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ORIGINAL ARTICLE

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Post-mortem orthopantomography – an aid in screening for identification purposes

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Abstract Ante-mortem orthopantomograms may be of great value in the identification of human remains. This x-ray technique provides an overall view of the teeth and jaws and thus of numerous individual structural characteristics within a short time. Standardised post-mortem orthopantomography has previously not been feasible in the forensic practice. The present study shows how orthopantomography can be applied to identification procedures. The reproduction of ante-mortem x-ray conditions is implemented here in the production of post-mortem x-rays, using a purpose-designed radiographic tripod. For the first time, account is taken not only of the size and structure but also of the nature of the soft tissue covering of exhibits. For post-mortem preparation of these radiographs, appropriate positioning aids, a spinal column substitute and a soft tissue filter were constructed. Individual macerated jaws as well as the complete cranium can now be positioned correctly in the upright orthopantomograph (OPG). The method presented expands the spectrum of forensic radiology for the individual case and in our opinion also offers a reliable aid for victim identification in the wake of mass disasters, aircraft crashes and terrorist attacks, where a large number of bodies have to be identified under great pressure.

Introduction

Short-wave electromagnetic radiation was first used for the identification of corpses in 1921 by Schueller, who drew attention to the high individual specificity of the frontal sinuses. In 1922, Bucky drew up a list of all possible applications for radiology in the forensic field including identification by comparison with existing x-rays, evidence of characteristic injuries and assessment of age. Once the value of the masticatory apparatus for the forensic practice had been recognised, the search was on for ways of producing post-mortem x-rays which provided highly detailed information. To enhance the comparative value, post-mortem and ante-mortem x-ray projections needed to coincide as closely as possible.

Henrikson et al. (1962), Gustafson (1966) and Graham (1973) were the first authors to describe the forensic use of small x-ray tubes placed intraorally to provide panorama-like x-rays of the jaws. However, the projecting direction was not reproducible with these techniques. Hazebroucq and Bonnin (1993) developed a radiographic method for resected jaw specimens on a film cassette. In 1966 Gustafson applied the then 12-year-old technique of orthopantomography according to Paatero (1954) to the forensic practice for the very first time. Rocca et al. (1994) considered orthopantomograms to be the most important ante-mortem sources of information outside the written treatment records. Various authors (Laaksonen et al. 1991; Pashinian 1992; Solheim et al. 1992; Rocca et al. 1994; Andersen et al. 1995; Lessig 1996) have published case reports of odontologic comparisons involving orthopantomograms.

As a radiographic technique providing an overall survey of the teeth and jaws and thus of numerous individual structural characteristics within a short time, ante-mortem orthopantomograms may be of great value in the identification of human remains. The present study shows how orthopantomography can be applied to the forensic practice. The reproduction of ante-mortem x-ray conditions is to be implemented in the production of post-mortem x-rays, using a purpose-designed radiographic tripod.

Principles of orthopantomography

Orthopantomography (OPG) provides a complete view of the teeth and both jaws in one image.

The following regions can be represented with this technique:

1. The dentoalveolar region of both jaws
2. The osseous structure of the maxilla
3. The osseous structure of the mandible

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4. The temporomandibular joint region including the retromaxillary and cervical region.

This method combines the principle of tomography with the familiar slit-beam technique (Ritter 1988). Whilst the maxilla and mandible remain stationary in the central tomographic plane (zone of greatest focal depth), the x-ray source and image interception plane (extraoral film) move round the patient on an ellipsoidal path for ca. 16 s. In this process, the jaw sections are located in the zone of greatest focal depth, that area in which the difference between the angular velocity of the radiation source and that of the film cassette is minimised. Objects located in this zone are subject to only minor motion-induced blurring and may be more sharply defined on the film than those located outside the zone. These imaging interdependencies underline the need for the jaw to be correctly positioned in the central tomographic plane, as the correct positioning of the visceral cranium is a fundamental prerequisite for the production of orthopantomograms of highly informative value in which overlaps and distortions of the two jaws are avoided.

The large range of commercially available equipment offers an equally large number of adjustment aids, comprising primarily bite blocks, chin rests and collimators. With almost all equipment, correct positioning is assured in three planes:

1. The Frankfurter horizontal plane (ear-eye plane)
2. The canine perpendicular
3. The midsagittal plane.

Most OPGs used routinely in dental practice are vertical devices with which the patient is radiographed in an upright posture with the cervical spine extended. The precondition for their use is that the patient can adopt such a posture in the OPG apparatus. To avoid side interchanges modern OPG apparatures have automatic side marking on the film.

As a result of methodological improvements introduced since the first studies (Paatero 1954, Fig. 1), orthopantomography has developed into a broadly applicable standard method in dentistry (Nitsch 1979; Rottke 1987; Pasler 1989; Rahn et al. 1991). In conjunction with the reduced radiation exposure resulting from the use of intensifying screens (Sonnabend and Polensky 1971), the improved technique has broadened the application range, so that applications are not confined to suspect pathology findings but extend to initial examinations for orthodontic issues in treatment. This expanded application range accounts for the widespread use of orthopantomography (Woolridge 1977).

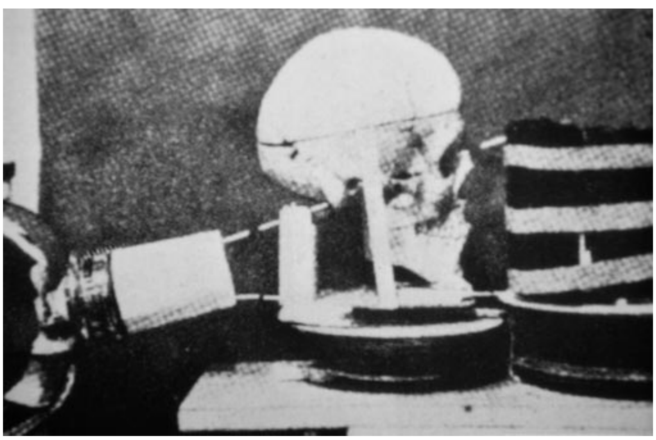

Fig. 1 Beam path in the OPG (Reproduced from Langland O (1982) Principles and practice of panoramic radiology. Saunders, Philadelphia, p 17)

Material and methods

The demand for reproducible radiographic techniques (Andersen et al. 1995; Hunger and Leopold 1978; Lessig 1996; Knight and Whittaker 1981; Doychinov and Yordanov 1994; Whittaker and McDonald 1993) motivated this study, in which the reproduction of ante-mortem x-ray conditions is implemented in the production of post-mortem x-rays by forensic pathologists, using a purpose-designed radiotranslucent tripod to improve the positioning of the jaws. As a survey of both jaws, orthopantomograms offer the basic structure for subsequent local examinations in the form of dental films with higher sharpness.

Bone specimens

Three different types of bone specimens were examined:

1. Intact skulls with neurocranium and viscerocranium
2. Incomplete skulls with fragments of the viscerocranium
3. Resected jaw specimens
   - both jaws fully dentulous, occlusal contact on both sides
   - occlusal contact on one side only
   - no occlusal contact

Design of an artificial spinal column, soft-tissue filter and radiotranslucent tripod

The tripod has to take over the retaining and supporting function of the living patient and to lock the jaw specimens in the correct position in the x-ray unit without obstructing the x-ray beam or absorbing rays in an uncontrolled manner.

The positioning of the jaw specimens in the zone of greatest focal depth requires three-dimensional mounting complying with normal cephalometric conditions. As the occlusal plane is inclined 8° ventrally to the Frankfurt horizontal plane in the cephalometric norm (Schumacher 1984), a special column whose top surface has a 8° slant was designed (Fig. 2). The column was constructed to stand vertically on the floor, so that the Frankfurt horizontal plane runs parallel to the floor. The jaw specimens are held by two acrylic brackets, whose positioning can be varied both in vertical and in sagittal direction. The specimens can be fixed quickly and easily with commercially available dental silicon (Provil, Bayer) and radiotranslucent screws (Dresselhaus). The maxilla is mounted with the teeth resting on the top surface of the slanting-top column. In this position it is engaged at an angle running perpendicular to the floor and thus by definition to the Frankfurt horizontal plane. The mandible is fixed to a second bracket or directly in the frame parallel to the occlusal plane of the maxilla. This jaw relation ensures that both jaws are projected without overlap onto the image-interception plane (Figs. 3 and 4).

The radiographs were taken with a Siemens Orthopantomograph 10 in conjunction with an intensifying screen and 30.5 × 12.7 cm Kodak x-ray films (T-MAT G/RA). The films were developed in a standard developer. The radiographic equipment used was thus on a technical par with that used in routine dental practice. The Orthopantomograph 10 has a minimum tube voltage of

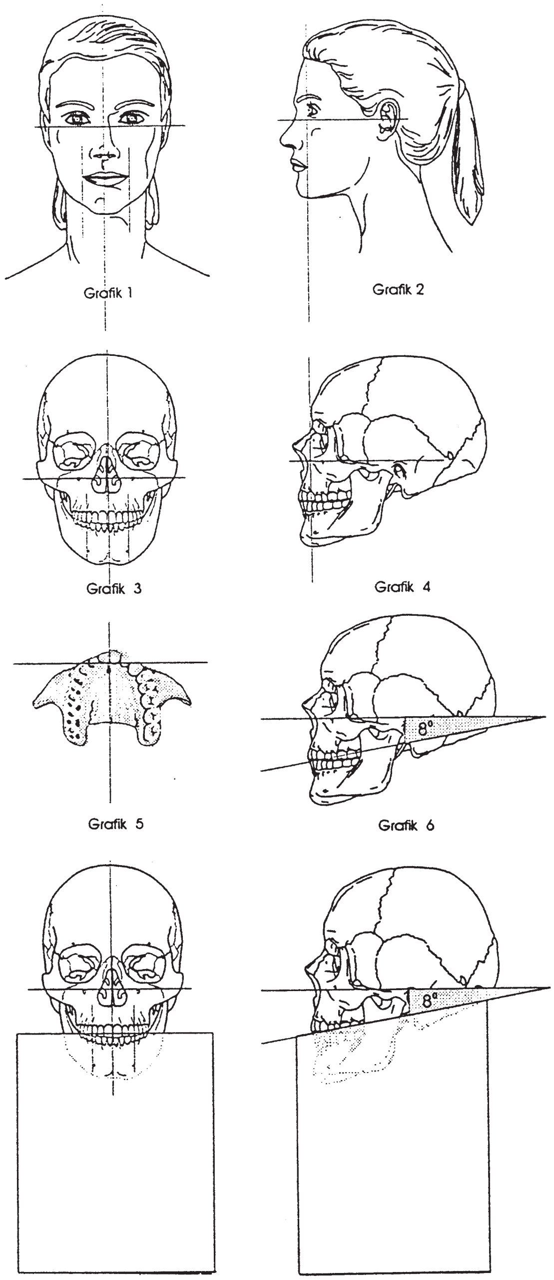

Fig. 2 The three positioning planes, Frankfurt horizontal, canine perpendicular and mediosagittal, can be transferred to the cranium for correct jaw positioning in the OPG

55 kV with three different absorption columns developed with varying diameters and filling components.

Cylindrical plastic spine phantoms with a length of 170 mm and diameters of 20, 35 and 45 mm were filled with a 50% mixture of calcium sulfate and sawdust. In a second test series, a cuboid spine phantom measuring 170 mm × 40 mm × 40 mm was filled with dental black wax prior to installation in the radiation path. To compensate for the lack of radiation absorption by the missing soft tissue, a tin foil with a thickness of 0.5 mm was positioned over the x-ray outlet. 55 kV was used for the exposure (Figs. 5–8).

Fig. 3 Complete crania, jaws or jaw fragments can be correctly positioned in the OPG

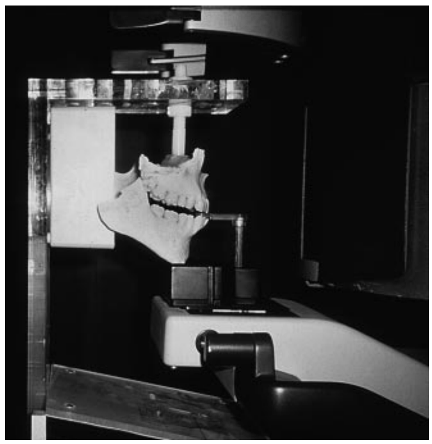

Fig. 4 Resected jaws fixed in the beam path of the OPG modified by the spine phantom and the soft tissue filter

Case study

To demonstrate the results of the described investigation technique a comparison between a post-mortem and an ante-mortem OPG is presented from an actual case.

The severely burnt corpse of an unknown man was found in a burnt out car. It was suspected that the corpse could be that of a relative of the owner of the car. The dentist who had treated this person was in possession of an OPG (Fig. 9) and also the x-ray photographs of a filling in 35 (Fig. 10) and a root filing in 12 (Fig. 11) taken at a later date.

For a post-mortem OPG the jaws excised at autopsy were available however the soft tissues and part of the jaw bone had been destroyed by the fire. By the use of a wax field artificial spinal column the central areas of the jaw could also be evaluated (Fig. 12).

The filling in 35 as demonstrated in the magnification from the post-mortem OPG (Fig. 13) was found to be identical with the fill-

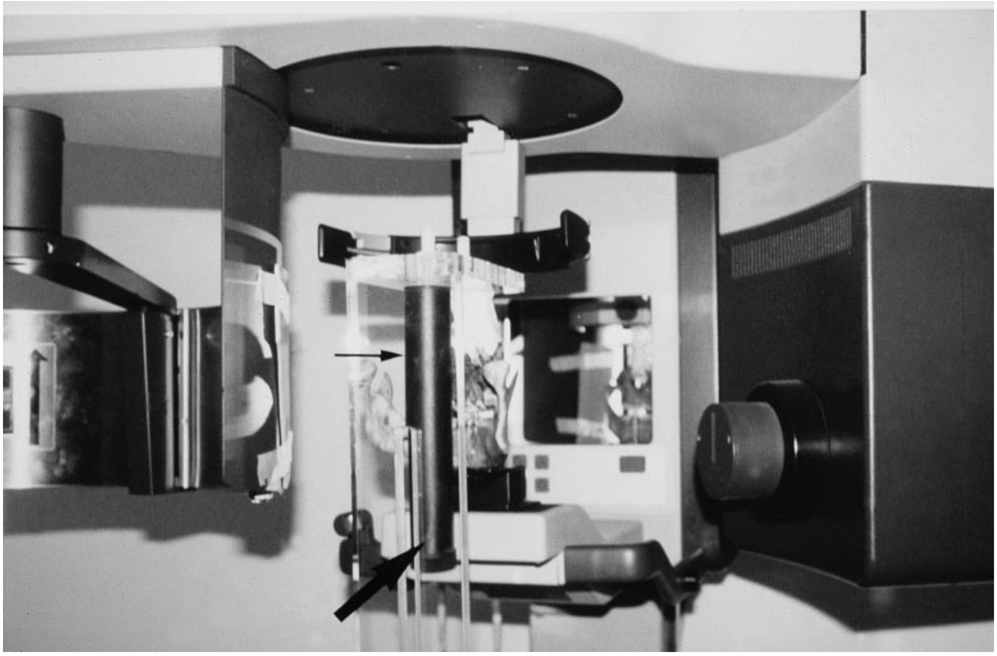

Fig. 5 Radiographic tripod with spinal column substitute in the OPG

Fig. 6 Orthopantomogram without soft tissue filter, 55 kV tube voltage

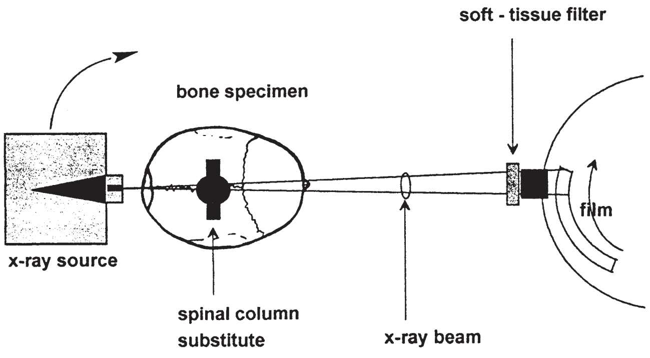

Fig. 7 Beam path in the OPG modified by the spine phantom and the soft tissue filter

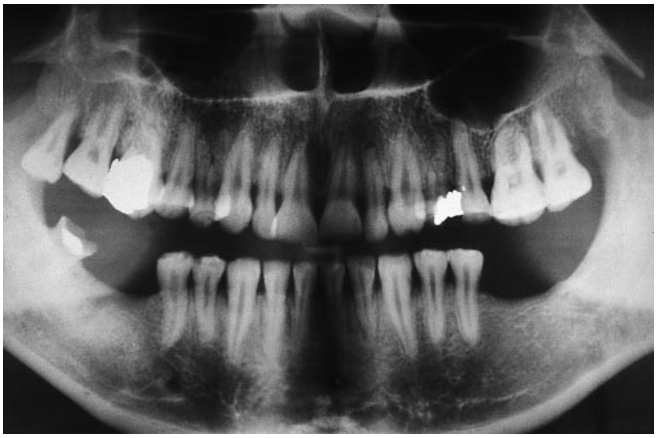

Fig. 8 Orthopantomogram with 170 × 40 × 40 mm cuboid spine phantom and soft-tissue filter, 55 kV tube voltage. The radiograph is uniformly exposed throughout, so that informative detailing is provided on the film in all regions

Fig. 9 Ante-mortem orthopantomogram obtained from the dentist of the suspected victim (case report)

ing in the x-ray photograph obtained from the dentist (Fig. 10). The root in 12 which was absent in the first OPG could be convincingly assigned to the root filling on the x-ray photograph taken subsequently by the dentist. A clear identification was possible with the aid of the post-mortem OPG.

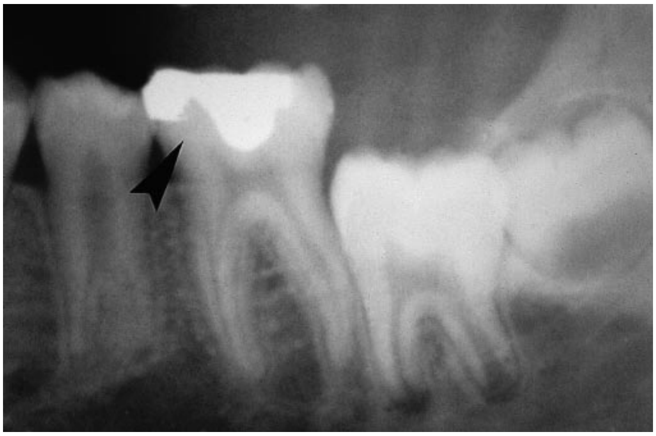

Fig. 10 Ante-mortem x-ray of the filling in tooth 35 obtained from the dentist of the suspected victim (case report)

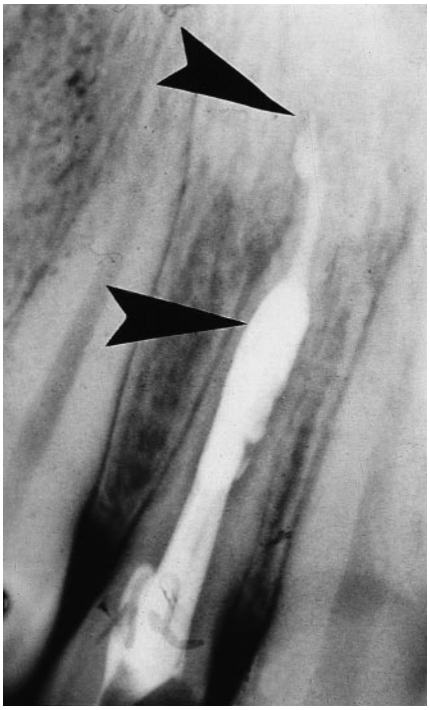

Fig. 11 Ante-mortem x-ray of the root filling of tooth 12 obtained from the dentist of the suspected victim (case report)

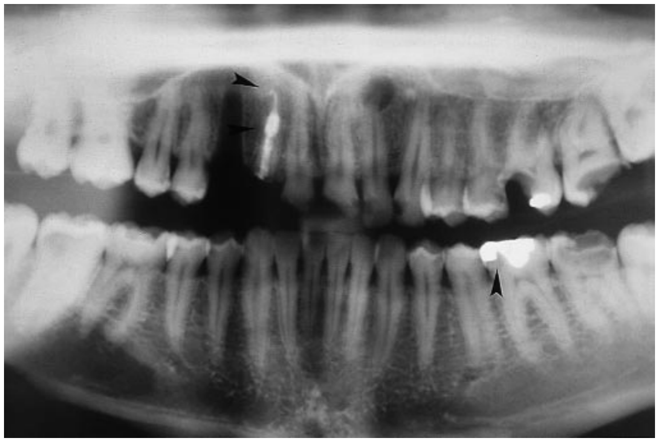

Fig. 12 Post-mortem orthopantomogram of the corpse from the burnt out vehicle (case report)

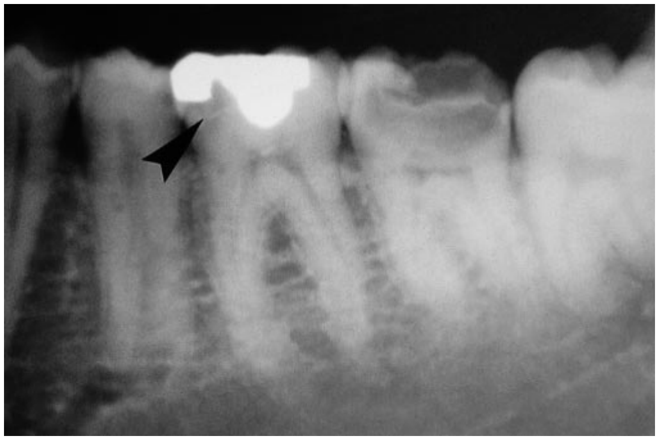

Fig. 13 Magnification of the filling in tooth 35 from the post-mortem orthopantomogram (case report)

Discussion

The success rate of odontologic identification depends decisively on the quality of the dental treatment records (Riepert et al. 1995). According to Borrmann et al. (1995) side interchanges and other mistakes in dental records occur in 70% of cases. In a recent study simulating a mass disaster we could not identify 26 out of 104 "victims" by assignment of the dental records to the orthopantomograms of the patients due to gross mistakes in the records (Höhmann et al. 1999).

Orthopantomograms were described by Haertig et al. (1991) as the only reliable and correct identification records, as this radiographic technique precludes any transfer errors or side interchanges when recording the dental status. To date, this technique has not been in standard use in forensic medicine, as post-mortem positioning of the jaws appeared to present problems.

The technique described by us (Fig. 5) permits complete skulls, jawbones or parts of jawbones to be positioned correctly in the OPG apparatus, irrespective of the size of the individual specimens (Figs. 3, 4). Using the translucent tripod, the jaw specimens can be correctly and securely positioned with no risk of blurring in the zone of greatest focal depth. Most ante-mortem projections can be reproduced for post-mortem specimens, enhancing the comparative value.

Fixing the maxilla and mandible separately enables them to be positioned in a locked bite situation, which prevents the occlusal region from overlapping and also allows partially or completely edentulous jaws to be x-rayed. Fixing the maxilla directly on the mandible as described by some authors, a method which is not feasible unless teeth are present in all four supporting areas, is redundant, as is the intercuspal overlapping of the occlusal surfaces.

The jaw fragments are devoid of soft tissue and in particular of cervical vertebrae, which would normally absorb radiation. This means that the dose absorbed by the film is higher, resulting in greater density (Fig. 6). As the beam passes through the spine segment, the radiation intensity is automatically increased. As this compensatory mechanism cannot be selectively disabled, an absorbent medium had to be placed topographically in the path of the beam as a spinal column substitute to compensate for the missing natural spine (Fig. 7). Using the calcium sulfate column as a spine phantom provided inadequate representation of the anterior segment, as the radiation absorption of the calcium sulfate was too great. The wax-filled spine phantom produced better results in that the anterior segment was more uniformly exposed (Fig. 8). The tin foil placed over the x-ray outlet compensated for the lack of absorption by the missing soft tissue.

Tier et al. (1996) reported the same problems as those confronting us in the handling of macerated specimens: positioning the skull in the x-ray unit on the one hand and compensating for the soft-tissue deficit in the beam path on the other. Because of the overexposure of the film with a minimum tube voltage of 55 kV, bone and tooth structures were hardly recognisable, if at all. The authors used acrylic hooks mounted in the zygomatic arches to position the mandible. The precondition for using the acrylic hooks is that not only both zygomatic arches, but also the two condyles or one condyle and one contralateral supporting contact respectively, must be present. This fixing system appears to be impractical in the forensic laboratory because zygomatic arch fixation is impossible with resected jaws for example, as the jaws are completely detached from the viscerocranium.

To mimic the soft tissue, Tier et al. (1996) suspended a drip bag containing Hartman's solution across the x-ray tube head and angled it to give a fluid thickness of 10 mm. Although the authors claim that Hartman's fluid has the same density as natural tissue, it must be borne in mind that a tissue phantom on this scale has a substantial weight which impedes the positioning of the cranium.

The system developed by us enables post-mortem orthopantomograms to be produced without the quality being affected. The experience gained by clinicians with this radiographic technique suggests that it should become a routine also in forensic practice. For instance, Rottke (1987) recorded unexpected pathology findings in 80% of 371 orthopantomograms. Examining 4454 orthopantomograms in 1991 for incidental findings, Rahn et al. (1991) registered a mean of 1.5 clinically undetected findings in need of treatment in 30% of the evaluated radiographs. As not only pathology but also non-pathology structural features are of interest as individual-specific markers for the identification of human remains in forensic practice and appear in every panoramic radiograph, orthopantomography can always be expected to provide additional information for the identification.

Andersen et al. (1995) reported their forensic-odontologic experience with fire victims (n = 292) where identification was achieved just as often with existing orthopantomograms as with conventional dental films, although orthopantomograms accounted for only 12% of all radiographic material in the period in question. So OPG was as useful in any single case as ordinary radiographs.

Besides prosthetic and conservative findings, panoramic radiography of both jawbones reveals important osseous findings such as cysts, apical osteolysis or foreign bodies. In restoration-free dentitions, specific structural anomalies which are not clinically manifest, such as individual-specific root curvatures, can be detected.

Healing processes in the alveolar bone may provide information on ante-mortem and post-mortem tooth loss and may also indicate the time of previous tooth removal, as it takes up to 18 months for alveoli to heal and be remodelled completely after extraction (Khoury 1988).

The dental age may be revealed by the primary, mixed and permanent dentition. Inferences on age may also be drawn from the wisdom teeth, where root growth is completed only around the age of 18 (Whittaker and McDonald 1993; Morse et al. 1994; Kullmann et al. 1995).

Woolridge (1977) described orthopantomography as a way of obtaining a survey of the entire dentition and the surrounding structures and thus as an indispensable technique in major disasters, as orthopantomograms show fractured jaws, retained root apices, anatomic specificities, the maxillary sinuses and the tooth development in one single image.

Orthopantomography also allows information to be transferred in an objective form not subjected to linguistic barriers (Borrmann et al. 1995). We concur with the view expressed in 1991 by Haertig et al. that orthopantomograms are the "only truly reliable identification records", as written dental records are compiled at different times during the patient's life and may contain unreliable information.

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