiographs will be acquired at different times and in different circumstances, and often using different equipment, the outcome illustrated here represents a good result.

Plain Film Radiography: Digital Sensor versus Analogue Film

Wood and Kogon(14) maintain that, for the present, analogue (chemically-processed film) should be used in DVI situations to provide a physical record of the image and that the resulting films should be photographed or scanned to a JPG format at relatively low resolution for emailing. They suggest that analogue film-processing systems are more portable, particularly in places where computers might not operate. However, this introduces significant labour overhead as a result of the need to process, mount and correctly identify films, all of which are sources of potential error.

Scanners almost universally introduce a linear distortion to the scanned object that is due to the scanner geometry, and which can affect attempts to superimpose PM images obtained by this method with AM images. Scanners therefore should not be used for this purpose. In addition, conventional scanners require a light source in order to scan radiographs, unless they are specifically equipped to do so. Following the South Asian Tsunami in Thailand, fluorescent lamps were frequently used as a light source, resulting in banding of the scanned images due to fluctuations in light intensity from the alternating current supplied to the lamps. It is therefore recommended that, should analogue film be used, it should be photographed rather than scanned.
Errors can also be introduced into photographed images as a result of careless photography. Care should be taken to photograph radiographic films from a distance of at least one metre (with a zoom lens to increase resolution) to avoid perspective, commonly manifested as barrel distortion. Further, the film must be placed perpendicular to the long axis of the lens to avoid distortion due to parallax, and kept absolutely flat. Correct alignment can be assured by including a right-angled forensic scale in the photographic field and demonstrating that its features are undistorted in the final image (Fig 5).

If the resulting image is subsequently rendered as a low-resolution JPG image as Wood and Kogon suggest (14), information is likely to be lost, and in these days of broadband connections, it seems unreasonable to accept such a compromise.

It might be noted that all of these sources of error can be avoided by the use of digital sensors, with the images being backed up routinely to prevent loss.

Additionally, near-instant feedback if the image appears directly on a computer screen makes it much simpler to duplicate the geometry of an AM radiograph by visual inspection and correction of relevant parameters for subsequent exposures.

It is therefore recommended that digital sensors be used in both routine and DVI situations, unless there are expected to be serious issues with power supply, and since such issues will also affect the use of x-ray sources as well unless adequate supplies of pre-charged batteries are available for hand-held sources, this situation should arise infrequently.

Choice of Radiation Source
Fixed (wall-mounted) and mobile dental x-ray sources are available, but more recently hand-held x-ray sources have become available to the forensic community. These provide a number of advantages for the forensic odontologist, including mobility (25) and ease of use (26). They are battery-operated and therefore cordless, and free the forensic odontologist from the need to have access to electrical power at a scene where radiographs are required (26) (although access to power for battery recharging is needed if the operation requires more than the number of pre-charged batteries available). When used with digital sensors, these devices can increase the speed and efficiency of the imaging phase of the post-mortem examination.

It has been shown that their image quality is excellent when used with appropriate image sensors or film (25, 26), and that they are safe when used as recommended, posing no significant health risk to operating staff (27).

Nearly all forensic odontologists working in Australia now have routine access to a hand-held radiation source.

Computed Tomography (CT)

Two mortuaries in Australia currently have CT scanners installed and routinely scan all post-mortem cases (Victoria and Queensland).

Multi-Slice Computed Tomography (MSCT) provides three significant advantages over plain-film radiography to the forensic odontologist. First, its data can be reformatted into three-dimensional computer models that can be viewed from different angles, and which respect perspective when zoomed into or away from on the computer screen. Secondly, they are metrically accurate, and different datasets can
therefore be compared on that basis, potentially adding a level of assurance that plain-
film radiographic comparison cannot. Finally, the data can be reformatted to simulate
plain-film radiographs including OPGs, and thus remove the necessity to wait for AM
radiographs to arrive before undertaking the post-mortem radiological examination if
image comparison or image superimpositions are contemplated.

There are, however, disadvantages. A major problem is that metallic restorations can
lead to artefacts that commonly make it difficult to determine their morphology in
sufficient detail to permit comparison (28), and although Jackowski et al. (29)
recommended the use of extended CT scale to reduce them as long ago as 2006, it is
only recently that significant progress on artefact reduction using a new algorithm has
been reported (30). It has also been claimed that ultra-high-resolution dual-source CT
can be used to differentiate between various filling materials (31), although this has
been disputed (28, 32).

The criticism of CT as a forensic diagnostic tool in DVI situations on the basis that it
does not accurately discriminate different dental materials appears to have been
predicated on the assumption that it will replace the need to dentally examine the
deceased (28) in such situations, but this criticism can be equally levelled at plain film
images. The bottom line is that radiology should never substitute for a physical dental
examination in such circumstances (or indeed in any forensic odontology procedure),
but instead should be seen as an adjunctive aid to the process. CT visualisations of the
jaws and teeth may help decrease the frequency of jaw resection for identification in
DVI situations (33). A program involving mobile MSCT for use in mass disasters in
the UK was described in 2009 (34).
Comparison of AM radiographs with PM CT reformats to produce a corresponding image can be undertaken, and while a plain film image is always to be preferred over a CT reformat for this purpose, the technique may be useful when the body of the deceased is either not available or is no longer so. Sidler et al. demonstrate such a comparison and discuss the advantages and limitations of MSCT in DVI operations (33). An example of such image comparison between an AM OPG and a PM multi-planar reformat (MPR) to simulate an OPG is shown in Fig 6.

While superimposition of an AM OPG and an MPR of a CT dataset to simulate an OPG is possible, there are too many variables to permit a good result, and it achieves little that a good image comparison will not. This is partly due to the difficulty of replicating the geometry of the AM OPG and partly due to the very real difficulty of replicating the relative positions of the jaws as they were in the AM image.

An as-yet unreported method of CT image data comparison will be the comparison of AM and PM two-dimensional and three-dimensional reformats. AM data may come from Cone Beam CT installations which are becoming increasingly common in specialist radiology practices and in dental offices. CBCT uses isotropic (cubic) voxels (image elements which represent a specific value of radiographic absorption) as opposed to conventional CT, which have previously used anisotropic (rectangular) voxels (35). Images from these different sources will need to be reformatted to be compared, but the comparison will have a degree of rigour that plain-film comparison cannot possess, due to the fact that the sizes of objects in the CT datasets can be assured. It should be noted, however, that the latest Multidetector CT units have voxels that are isotropic.
Given the problems with flare from metallic restorations, it seems likely that three-dimensional surface model comparisons will provide the best results in individuals without these types of restorations, or with unrestored teeth. Thus, the cases that are most difficult with other comparison types potentially stand to benefit most, including comparisons of edentulous jaws, and given the constellation of minutiae that will be matched, may well provide overwhelming evidence that the AM and PM images derive from the same individual.

The Probity of Digital Images

Any digital picture image, including a digital radiograph, can be subject to alteration by anyone with rudimentary knowledge and a commercial program for manipulating digital picture images. In the present context, Wood (5) illustrates a case in which a dental radiograph was altered to mislead third-party insurers. While this is undoubtedly an easier task to accomplish with a digital image, it is also possible to achieve with analogue film.

In photography, it is possible to shoot a digital photograph in RAW format, which captures the data direct from the camera’s image sensor. This file is not a picture image file, and it requires processing to transform it into a viewable picture file format. Thus, it can act as a negative would do in chemical film processing to assure a Trier of Fact that the original image seen by the camera has not been altered in such a way as to decrease its evidential value.

When digital radiographic images are processed, they are generally automatically stored in a proprietary non-editable format in a proprietary database and can be
exported to a viewable image file if required. In the event of a dispute, reference can be made to the stored file in the database to demonstrate that the radiographic image in question has not been altered in such a way as to change its appearance.

In the same way, CT data is generally acquired in such a way that any alterations made are overlaid on the original data, which is usually stored in DICOM (Digital Imaging and Communications in Medicine) format on a corporate PACS (Picture Archiving and Communication System). Stored image data is regarded as a legal document and cannot be altered or deleted from the system via a user interface, and an audit trail of operations performed is kept by the system. The probity of CT data can therefore be assured by reference to the stored data on the PACS.

Dental CBCT (Cone Beam CT) is now appearing in specialist radiological practices and in some dental surgeries. Data acquired from scans using such machines also represent legal documents and should be treated as such, with similar requirements for safeguards and audit trails. Secure data archiving systems should be in place as a matter of corporate policy.

Always provided that appropriate arrangements are in place to protect the original image data in a secure way, digital radiographic images should have the same degree of probity in a courtroom as chemically-processed images, although there is very little in the recent literature to address this issue.

Conclusion

Radiographs are a crucial aid to personal identification in forensic odontology. They are objective, morphologically specific recordings of features of an individual, where
written dental records are not. This greatly increases the value of radiographic image comparison when it is used to determine if AM and PM images derive from the same person. While the specific techniques used in any situation depend on the type and quality of the ante-mortem radiographs that are available, the advantages and limitations of different radiological techniques determine their suitability in different situations. Future techniques for three-dimensional image comparison potentially add the assurance of size comparison between objects in AM and PM images, increasing the level of confidence in the outcome.
References


Figure Legends

Figure 1: Comparison between an AM right bitewing radiograph of a missing person, and two PM radiographs of the corresponding dental areas of a deceased person. The PM radiographs have been taken on the upper and lower jaws separately because of the difficulty of keeping the jaws closed and maintaining the relationships between the upper and lower jaws in a deceased person to correctly secure a bite-wing radiograph. While it may be clear to a dentist that these images derive from the same individual, minor differences in image geometry between the AM and PM images may raise questions for non-experts.

Figure 2: At post-mortem examination, an AM radiograph was made available (f). A PM radiograph of the corresponding portion of the mandible was secured, attempting to duplicate the geometry of the AM image as closely as possible. The two radiographs are digitally overlaid and aligned, maintaining the original aspect ratio. Pictures (a) – (f) show how the opacity of the overlying (PM) image is progressively reduced to show the features of the AM image below. This is performed in real-time if required before a tribunal, or included in a Statement of Evidence in the form shown above.

Figure 3: Subtraction Imaging to demonstrate image similarity between corresponding AM and PM radiographs.
Figure 4: Enlargement of area of forensic interest from fig 3. Features common to both images cancel out to leave a neutral grey shadow. The line of mismatch around the amalgam restorations shows that the morphology is similar, but there is a slight offset due to slightly different image geometry in each radiograph.

Figure 5: The similar lengths of the two limbs of the ABFO No 2 Bite Mark scale in this image demonstrates that uncontrolled distortions have not been introduced into the radiograph by poor photographic technique.

Figure 6: Comparison of a CT multiplanar reformat (MPR) simulating an OPG with an AM OPG. Note also the horizontal streaking artefact on the CT image originating from the metallic filling material.
Figures

(a) AM right bite wing radiograph

(b) PM upper right radiograph

(c) PM lower right radiograph

Figure 1
<table>
<thead>
<tr>
<th>(a) PM Radiograph Opacity 100%</th>
<th>(b) PM Radiograph Opacity 80%</th>
<th>(c) PM Radiograph Opacity 60%</th>
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<tbody>
<tr>
<td>(d) PM Radiograph Opacity 40%</td>
<td>(e) PM Radiograph Opacity 20%</td>
<td>(f) PM Radiograph Opacity 0%</td>
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Figure 2
(a) original AM radiograph
(b) corresponding PM radiograph
(c) PM image overlayed as a negative
(d) negative reduced in opacity until common features with original radiograph cancel to leave a neutral grey

Figure 3
Figure 4
Figure 5
(a) AM OPG

(b) PM CT MPR. 18 and 28 are missing and a crown is now present on 26, all of which can be accounted for in an AM dental record. Note the similar features, including tooth and root anatomy, restorations, and a small radio-opacity inferior to the apex of 31

Figure 6
50\times40\text{mm (300 x 300 DPI)}