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Literature Review

Forensic identification using dental restorations: A radiographic and material-based perspective

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ABSTRACT

Background: *Forensic identification is a critical aspect of criminal investigations and disaster victim identification (DVI). Dental records, particularly dental restorations, serve as essential forensic markers due to their resistance to decomposition and environmental conditions. The integration of radiographic imaging and material-based analysis enhances the accuracy of forensic identification, allowing experts to match post-mortem findings with ante-mortem records.* ***Purpose:*** *This literature review aims to explore the role of dental restorations in forensic identification, focusing on the radiographic techniques and material-based forensic analysis used in modern forensic odontology.* ***Reviews:*** *This literature discusses the durability and uniqueness of dental restorations in forensic investigations. Various radiographic techniques, including periapical, panoramic, and cone-beam computed tomography (CBCT) imaging, are examined for their effectiveness in detecting and analyzing restorations. Additionally, the forensic relevance of restorative materials—such as amalgam, composite resins, ceramics, and metal-based prosthetics—is evaluated in cases where conventional soft tissue or DNA-based identification is not feasible. The review also explores technological innovations, including machine learning algorithms and digital forensic methods, that enhance forensic odontology.* ***Conclusion:*** *Dental restorations remain one of the most reliable forensic markers, particularly in challenging identification cases where DNA and soft tissues are compromised. The integration of advanced radiographic imaging and material analysis significantly enhances the precision of forensic identification. Future developments in AI-driven forensic imaging and automated restoration detection will further strengthen forensic odontology as a crucial field in legal and disaster investigations.*

Keywords: *forensic odontology; dental restorations; radiographic analysis; forensic identification*

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INTRODUCTION

Forensic identification is a critical component in criminal investigations and disaster victim identification (DVI), where establishing the identity of deceased individuals is paramount. Dental records, particularly dental restorations, have long been recognized as reliable sources for identification due to their durability and unique characteristics.[1] Forensic identification utilizing dental restorations is an essential aspect of forensic odontology, which plays a critical role in the identification of individuals in various legal contexts. This field of study is particularly significant given the increasing reliance on dental records for identifying victims of crime and disasters. Forensic odontology encompasses the examination and evaluation of dental evidence, which is crucial in legal proceedings, especially when conventional identification methods are insufficient or impossible due to the condition of the remains.[2] Dental restorations, such as fillings, crowns, and bridges, are designed to withstand significant wear and environmental factors, making them valuable in forensic contexts. Their unique features can be captured through various radiographic techniques, including periapical, panoramic, and cone-beam computed tomography (CBCT) imaging. These imaging modalities enable forensic experts to detect and analyze restorations, facilitating accurate identification even when other means are compromised.[3]

The urgency of discussing forensic identification through dental restorations arises from the growing number of mass disasters and criminal cases where traditional identification methods fail. The unique characteristics of dental restorations, which can be documented through radiographic imaging, provide a reliable means of establishing identity when other methods may be inadequate.[4] The importance of this topic is underscored by the increasing complexity of dental materials and the advancements in radiographic technology. As dental practices evolve, so do the materials and techniques used in restorations, necessitating continuous research to understand their implications in forensic identification.

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Moreover, the integration of artificial intelligence (AI) and digital forensics into radiographic analysis holds promise for enhancing accuracy and efficiency in the identification process.[5] This literature review aims to explore the role of dental restorations in forensic identification, focusing on radiographic techniques and material-based analysis. By examining current practices and emerging technologies, this review seeks to highlight the significance of dental restorations in forensic science and the potential for future advancements in this field.

METHOD

Article searches in English was done through PUBMED database to identify studies regarding dental restoration and forensic identification published from 2014 to 2024. The keywords used are dental restoration, forensic identification, dental radiography and dental materials. The information collected was taken from secondary data of published studies.

REVIEWS

The Forensic Significance of Dental Restorations

Dental restorations, including fillings, crowns, and bridges, are designed to endure significant wear and environmental factors, making them invaluable in forensic contexts. One of the primary reasons dental restorations hold forensic significance is their durability and resistance to environmental factors. Unlike soft tissues, which decompose rapidly, dental structures can withstand significant degradation over time, making them reliable indicators of identity.[6] Their unique features can be captured through various radiographic techniques, such as periapical, panoramic, and cone-beam computed tomography (CBCT) imaging. These imaging modalities enable forensic experts to detect and analyze restorations, facilitating accurate identification even when other means are compromised.[7] Forensic odontologists can analyze the unique characteristics of dental restorations, such as the type of material used and the specific techniques employed during their placement, to establish identification. This process is particularly valuable in situations where only skeletal remains are available, as the dental features can provide critical insights into the individual's identity.[8]

Amalgam restorations, which have been widely used for decades, are composed of a mixture of metals, including silver, mercury, tin, and copper. Their durability and resistance to wear make them a common choice for posterior teeth restorations. In forensic contexts, the presence of amalgam restorations can provide valuable information regarding an individual's dental history and treatment patterns. For instance, the specific type of amalgam used, as well as its placement and condition, can be compared against antemortem records to facilitate identification.[9] Composite resins, another commonly used restorative material, offer aesthetic advantages due to their tooth-like appearance. These materials are often used for anterior restorations and can be customized to match the color of the surrounding teeth. In forensic identification, composite resins can also provide unique identifiers based on their specific composition and placement techniques. The radiopacity of composite materials varies, which can be utilized in radiographic comparisons to identify individuals.[10]

Ceramic and metal-based restorations, such as crowns, bridges, and implants, are increasingly popular due to their strength and aesthetic qualities. These restorations can be particularly significant in forensic investigations, as they often contain unique identifiers that can be traced back to specific dental practices or manufacturers.[11] Fixed and removable prosthetics also play a crucial role in forensic identification. Dentures, partial dentures, and other prosthetic devices can be uniquely identified based on their construction materials and design features. Forensic odontologists can analyze these devices to gather information about the individual's dental history, including the presence of specific restorative techniques or materials used in their fabrication.[12]

Radiographic Techniques for Analyzing Dental Restorations

Radiographic techniques are indispensable in forensic odontology, providing detailed visualization of dental structures and restorations that are crucial for identification purposes. Intraoral periapical radiographs, for instance, offer high-resolution images of individual teeth and their surrounding bone structures, enabling forensic experts to assess specific dental restorations and pathologies. These radiographs are particularly useful for comparing antemortem and post-mortem dental records to establish identifications.[3] Panoramic radiography, also known as orthopantomography, provides a comprehensive view of the entire dentition, jaws, and adjacent structures in a single image. This broad perspective is advantageous in forensic cases involving multiple missing persons or mass disasters, as it allows for efficient screening and comparison of dental features. However, panoramic images may have limitations in resolution and may not capture fine details of individual restorations as effectively as intraoral radiographs.[13]

Cone-beam computed tomography (CBCT) has emerged as a valuable tool in forensic dentistry due to its ability to produce three-dimensional images of dental and maxillofacial structures. CBCT allows for precise assessment of the spatial relationships and morphology of dental restorations, which is particularly beneficial in complex cases where traditional two-dimensional radiographs may be insufficient. The technology also facilitates virtual autopsies and 3D reconstructions, enhancing the accuracy of forensic analyses.[14] The selection of appropriate radiographic techniques in forensic investigations depends on various factors, including the condition of the remains, the availability of antemortem records, and the specific forensic questions at hand. In many cases, a combination of radiographic methods is employed

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to obtain a comprehensive understanding of the dental evidence. Advancements in digital radiography and image processing have further improved the ability to detect and analyze dental restorations, thereby increasing the reliability of forensic identifications.[5]

Material-Based Analysis in Forensic Identification

Material-based analysis in forensic odontology involves the examination of dental tissues and restorative materials to aid in the identification of individuals. Teeth are composed of highly durable tissues, such as enamel and dentin, which can withstand extreme conditions, including high temperatures and prolonged decomposition. This resilience makes them invaluable in forensic investigations, particularly when other biological tissues are not available for analysis. Additionally, dental restorations, such as fillings, crowns, and implants, are often made from materials that are resistant to environmental degradation, providing unique identifiers that can be matched to dental records.[15] Advancements in analytical techniques have enhanced the capabilities of material-based analysis in forensic dentistry. Methods such as scanning electron microscopy (SEM), energy-dispersive X-ray spectroscopy (EDX), and mass spectrometry allow for detailed examination of the microstructure and composition of dental materials. These techniques can identify trace elements and isotopic signatures that may link a person to a specific geographic region or dietary practice, thereby providing investigative leads in cases where identification is challenging.[16]

The integration of DNA analysis with material-based approaches has further strengthened forensic identification processes. Teeth serve as a protected source of DNA, often yielding genetic material when other sources have been compromised. The combination of DNA profiling with the analysis of dental restorations and anomalies provides a multifaceted approach to identification, increasing the likelihood of accurate and reliable results. This multidisciplinary strategy is particularly valuable in mass disaster scenarios, where rapid and precise identification of victims is essential.[11] Variations in dental treatment practices, the availability of antemortem records, and the degradation of materials over time can complicate the identification process. Ongoing research and the development of comprehensive databases of dental materials and their properties are crucial for improving the accuracy and reliability of forensic dental identifications. Collaboration between forensic odontologists, material scientists, and law enforcement agencies is essential to address these challenges and to advance the field of forensic identification.[17]

DISCUSSION

Forensic identification through dental restorations relies heavily on the durability and uniqueness of dental materials. Materials such as amalgam, composite resins, ceramics, and various metals used in crowns and bridges are designed to withstand significant wear and environmental factors. This resilience ensures that even in cases of severe decomposition or exposure to extreme conditions, dental restorations often remain intact, providing critical information for identification purposes. The unique composition and placement of these materials can be matched to dental records, facilitating positive identification.[15]

Radiographic imaging is essential for identifying these restorations within dental structures. Methods including periapical and panoramic radiography, in addition to advanced methods such as cone-beam computed tomography (CBCT), enable forensic specialists to obtain intricate images of dental restorations. These photos can be juxtaposed with ante-mortem records to confirm a match. The radiopacity of materials such as amalgam and certain composites improves their visibility on radiographs, facilitating the distinction between different types of restorations. The integration of digital radiography and artificial intelligence (AI) has further advanced the field of forensic odontology. Digital radiographs offer superior image quality and the ability to manipulate images for enhanced analysis. AI algorithms can assist in the automated detection and classification of dental restorations, increasing the efficiency and accuracy of forensic examinations. These technological advancements hold promise for streamlining the identification process, particularly in mass disaster scenarios where rapid identification is crucial.[5]

Despite these advancements, challenges persist in the analysis of dental restorations for forensic identification. Variations in restorative materials, techniques, and the quality of dental records can complicate the comparison process. Additionally, the degradation of materials over time or due to environmental exposure can affect their radiographic appearance. Continuous research is necessary to understand these variables and develop standardized protocols for the forensic analysis of dental restorations.[18] The legal and ethical considerations in forensic identification using dental restorations cannot be overlooked. Maintaining the integrity of dental records, ensuring the accuracy of radiographic imaging, and upholding the chain of custody are critical components of the forensic process. Adherence to established guidelines and protocols is essential to ensure that the identification process is both scientifically valid and legally defensible.

In conclusion, dental restorations are valuable in forensic identification due to their durability and unique characteristics. Forensic identification using dental restorations is a crucial aspect of forensic odontology, offering a reliable means of identifying individuals, especially in cases where conventional methods fail. The durability of dental restorations, including amalgam, composite resins, ceramics, and metal-based prosthetics, ensures their resilience under extreme conditions, making them valuable forensic markers. Radiographic imaging, particularly with advancements in digital technology and AI, enhances the ability to analyze these restorations effectively. However, challenges remain, and ongoing research is essential to address these issues and improve

the reliability of forensic dental identification methods. By adhering to rigorous scientific and ethical standards, forensic odontologists can continue to provide critical support in identifying individuals in both routine and mass disaster scenarios.

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