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Review

Forensic dental identification

Dorthe Arenholt Bindslev, Rebecca Gahn, Jaana Hurnanen,
Sonja Rut Jonsdottir, Sigrid I. Kvaal

Dental tissues and dental restorations can withstand extreme conditions. For dental identification, accurate odontological details recorded on deceased individuals are compared to dental records on missing persons. Forensic dental identification and profiling are common tasks for forensic odontologists. Dental identification can be essential when unknown bodies are found. It may be relevant in single cases as well as following mass disasters, when bodies are decomposed beyond recognition, severely mutilated or only skeletal remains exist. Forensic dental identification is recognised internationally as one of three so-called "primary identifiers", together with fingerprints and DNA.

Keywords: Forensic dentistry, Identification, Disaster victims, DVI

Clinical relevance

Both ante- and postmortem dental data must be available for performing a forensic dental identification. Forensic odontologists depend greatly on collaboration with practising dentists. Without dental data on missing individuals, there is no possibility for a comparison with detailed data obtained during an autopsy of a deceased with an unknown or uncertain identity. Increased knowledge about the identification processes and the importance of accurate record keeping may encourage interdisciplinary communication and facilitate efficient and well-qualified communication between dental practitioners, forensic odontologists and the police when collaboration is needed.

The identification of unknown individuals is essential for resolving criminal investigations, issuing death certificates, ensuring proper burials and providing crucial answers for relatives. Dental identification is an important issue in forensic odontology. Antemortem (before death) dental records are compared with postmortem (after death) findings to verify or exclude identities. Detailed antemortem (AM) dental records are essential for accurate identification, and, in this context, encompass all dental information collected during a person's lifetime. Postmortem (PM) dental data for the full documentation of the dental conditions of a deceased are obtained during a meticulous PM forensic dental examination.

The INTERPOL Disaster Victim Identification (DVI) guidelines recognise dental comparison as one of the three primary identification methods, alongside DNA and fingerprints (1).

Teeth are among the most resilient structures in the human body, primarily due to their high mineral content. Enamel is particularly resistant to environmental degradation (2). Dentin and cementum, while

also mineralised, contain a lower percentage of hydroxyapatite and degrade more readily. Dental pulp, being the least resilient part of the tooth, decomposes rapidly after death but remains a valuable source of DNA for forensic identification (3). Dental restorations, such as amalgam fillings, ceramic crowns, gold restorations, and titanium implants, can withstand extreme temperatures, making them crucial forensic markers (4).

When detailed AM dental records are available, dental AM and PM records can be matched quickly. Dental human identification can be vital in mass disasters, such as plane crashes, natural disasters, terrorist attacks, and mass graves, when rapid and accurate victim identification is requested (5, 6, 7).

PM forensic dental examination

According to DVI guidelines, a PM examination related to disasters is carried out by two forensic odontologists (FO's), one being the examiner of the body, the other recording and verifying the findings (1). At a PM dental examination (Figure 1), a dental status is registered, including tooth status (primary, permanent, or missing), restorations (by surfaces and material), and other dental work, such as crowns and implants. Additionally, all information of occlusion, tooth wear and abrasion, tooth position, morphological traits, anatomical anomalies and periodontal condition is gathered (8).

The use of diagnostic fibre light and UV light is recommended. Dental prothesis are described and photographed in situ, as well as extra orally, and subsequently replaced in situ. Any markings or labelling on dentures are checked and recorded (9, 10).

PM-photographs

PM-photographs must document the whole dentition, covering at least five different views: in occlusion, an anterior and both lateral views and an occlusal view of both dental arches (9,10). A full-face PM image comparison with selfies from the deceased's mobile phones can help to suggest an identity, subsequently to be verified with primary identification methods (11, 12). Frontal dental images and dental superimposition techniques can similarly assist (13). PM intraoral surface scans have been introduced as an alternative or supplement to 2D photographs.

PM-radiographs

The radiographic examination (Figure 2) should always cover all alveolar bone regions, either with a panoramic radiograph supplemented with separate images of teeth with distinctive features such as root canal fillings or prosthetic restoration, or a full set of periapical images (1). Impacted teeth, roots, abnormalities and pathologies in bone structure, precise details in the shape of dental restorations, parapulpal pins, screws, implants and other structural features are disclosed by thorough radiological documentation.

Figure 1. Morgue setting ready for FO dental examination. The deceased will be moved to the autopsy table for examination.

PM radiographs enable a visual comparison of shapes and positions with AM data. Various conventional radiological methods can be applied and full computed tomography (CT) scans are often useful for comparisons; 3D overviews can be created, and data can be reformatted to simulate periapical and panoramic radiographs.

Additional special PM-measures

Dental casts provide a 3D view of the dental arches, tooth morphology and positions, and palatal rugae (14). When AM casts are available, either conventional impressions are taken to process PM casts, or intra-oral surface scanning is carried out to generate digital 3D images or printed casts. Both methods are extremely applicable for identification purposes (9, 10).

Teeth, due to their structure and their protected location in the oral cavity, make them a good source of DNA and may be the only source in special cases. Dental DNA is mainly extracted from cellular cementum and pulp tissue. A molar is most preferable but, if not present, premolars have more cellular cementum, whereas canines have a larger pulp cavity. Additionally, roots that are still retained in the socket are protected by the surrounding alveolar bone, reducing the likelihood of contamination (15).

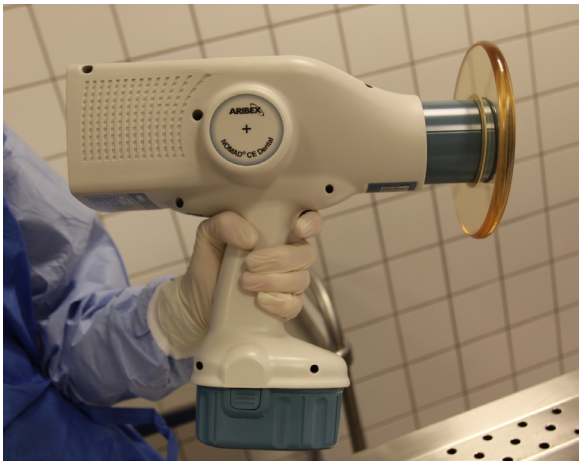


Figure 2. A handheld cordless X-ray device can be preferable for post mortem intraoral radiographs.

Body conditions

Fresh human remains, after the rigor mortis stage, as well as decomposed human remains are relatively easily handled for PM dental investigation. However, in highly decomposed and skeletonised human remains, teeth may loosen from their sockets and be mingled or lost. In dry, well-ventilated conditions, human remains may mummify, which makes the skin leathery and opening the mouth may thus become difficult, even impossible. With highly incinerated remains. teeth become fragile and easily crumble (16). FOs are trained to perform special tissue sectioning techniques to achieve sufficient access to the oral cavity even under complex conditions (9, 10).

PM age assessment

Particularly in cases where the identity of an unknown individual is unclear, the FO can assist the police by estimating age, which helps to narrow down possible matches in a DVI incident or in cases of unidentified bodies (9). For children and subadults, tooth development is one of the most reliable methods for age estimation. Teeth follow predictable developmental stages, and each tooth has a known pattern of formation and development. This process can be assessed through dental radiographs, providing a fairly accurate estimate of the individual's age (17, 18).

In adults, the age estimation process becomes more complex, and the assessment is based on regressive changes and degeneration. The techniques for post-mortem age estimation in adult teeth include attrition, secondary dentine, periodontal recession, cementum apposition, root resorption, and apical translucency. These methods include tooth extraction (with or without sectioning) or radiographic methods (19). Other methods of age estimation are radiocarbon dating (C-14) (20) and amino acid racemisation (AAR) (21, 22), where C-14 can be used to estimate the date of birth of an individual (the incorporation of radiocarbon from the atmosphere in biological tissue) and AAR can be used to estimate the age of biological materials by measuring the conversion of amino acids from their L-form to the D-form.

PM profile of an assumed individual or an unknown individual

For a PM profile, all important dental information (Figure 3) gathered in the PM examination is summarised in clear and straightforward writing that can be understood by police and other relevant stakeholders. The dental information is then integrated into the overall description of the unknown body to assist in the identification process.

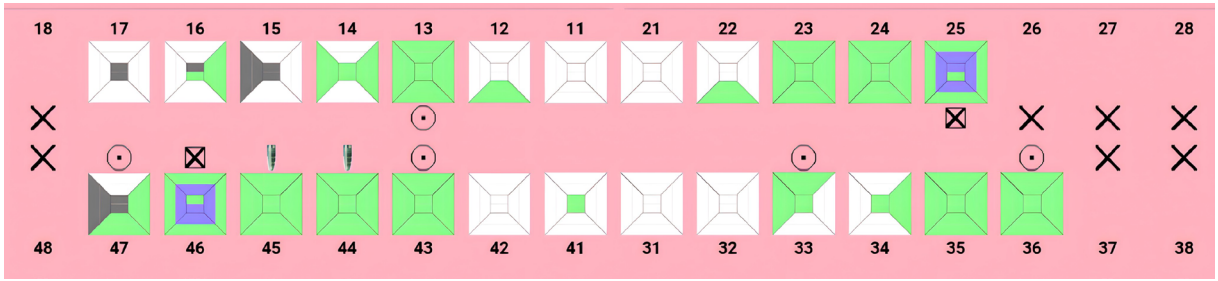
The detailed PM-data of an individual who remains unidentified is subsequently downloaded into internationally recognised software and transferred into a national "Missing persons/unidentified human remains" register. The police may pass the full PM profile, incl. dental, on to, e.g. INTERPOL for scrutiny in relation to their international missing persons database.

Collection and handling of AM dental data

The main source of dental AM data is from dental clinics, but also hospitals, the military and other employers might have clinics or access to dental records. The collection of dental records is done in the Nordic countries by the police and often in close cooperation with FO's.

Dental records contain confidential material and must be handled accordingly. The direct transfer of electronic records can be made through encrypted and secure internet systems but may create challenges since the health services and police are generally not on the same systems. Alternatively, electronic records can be copied to appropriate storage media and transported to the FO. It is important that such storage devices are handled with the same care as any other confidential material. Material from abroad may be obtained through INTERPOL or sometimes directly from the DVI-team in that country.

The complete dental records to be collected for identification consist of all available material: the written record, all radiographs, photos, casts, CBCT or CT scans and 3D photo scans. All radiographs should be collected, even those of poor quality – they might still contain useful information (23).



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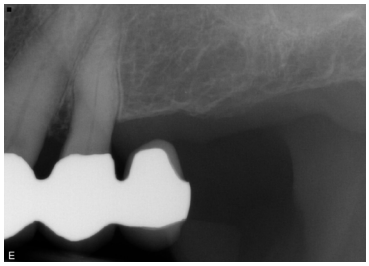

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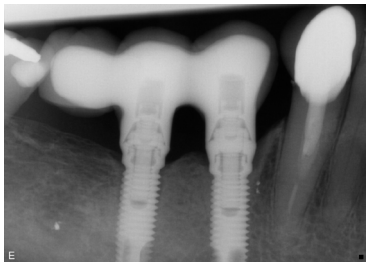

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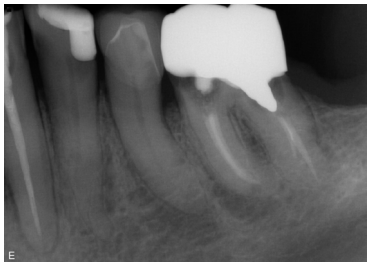

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Figure 3. A, B, C, D. PM dental status (A) and a few selected aspects of intraoral PM radiographs (B, C and D).

Electronic radiographs and photos are best collected in digital format. Casts, photos and intraoral 3D surface scans provide extremely important details of the dentition not documented in conventional records (8, 9, 14). Occasionally, medical records from a hospital may contain information which are helpful in identifications, e.g. following jaw fractures or radiographs of sinuses (24). Smiling photographs may also assist in the identification (11, 12).

Today, most dental records are electronic, but historic handwritten or typed AM record material is equally important for identification purposes. The FO must interpret and import all AM dental information into a special identification record system (Figure 4).

Comparison of AM and PM registrations

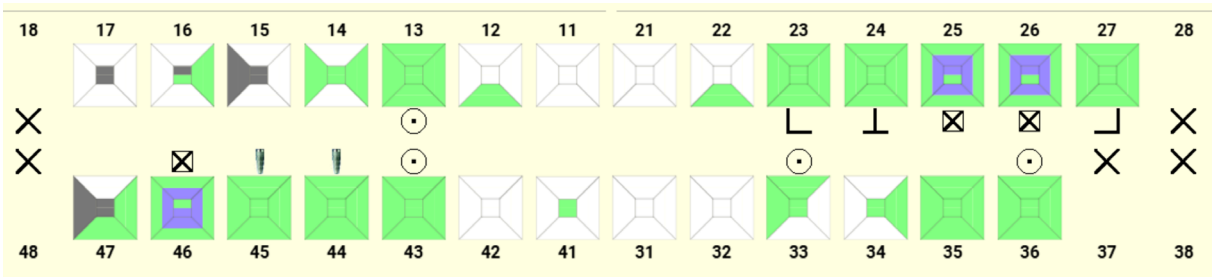
According to available guidelines, the quality assessment of both AM and PM data must be performed before the comparison process. To find the best possible matches between AM and PM data sets, it is helpful to prepare a list of special AM and PM markers. This way, only particularly noteworthy features of a missing person or body are recorded in a list. When several deceased individuals need identification, a key marker list can be prepared for both the AM and PM subgroups.

The Nordic countries, as well as many other countries worldwide, use the INTERPOL adopted software DVI system (KMD PlassData DVI, Denmark) for recording, documentation and matching in DVI operations (1). It is also applicable for single cases. Special INTERPOL forms are used for the digital registration of both AM and PM data, which are imported into a structured database. The DVI software can suggest matches, and the FOs must evaluate these matches carefully to depict the most pertinent (25). These must then be checked by individual comparison of the details in the AM missing persons file with the corresponding findings in the PM file (Figure 5).

Obviously special findings like prostheses, implants, root canal fillings, special fillings or rare/striking morphological or anatomical features constitute important proof to aid a dental identification. However, a sound inconspicuous dentition without any dental treatment may also be identified with certainty when detailed AM dental data are available, e.g. high-quality regular BW's, and intraoral 3D surface scanning prior to orthodontic treatment.

When comparing AM and PM data, inconsistencies may occur. These may be explainable, i.e. as charting errors or misinterpretations (e.g. were 1st or 2nd premolars extracted o.c.). Incompatible inconsistencies are discrepancies where no explanation is possible, e.g. a restored tooth cannot turn into a sound tooth. The FO must consider all inconsistencies very carefully.

According to international guidelines, the FO comparison analysis can result in i*dentification established, rejection* (non-identification), or the



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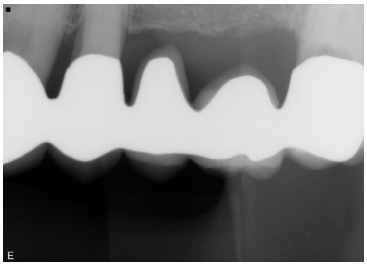

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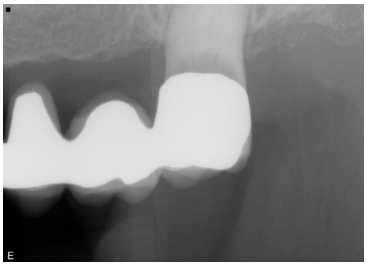

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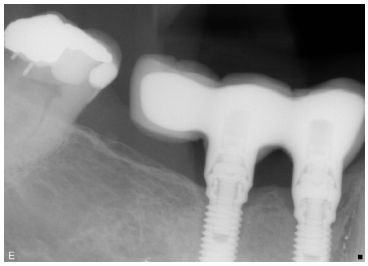

D

Figure 4. A, B, C, D. AM dental status (A) and a few selected aspects of intraoral radiographs (B, C and D) from the AM dental record of the person suspected to be the deceased in PM case shown in Figure 3.

establishment of a *possible* or *probable* identity (1, 26). *Insufficient evidence* may also be a conclusion (26).

Since no useful data exist on the prevalence of all features that may be recorded in the human dentition, no valid objective statistics can be applied to support the FO judgement of the identification level. For the same reason, no evidence-based decision criteria based on the number of points of concordance can be established, although efforts were made (27, 28). The clinical experience of the involved FOs, in combination with thorough scrutiny of all the data by at least two independent FO colleagues, result in a comparison report and, finally, an identification certificate in case identity can be established (1, 25).

In DVI operations after mass disasters, an interdisciplinary reconciliation board will review and reconsider all the proposed identification reports before a final identification report and certificate can be issued (1, 25).

Conclusion

Forensic dental identification is a reliable method for establishing identity and has the advantage of being very fast. However, it relies on the availability of detailed AM dental data, trained forensic odontologists, and required equipment and facilities. In the Nordic countries, a substantial part of the population visits a dentist regularly, therefore AM dental records are commonly available when needed.

Due to the rapid expansion of new diagnostic tools in dental clinics (e.g. CBCT-scanners and intraoral surface scanners), the amount of detailed AM dental data is growing and, thus, available for identification purposes. Forensic dental identification is likely to remain a highly relevant method despite trends towards improved dental health and fewer dental restoration characteristics in younger individuals. ■

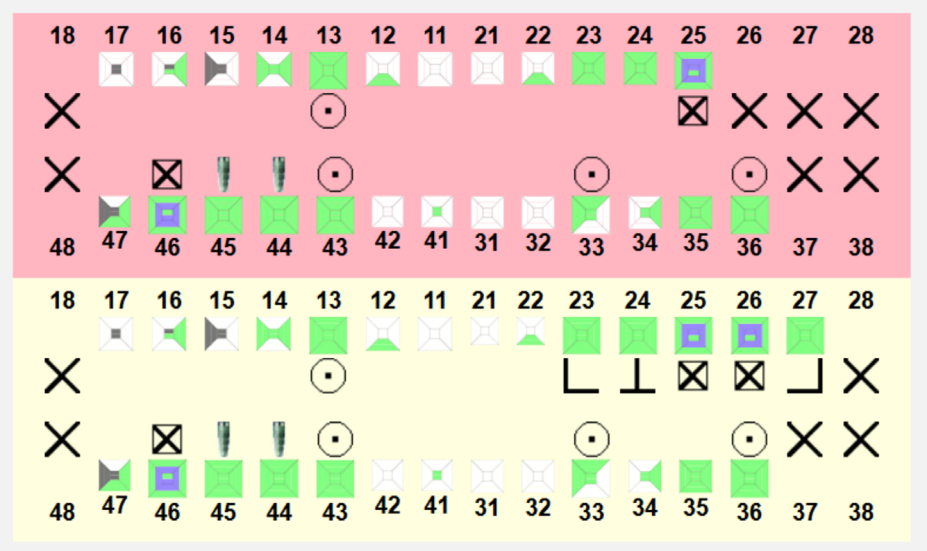

Figure 5.

A. Comparison of PM and AM dental status (Figure 3A and Figure 4A).

Tooth#	Diagnoses	Res...	Diagnoses	Tooth#
18	mam	+	mam	18
17	amf O	+	amf O	17
16	amf O, tcf MO	+	amf O, tcf MO	16
15	amf OD	+	amf OD	15
14	tcf MOD	+	tcf MOD	14
13	mcc rfx pox	+	mcc, rfx, pox	13
12	tcf L	+	tcf L	12
11	nad	+	nad	11
21	nad	+	nad	21
22	tcf L	+	tcf L	22
23	abu mcc	+	abu mcc	23
24	abu mcc	+	abu mcc	24
25	pon mcc	+	pon mcc	25
26	mam	?	pon mcc	26
27	mam	?	abu mcc	27
28	mam	+	mam	28
38	mam	+	mam	38
37	mam	+	mam	37
36	tcc rfx pox	+	tcc, rfx pox	36
35	tcc	+	tcc	35
34	tcf OD	+	tcf OD	34
33	tcf OML, rfx	+	tcf MOL, rfx	33
32	nad	+	nad	32
31	nad	+	nad	31
41	tcf O	+	tcf O	41
42	nad	+	nad	42
43	rfx pox mcc	+	mcc, rfx, pox	43
44	ipx abu mcc	+	ipx, abu mcc	44
45	ipx abu mcc	+	ipx, abu mcc	45
46	pon mcc	+	pon, abu mcc	46
47	amf OD, tcf MV, ppx	+	amf OD, tcf MV, ppx	47
48	mam	+	mam	48

B. Comparison scheme from the DVI software (PM dental codes to the left, AM dental codes to the right) showing discrepancy between the AM and PM dental data (yellow marking). The discrepancy is explainable, a tooth with poor prognosis AM is extracted PM and an adjacent pontic is also removed.

DORTHE ARENHOLT BINDSLEV
DDS, PhD. Professor emerita, forensic odontologist, specialist in orthodontics, Department of Forensic Medicine, Aarhus University, Denmark
dbindslev@forens.au.dk
Orcid ID: 0009-0006-5653-2163

REBECCA GAHN
DDS, Forensic Odontologist. Department of Forensic Medicine, the National Board of Forensic Medicine, Sweden
Rebecca.gahn@rmv.se
Orcid ID: 0009-0006-3480-1561

JAANA HURNANEN
DDS, PhD. Forensic odontologist, Forensic Medicine Unit, Finnish Institute for Health and Welfare, Helsinki, Finland
jaana.hurnanen@thl.fi
Orcid ID: 0000-0003-2541-2952

SONJA RUT JONSDOTTIR
DDS, Adjunct, Faculty of Odontology, University of Iceland, Iceland
sonjarut@hi.is
Orcid ID: 0009-0008-5692-0486

SIGRID I. KVAAL
BDS, dr odont. Associate professor (emerita). Faculty of Dentistry, University of Oslo, Norway
s.i.kvaal@odont.uio.no
Orcid ID: 0000-0002-3825-9048

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