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Role Of Orthodontics In Forensic Dentistry: A Review

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Abstract

Forensic odontology plays a crucial role in human identification through the examination of dental evidence, and orthodontics contributes significantly to this field by providing detailed, individualized records essential for forensic investigations. Orthodontic documentation including study casts, radiographs, and treatment notes preserves unique dental and craniofacial characteristics that remain reliable even under adverse conditions. These records facilitate accurate age and sex estimation, radiographic superimposition, and ante-mortem/post-mortem matching. Cephalometric analyses and dental arch measurements reveal sexual dimorphism, while age estimation techniques such as Demirjian's and Cameriere's methods enhance forensic precision. Orthodontic appliances serve as durable physical identifiers, particularly valuable in mass disaster victim identification (DVI). Advances in digital orthodontics, including CBCT and AI-based morphometric analysis, have further improved forensic accuracy. Thus, orthodontics bridges clinical documentation and legal identification, reinforcing its indispensable role within modern forensic odontology.

Keywords: Forensic Odontology, Orthodontic Records, Age Estimation, Sex Determination, Mass Disaster Identification

Introduction

Forensic odontology, a specialized branch of dental science, plays a pivotal role in legal investigations by focusing on human identification and the analysis of dental evidence in both criminal and civil contexts. Its scope encompasses the identification of unknown bodies, bite mark analysis, age and sex estimation, assessment of dental injuries, and expert testimony in judicial proceedings.[1] Teeth and associated oral structures possess remarkable resistance to environmental factors such as fire, trauma, and decomposition, making them invaluable for establishing identity when other tissues are no longer recognizable. Orthodontics, with its meticulous emphasis on detailed documentation including clinical photographs, radiographs, study casts, progress notes, and appliance specifications shares significant overlap with forensic odontology.[2] Orthodontic treatment often leaves behind unique anatomical and therapeutic markers, such as bracket scars, tooth alignment changes, and specific appliance placements, which serve as individualized identifiers in forensic comparisons. These records, combined with radiographic and photographic evidence, allow for accurate ante-mortem and post-mortem matching, while dental casts capture three-dimensional occlusal relationships that further enhance the precision of identification.[3] Moreover, orthodontic appliances, whether fixed or removable, provide distinctive forensic clues through

their design, material composition, and positional remnants, which may persist even after decomposition.[4] The advent of digital imaging, three-dimensional modeling, and artificial intelligence-driven dental profiling has further expanded the orthodontist's role in forensic investigations, improving accuracy in age estimation and personal identification. Beyond clinical practice, orthodontists hold ethical and legal responsibilities as expert witnesses, contributing professional testimony in court and adhering to mandatory reporting obligations in suspected abuse or assault cases. This article gives an overview on role of orthodontics in forensic dentistry.[5]

Orthodontic Records as Forensic Evidence

Orthodontic records serve as invaluable forensic tools in human identification by preserving distinct anatomical, morphological, and therapeutic markers that remain reliable even under adverse environmental conditions.[3] Study casts and digital models accurately capture the three-dimensional anatomy of teeth, including variations in size, shape, spacing, arch form, and occlusal relationships, which are unique to each individual and remain distinguishable even in fragmented remains. The advancement of digital models further enhances forensic precision by enabling virtual comparisons and 3D superimpositions between ante-mortem and post-mortem data.[4] Radiographic evidence, including Orthopantomograms (OPG), Lateral Cephalograms, and Cone Beam CT (CBCT) scans, offers detailed visualization of dental and skeletal structures, allowing investigators to perform radiographic superimpositions that confirm morphological concordance in tooth contours, root configurations, and craniofacial landmarks. CBCT's volumetric imaging adds depth and accuracy to forensic analysis beyond traditional 2D radiography.[5] Complementary to these are clinical photographs and treatment notes, which document changes in facial soft tissue, dental arch form, and appliance placement, contributing to facial reconstruction and forensic profiling. Standardized and meticulously maintained treatment records ensure traceability, authenticity, and legal admissibility in investigative contexts.[6] Furthermore, orthodontic appliances both fixed and removable bear distinctive identifiers through design patterns, positioning, wear characteristics, and even serial or manufacturer markings that can directly associate them with specific individuals. Constructed from resilient materials such as metal alloys, these appliances often endure fire, trauma, or decomposition, providing tangible forensic evidence when other biological tissues fail. Collectively, these comprehensive orthodontic components form a scientifically robust and legally credible framework for accurate personal identification, reinforcing the vital role of orthodontics within forensic odontology.[7]

Table 1: Orthodontic Records as Forensic Evidence

Component	Description / Forensic Role	Unique Identifiers & Advantages	Forensic Significance
Study Casts and Models	Plaster and digital models preserve detailed dental anatomy such as tooth size, shape, arch form, and occlusal relationships.	Capture 3D morphology, spacing, rotations, and alignment patterns unique to each individual. Digital models enable 3D comparison and virtual superimposition with post-mortem data.	Serve as durable, precise records for ante-mortem and post-mortem matching, even in fragmented remains.
Radiographs	Include Orthopantomograms (OPG), Lateral Cephalograms, and Cone Beam CT (CBCT) scans that visualize dental and skeletal structures.	Provide high-resolution details of tooth contours, root morphology, and bone landmarks. CBCT offers 3D volumetric imaging.	Allow radiographic superimposition and confirm morphological concordance, improving accuracy in identification.

Component	Description / Forensic Role	Unique Identifiers & Advantages	Forensic Significance
Photographs and Treatment Notes	Clinical photographs document facial and dental changes, while treatment notes record procedural and appliance details.	Capture soft tissue profiles, appliance placements, and progressive dental changes. Standardized documentation enhances reliability.	Aid in facial reconstruction, profiling, and verification of ante-mortem identity through traceable clinical information.
Orthodontic Appliances and Materials	Fixed and removable appliances (brackets, bands, wires, retainers) act as physical identifiers.	Contain unique positioning, wear marks, and sometimes serial or manufacturer markings. Made of durable materials that resist decomposition.	Provide direct evidence linking remains to individuals; withstand trauma or environmental degradation.

Role of Orthodontics in Forensic Age Estimation

Forensic odontology extensively employs orthodontic data for age estimation, which serves as a crucial component of biological identification in both living individuals and unidentified deceased persons. Orthodontic records, particularly radiographs and clinical documentation, allow the evaluation of growth stages and maturity indices that reflect dental and skeletal development.[8] Age estimation relies on assessing the stages of tooth calcification, eruption patterns, and root formation, as well as skeletal maturity indicators such as cervical vertebral morphology visible on lateral cephalograms.[9] Among the most widely accepted techniques, Demirjian's method evaluates the calcification stages of seven mandibular permanent teeth on radiographs to assign dental age, offering high reproducibility and accuracy in children and adolescents while minimizing environmental influence due to genetic control of tooth formation.[10] Cameriere's method, which quantifies open apices of teeth to determine maturation levels, is particularly valuable for assessing legal age thresholds, such as determining whether an individual is above or below 18 years. Complementing these dental indicators, the Cervical Vertebral Maturation (CVM) approach analyzes the morphological changes in vertebral bodies to estimate skeletal maturity, enhancing the reliability of age determination when integrated with dental data.[11] Orthodontic radiographs like Orthopantomograms (OPG) and lateral cephalograms are especially advantageous as they reflect biological rather than chronological age, with minimal influence from environmental or nutritional factors, though slight variations may occur across different populations.[12] With the advent of digital technologies such as Cone Beam Computed Tomography (CBCT) and artificial intelligence–based analysis, forensic age estimation has gained improved precision and objectivity through three-dimensional assessment and automated interpretation. Overall, orthodontic records form a scientifically validated and legally admissible foundation for forensic age estimation, offering a balanced integration of dental and skeletal maturity indices that ensure accurate, reproducible, and ethically sound identification in medico-legal investigations.[13]

Role of Orthodontics in Forensic Sex Determination

The role of orthodontics in forensic sex determination lies in analyzing the inherent sexual dimorphism present in craniofacial morphology and dental parameters through both qualitative and quantitative assessments. Distinct differences in craniofacial structures such as mandibular shape, jaw angle, maxillary width, and overall facial proportions serve as measurable indicators of gender and are effectively utilized in forensic investigations.[14] Dental arch dimensions, including mesiodistal (MD) and buccolingual (BL) measurements, also display statistically significant variations, with males generally exhibiting larger tooth dimensions than females. Among the dentition, posterior and maxillary teeth often yield higher

discriminative accuracy in sex estimation compared to anterior or mandibular teeth.[15] Cephalometric radiographs further enhance forensic analysis by providing linear and angular parameters such as mandibular ramus height, gonial angle, and maxillary length that demonstrate consistent sexual dimorphism. Advanced statistical tools like discriminant function analysis (DFA) applied to cephalometric data have achieved high levels of accuracy in gender classification, affirming their value in forensic identification.[16] In addition to morphometric approaches, molecular techniques such as DNA analysis of dental pulp and enamel proteins, notably through the amelogenin (AMEL) gene, offer highly precise sex determination, particularly when skeletal or dental morphology is compromised due to decomposition or trauma. Collectively, orthodontic and craniofacial data provide quantifiable, reproducible, and legally admissible evidence for determining sex in forensic contexts.[17]

Orthodontic Contributions to Mass Disaster Victim Identification (DVI)

Orthodontic contributions to Mass Disaster Victim Identification (DVI) are of immense significance due to the precision, individuality, and durability of orthodontic records, which enable accurate identification when visual recognition or soft tissue-based methods are impossible.[18] Ante-mortem orthodontic data such as digital or plaster study casts, radiographs (including OPG, cephalograms, and CBCT), clinical photographs, treatment notes, and appliance specifications offer unique morphological and therapeutic characteristics that persist despite trauma, incineration, or decomposition.[19] These records provide valuable markers for post-mortem comparison, allowing forensic teams to match victims with high accuracy.[20] Orthodontists play a vital role in DVI operations by supplying detailed ante-mortem records that often include chronological treatment progress and appliance serial details not available in general dental files. Within the Interpol DVI framework, standardized ante-mortem dental forms incorporate orthodontic records to facilitate systematic comparison with post-mortem findings.[21] Each victim is assigned a unique identification number linking all associated data, ensuring global consistency and traceability in identification. Orthodontic appliances, particularly fixed metallic components, frequently survive extreme environmental conditions and can retain identifiable features like manufacturer markings or serial numbers, as demonstrated in several disaster cases involving plane crashes and fire victims. These enduring characteristics make orthodontic records an indispensable component of the DVI process, strengthening both scientific reliability and legal admissibility in complex mass casualty events.[22]

Advances in Digital Orthodontics and Ethical-Legal Considerations in Forensic Applications

The emergence of digital orthodontics has revolutionized forensic applications by enhancing precision, efficiency, and accessibility in dental identification and analysis. Advanced imaging modalities such as Cone Beam Computed Tomography (CBCT), 3D surface scanning, and intraoral scanners generate highly detailed, reproducible datasets that allow forensic experts to visualize dental and craniofacial structures with exceptional clarity for purposes such as age estimation, sex determination, and bite mark analysis.[23] Artificial intelligence (AI) and machine learning (ML) have further automated morphometric evaluations, enabling objective, reproducible assessments through pattern recognition and predictive modeling in panoramic radiographs and 3D datasets. Additionally, CAD/CAM systems and comprehensive digital archives facilitate the storage of orthodontic records and appliance designs, which are invaluable for ante-mortem/post-mortem comparisons.[24] Cloud-based storage further enhances global accessibility and rapid data sharing, streamlining forensic collaboration during mass disasters or cross-border investigations. However, these technological advancements necessitate strict ethical and legal oversight. The confidentiality and legal admissibility of orthodontic data must be safeguarded under privacy regulations, ensuring that records are accurately maintained, verified, and collected according to standardized forensic protocols. Standardization of imaging, documentation, and data formats is critical to ensure consistency and comparability across institutions. Orthodontists, as forensic collaborators, bear the responsibility of providing expert interpretation, assisting in legal testimony, and upholding ethical integrity in forensic practices.[25]

Conclusion

In conclusion, orthodontic records serve as a dependable and scientifically robust source of forensic evidence, aiding in accurate human identification, age estimation, and sex determination. Their detailed, individualized nature ensures reliability even under adverse conditions. Emphasis on maintaining standardized, digitized, and easily retrievable records enhances their forensic and legal utility. Thus, orthodontics plays an indispensable role in strengthening the scope and precision of forensic odontology.

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