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REVIEW ARTICLE

Digital Dental Records in Forensic Identification: Emerging Frontiers in Contemporary Forensic Odontology—A Narrative Review

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Abstract

Forensic odontology has emerged as an indispensable component of forensic science owing to its significant role in human identification, particularly in cases involving mass disasters, advanced decomposition, carbonization, and fragmented human remains. Dental tissues exhibit remarkable resistance to environmental insults, making dental evidence one of the most reliable biological identifiers when fingerprints or facial features are unavailable. The transition from conventional paper-based dental records to comprehensive digital documentation has transformed forensic identification by improving the accuracy, accessibility, storage, and comparison of antemortem and postmortem records. Recent technological advancements, including electronic dental records (EDRs), digital radiography, cone-beam computed tomography (CBCT), intraoral scanners, three-dimensional (3D) digital dental models, and artificial intelligence (AI), have significantly enhanced the efficiency and precision of forensic investigations. These technologies facilitate detailed evaluation of dental morphology, restorations, prostheses, implants, and craniofacial structures while enabling rapid electronic data retrieval and remote consultation during disaster victim identification. Furthermore, AI-assisted image analysis and automated dental record-matching systems have demonstrated considerable potential in reducing identification time and minimizing observer-related variability. Despite these advances, challenges related to standardization, interoperability, data security, ethical concerns, and legal admissibility continue to influence the implementation of digital technologies in forensic practice. This narrative review discusses the evolution of digital dental records, highlights recent technological innovations, and critically examines their applications, advantages, limitations, and future perspectives in contemporary forensic odontology. The integration of digital technologies with conventional forensic principles is expected to redefine human identification by providing more accurate, efficient, and evidence-based forensic investigations.

Keywords: Artificial intelligence; Cone-beam computed tomography; Digital dental records; Digital radiography; Disaster victim identification; Forensic odontology; Human identification; Intraoral scanners.

Introduction

Forensic odontology applies dental science to legal investigations, identifying the living and the dead, estimating age, analyzing bite marks,[1] and supporting disaster victim identification (DVI). Teeth hold up where almost nothing else does: they survive decomposition, heat, chemical exposure, and blunt trauma that destroy fingerprints and soft tissue almost immediately. That durability, combined with how reliably and cheaply dental comparison can be done, is why forensic dental examination remains one of the most trusted identification methods available.[2-4]

What makes it work is that no two people's dentitions are quite alike. Tooth morphology, developmental quirks, restorations, prosthetics, implants, root canal and orthodontic history, and occlusion all combine into something close to a fingerprint. Comparing this profile between antemortem and postmortem records is the basis of dental identification, which is why clinical notes, odontograms, radiographs, photographs, study models, and treatment histories are worth so much more than routine paperwork. Keeping them properly is as much a medico-legal duty as a clinical one.[5-10]

For most of the field's history, that documentation meant handwritten charts, paper odontograms, film radiographs, and plaster casts, all vulnerable to damage, hard to store at scale, and rarely standardized between practices. That began changing roughly two decades ago, as electronic dental records (EDRs), digital radiography, cone-beam CT (CBCT), intraoral scanners, 3D digital models, and CAD/CAM systems

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took hold. Beyond just being more convenient, these tools have made forensic evidence sharper, easier to access, and simpler to reproduce, and they let forensic teams and disaster response agencies coordinate far faster than paper ever allowed.[11-15]

Artificial intelligence is the newest addition. Machine learning and deep learning models are already showing promise for automated record matching, age and sex estimation, dental segmentation, and reading radiographs, though it is best understood as a tool that supports forensic experts, not one that replaces them, given how much is still unresolved around validating these algorithms, data quality, legal admissibility, and ethical oversight.[16,17] None of this progress has come without friction. The lack of a universal EDR standard, poor interoperability between software platforms, and ongoing concerns about patient confidentiality, cybersecurity, and how digital evidence holds up legally all still shape how these tools get used. Closing those gaps will take standardized protocols and real international cooperation.[12,18]

This narrative review looks at where digital dental records currently stand in forensic identification, focusing on digital radiography, CBCT, intraoral scanning, 3D dental models, and artificial intelligence, along with the challenges, ethical questions, and future direction of the field.

Methodology

This narrative review is based on a literature search of PubMed, Scopus, and Google Scholar for articles published between 2000 and 2025, using combinations of the keywords "forensic odontology," "digital dental records," "CBCT," "digital radiography," "intraoral scanners," and "artificial intelligence." Relevant peer-reviewed articles, reviews, and guidelines in English were included at the authors' discretion; no formal systematic screening or quality-scoring protocol was applied.

Importance of Dental Records in Forensic Identification

Dental records are a reliable source of evidence for human identification due to the uniqueness and durability of teeth. They can withstand extreme conditions such as heat, trauma, and decomposition, making them valuable when other identification methods fail. Forensic odontology is therefore essential in medico-legal investigations, especially in mass disasters and cases involving severely damaged remains.[2-4]

Identification is based on comparing antemortem (AM) and postmortem (PM) dental records, including clinical notes, radiographs, photographs, and treatment details. The accuracy of identification depends on the quality and completeness of these records.[3,5]

Each individual has a unique dental profile shaped by genetics, environment, and dental treatments. Features such as tooth morphology, restorations, implants, and orthodontic appliances aid in identification, even among identical twins.[6,14]

Dental records are also crucial in Disaster Victim Identification (DVI), where they serve as a primary method alongside fingerprints and DNA. They provide a rapid and cost-effective means of identification in mass-casualty events.[4,18,19]

Additionally, dental records assist in forensic profiling, including age and sex estimation. Proper maintenance of accurate dental records is both a legal and ethical responsibility, as incomplete records can hinder identification.[8,20]

Evolution from Conventional to Digital Dental Records

Traditional forensic identification relied on paper records, radiographs, and study casts, which were prone to damage, storage issues, and slow retrieval.[2,5]

- The shift to Electronic Dental Records (EDRs) has improved documentation by integrating clinical data, images, and treatment history into a single digital system. This allows faster access, better accuracy, and easier sharing of information.[11,12]
- Digital records offer advantages such as secure storage, quick retrieval, and efficient data transfer, enhancing forensic comparisons. They also integrate with modern technologies like digital radiography, CBCT, and 3D scans, improving identification accuracy.[11,14,15]
- However, challenges remain, including lack of standardization, software compatibility issues, and cybersecurity concerns. Efforts are ongoing to develop standardized systems for better data sharing and preservation.[12,18]
- Overall, digital dental records have significantly improved forensic identification by combining accurate documentation with advanced technology.[2,4]

Digital dental records offer several concrete advantages over their paper-based predecessors. Because EDRs, digital radiographs, and 3D scans can be duplicated instantly and stored on secure servers, records are far less likely to be lost, damaged, or degraded over time, and multiple examiners can access the same case file simultaneously from different locations. Standardized digital formats also make it possible to search and cross-reference large record databases automatically, which shortens identification time in cases involving many victims. In everyday forensic practice, this translates into faster antemortem record retrieval from dental clinics, more consistent documentation across practitioners, and easier transfer of evidence between forensic teams, law enforcement agencies, and courts.[11,12]

These benefits come with trade-offs. Digital systems depend on compatible hardware, software, and file formats, and a record created in one proprietary system is not always

readable in another, which can complicate multi-agency disaster response. Long-term data storage raises questions about who is responsible for maintaining archives as software is updated or discontinued, and digital files are vulnerable to corruption, hacking, and unauthorized access in ways that paper records are not. There are also upfront costs: digital radiography units, CBCT machines, and intraoral scanners require significant investment and training, which can limit adoption in smaller practices and lower-resource settings, creating uneven record quality across the antemortem pool that forensic teams eventually have to work with.[13,20]

In practice, these digital tools are applied throughout the identification workflow. Digital radiography and CBCT are used to compare restorations, root morphology, and bone structure between antemortem and postmortem records; 3D surface models support non-destructive comparison of severely decomposed or fragmented remains; and automated matching software can screen large record databases far faster than manual review, flagging likely matches for an examiner to confirm. Combined, these applications have made digital records a practical tool not just for individual case identification but for the kind of large-scale, time-pressured comparison work required in mass disaster response.[14,15]

Digital Radiography in Forensic Identification

Digital radiography is central to modern forensic odontology, offering improved accuracy, speed, and reproducibility compared to conventional film. It enables immediate image acquisition, electronic storage, enhancement, and rapid sharing, facilitating efficient comparison of antemortem (AM) and postmortem (PM) records.[11,13]

Forensic identification relies on matching AM and PM radiographs based on unique dental features such as tooth morphology, restorations, root structure, and implants. The reliability increases with the number of matching characteristics.[6,7]

Intraoral Radiography

Intraoral radiographs provide high-resolution images of individual teeth and supporting structures. Periapical images reveal root anatomy, pulp chambers, and endodontic treatments, while bitewings show restorations, proximal surfaces, and bone levels. These features often remain stable over time, making them highly reliable for identification.[11,13]

Panoramic Radiography

Panoramic radiographs offer a broad view of both jaws and surrounding structures. They help identify impacted or missing teeth, implants, fractures, and other anatomical features, making them valuable in large-scale identification, especially in disaster scenarios.[4,19]

Digital Image Enhancement and Computer-Assisted Analysis

Digital systems allow image manipulation (contrast, magnification, filters) to improve visibility of details. Computer-assisted tools enable precise comparison of AM and PM images, reducing observer bias and improving accuracy.[13,16,17]

Digital Radiography in Disaster Victim Identification

Digital radiography plays a key role in disaster victim identification (DVI), where traditional methods may fail. Images can be quickly shared across institutions, allowing rapid and coordinated identification. Electronic storage also prevents data loss and supports international collaboration.[4,18,19]

Advantages of Digital Radiography

Digital radiography offers faster imaging, lower radiation, better image quality, easy storage, and quick data sharing. It also integrates with electronic dental records, improving documentation and accessibility for forensic use.

Limitations and Future Directions

Limitations include variability in imaging protocols and software compatibility. Future advancements include standardized systems, cloud databases, and AI-based automated matching, which may further enhance speed and accuracy (Table 1).[17]

Key Points

- Digital radiography is the primary tool for forensic dental identification.
- AM-PM comparison is highly reliable.
- Digital storage improves disaster response.
- Image enhancement increases accuracy.
- AI integration will further improve identification.

Table 1: Advantages of Digital Radiography in Forensic Identification

Feature	*Conventional radiography*	*Digital radiography*
image acquisition	Delayed	Immediate
Image quality	Fixed	Enhanced
Storage	Physical films	Electronic
Data sharing	Difficult	Instant
Image manipulation	Not possible	Available
Disaster victim identification	Slow	Rapid
Integration	Limited	Compatible with digital systems

Cone-Beam Computed Tomography (CBCT) in Forensic Odontology

Cone-beam computed tomography (CBCT) is a major advancement in forensic odontology, providing high-resolution three-dimensional (3D) images of craniofacial structures. Unlike conventional radiographs, CBCT eliminates distortion and superimposition, allowing accurate assessment of dental and skeletal features for human identification.[11,14]

CBCT datasets, increasingly available from routine dental care, serve as valuable antemortem records. They capture detailed information on tooth morphology, bone structures, sinuses, joints, and implants, enabling reliable comparison with postmortem scans.[11,14]

Three-Dimensional Anatomical Comparison

CBCT enables precise 3D visualization of structures such as the mandibular canal, maxillary sinus, and temporomandibular joint. Unique features like root morphology, pulp anatomy, impacted teeth, and surgical alterations provide stable markers for identification. Multiplanar reconstruction improves accuracy and reduces interpretation errors.[11,14]

CBCT in Human Identification

CBCT enhances identification by allowing detailed comparison of dental and skeletal features. Restorations, implants, surgeries, and pathological changes are clearly visible. Dental implants, with their unique design characteristics, are especially useful identifiers, even when natural teeth are damaged.[5,11,14]

CBCT in Age Estimation

CBCT improves age estimation by enabling 3D analysis of dental development and pulp volume reduction due to secondary dentin deposition. It also aids in assessing third molar development and bone changes, providing reliable age indicators.[11]

Table 2: Major Applications of CBCT in Forensic Odontology

Application	Forensic Significance
Human identification	AM–PM comparison of craniofacial structures
Dental implant analysis	Identification using implant morphology
Age estimation	Pulp volume, third molar development
Sex estimation	Mandibular and craniofacial measurements
Disaster Victim identification	3D reconstruction of fragmented remains
Maxillofacial trauma	Evaluation of fractures and surgical reconstruction
Digital archiving	Permanent electronic forensic records

Sex Estimation Using CBCT

CBCT supports sex estimation through analysis of craniofacial features such as mandibular dimensions and gonial angle. Its 3D accuracy enhances measurement reliability, and combining multiple parameters improves diagnostic accuracy.[11]

Applications in Disaster Victim Identification

CBCT is valuable in mass disasters, allowing non-destructive 3D analysis of fragmented or decomposed remains. Digital datasets can be shared globally, enabling collaborative identification and faster forensic workflows.[18]

Advantages of CBCT in Forensic Dentistry

- High-resolution 3D imaging
- Minimal distortion
- Accurate measurements
- Clear visualization of implants and restorations
- Digital storage and easy sharing
- Compatibility with reconstruction software
- Integration with AI tools

Limitations and Future Directions

Limitations include high cost, limited access, and need for specialized training. Future developments will focus on standardization, AI integration, automated analysis, and global data-sharing systems to enhance forensic identification (Table 2).

Key Points

- CBCT provides accurate 3D imaging for forensic identification.
- It improves AM–PM comparison and analysis of complex cases.
- Major uses include implants, craniofacial landmarks, and age estimation.
- Integration with digital records and AI will shape future forensic practice.

Intraoral Scanners in Forensic Odontology

Intraoral scanners (IOS) generate high-resolution 3D digital models of the dentition and surrounding soft tissue directly from the mouth, without the distortion, shrinkage, or damage risk associated with conventional impression materials and plaster casts. Originally adopted for restorative and orthodontic treatment planning, these devices are increasingly being examined for forensic use, since many patients already have IOS-based digital models on file as part of routine dental care, effectively creating a ready-made antemortem record.[21,22]

A particularly useful application is the digitization of palatal rugae, the ridged folds on the hard palate that are unique to each individual and remain stable throughout life. Because the palate is shielded by the teeth, cheeks, and jawbone, rugae patterns tend to survive heat, trauma, and decomposition that destroy more exposed tissue, making

them a valuable identification feature when conventional dental structures are compromised. Studies comparing IOS-generated palatal scans with antemortem records have reported that the technology can reliably capture this morphology for comparison purposes, though its accuracy on postmortem tissue, which may be dehydrated or distorted, is less well established than its accuracy in living patients.[21]

Direct studies on deceased subjects support the feasibility of the approach. In one study, intraoral scans of 23 corpses were superimposed against existing dental records and radiographs, with the resulting matches showing statistically reliable agreement and suggesting that IOS-based comparison can perform at least as well as traditional methods while working faster and non-destructively. Separate accuracy testing across several commercial scanner models has confirmed that repeatability and precision are high enough to support forensic use, though performance varies somewhat between devices, reinforcing the need for standardized scanning protocols before the technology is adopted more broadly in casework.[22,23]

Compared with conventional impressions, intraoral scanning is faster, better tolerated by patients, and produces a digital file that can be stored indefinitely, shared instantly between institutions, and superimposed directly onto other digital records such as CBCT scans. Its main limitations are practical rather than technical: operators need training to use the devices effectively, scanning is more difficult on deceased individuals affected by rigor mortis or advanced decomposition, and, as with other digital tools, there is no universal standard yet for file format or long-term archiving. Even so, as intraoral scanners become routine in general dental practice, they are likely to become an increasingly common source of ready-made antemortem records for forensic comparison.[21,22]

Conclusion

Digital transformation has fundamentally reshaped the practice of forensic odontology by improving the accuracy, efficiency, and reliability of human identification. The transition from conventional paper-based dental records to comprehensive digital documentation has enabled rapid retrieval, secure storage, and seamless comparison of antemortem and postmortem records, thereby strengthening forensic investigations. Technologies such as digital radiography, cone-beam computed tomography (CBCT), intraoral scanners, three-dimensional dental models, and artificial intelligence have significantly expanded the scope of dental evidence by providing detailed anatomical visualization and facilitating objective, reproducible analyses.

Among these innovations, digital radiography and CBCT have become indispensable tools for comparative identification, age estimation, sex estimation, and disaster victim identification. Similarly, intraoral scanners and digital dental models have introduced highly accurate virtual records that support long-term preservation and efficient forensic comparison. The emerging application of artificial intelligence further complements these technologies by enabling automated image analysis and rapid dental record matching, with the potential to improve efficiency during large-scale forensic investigations.

Despite these advancements, challenges related to standardization of electronic dental records, interoperability between digital platforms, data security, patient confidentiality, and legal admissibility remain important considerations. Addressing these issues through international guidelines, standardized documentation protocols, and continued technological innovation will be essential for maximizing the forensic value of digital dental records.

Overall, digital dentistry is redefining contemporary forensic identification by integrating advanced imaging technologies, computerized data management, and intelligent analytical systems. Continued collaboration among clinicians, forensic odontologists, researchers, and technology developers will further strengthen the role of digital dental records as a reliable, evidence-based tool for human identification in modern medico-legal practice.

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