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Forensic assessment of trauma using periodontal tissues evaluation: possibilities and future perspectives *

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Abstract

This article reviews the emerging field of periodontal tissue analysis in the context of forensic trauma assessment. Periodontal tissues are examined for their unique potential to improve the accuracy and scope of forensic investigations. They respond dynamically to different types of injuries, exhibiting distinct histological changes and features, thereby providing insights into the nature and timing of injuries. Although this method is promising, it also poses notable challenges, including contamination risks, post-mortem changes, and interpretation of histological results. Future implications will focus on advances in molecular analysis, integration of imaging technology, and establishment of reference databases. Standardization, quality assurance, and interdisciplinary collaboration are essential for reliable periodontal tissue analysis. In summary, periodontal tissue analysis is a dynamic and promising tool with significant implications in forensics, provided that it is used ethically and in accordance with the highest standards. This emerging field highlights the use of periodontal tissue analysis and the commitment of forensic experts needed to unravel the complexities of trauma, offering a potential path in the field of forensic science.

Keywords: trauma; periodontal tissue; forensic; analysis

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Introduction

The forensic examination of trauma cases plays an important role in helping to decipher the cause, manner, and circumstances of the injury, the timing of the injury, and, in some instances, the identity of the victim or assailant. Among the multitude of tools and techniques used in forensic assessments, periodontal tissues have garnered increasing attention for their potential to enhance the precision and comprehensiveness of trauma assessment - periodontal tissues (1).

The field of forensic science has grown significantly, encompassing different scientific disciplines and methods that meet the multifaceted needs of crime scene investigation, victim identification, and establishing key events in legal proceedings. In such efforts, accuracy and reliability are paramount, making the accuracy of forensic assessments a pillar component of the justice system (2). Trauma assessment is an integral part of forensic science, covering many situations from accident reconstruction to criminal investigations. It relies on careful examination of injuries, seeking to answer important questions about the cause of the injury, when it occurred, and the significance of the case in question (3).

During this challenging investigation of periodontal tissues, including the delicate supporting structures of the teeth and surrounding gums, emerged as a promising avenue for forensic examination. Periodontal tissues exhibit specific histological changes and characteristics in response to different types and durations of trauma (4). The intimate relationship between these tissues and the teeth they support allows for in-depth investigation into the cause and timing of injury.

Forensic science includes many different scientific disciplines, each with its own methods and techniques. Its primary objectives include identifying individuals, determining the cause of death, reconstructing the events leading up to the trauma or injury, and providing conclusive evidence to support or refute legal claims (5). One of the most fundamental aspects of forensic science is the meticulous examination of wounds, injuries, and trauma.

Traditionally, forensic investigators have relied on a set of methods and tools to evaluate trauma, each addressing specific types of injuries or circumstances. These techniques have advanced significantly from macroscopic observations to detailed microscopic analysis. Common methods include examining external injuries, such as abrasions, lacerations, and contusions, as well as using radiology, computed tomography, or magnetic resonance imaging to investigate internal wounds (6). Additionally, DNA profiling and forensic dentistry are often used to identify human remains and track evidence (7).

In recent years, increasing research has focused attention on the potential of periodontal tissue as a valuable asset in the forensic assessment of trauma (8). Periodontal tissues, which include the gingiva, cementum, periodontal ligament, and alveolar bone surrounding the tooth root, have emerged as a new method to improve the accuracy and completeness of trauma assessment. These tissues possess unique properties that distinguish them from other forms of forensic evidence, making them a promising avenue for forensic examination.

Periodontal tissues undergo histological changes and exhibit specific characteristics in response to different types and durations of trauma (9). The relationship between these tissues and the teeth they support is intimate, providing rich information to the forensic investigator.

This article explores the use of periodontal tissues in the forensic assessment of trauma, highlighting the unique characteristics of the periodontal tissues that make them useful in forensic assessment.

We will delve deeper into the case studies, review the methods and tools used for analysis, address potential challenges and limitations, and discuss future implications of periodontal tissue analysis in the forensic field. In doing so, we aim to contribute to the evolving landscape of forensic science by highlighting the potential of periodontal tissue to enhance and improve trauma assessments, thereby strengthening forensic investigation options and methods.

Periodontal tissues in trauma assessment

Periodontal tissues have recently garnered attention in the field of forensic science because of their potential to provide valuable insights into trauma assessment. These tissues play a unique and integral role in supporting and anchoring the dentition within the oral cavity, making them an excellent focal point for forensic examination (10).

Histological Changes and Reactions: Periodontal tissues respond dynamically to different types of trauma that may result from accidents, violence, falls, or other events. These reactions are often marked by marked histological changes, which become clear when analyzed under a microscope. Common changes in periodontal

tissue include hemorrhage, inflammation, cellular changes, and structural changes. The nature and extent of these changes vary depending on factors such as the type of injury, the force applied, and the length of time since the injury.

Discriminating Features: Microscopic examination of periodontal tissues allows forensic experts to identify specific features that indicate different types of trauma. For example, acute trauma may be associated with marked inflammation and hemorrhage in the periodontal tissues, whereas chronic or repeated trauma may result in distinctive cellular changes and resorption of bone and cementum (11,12). This specificity provides a valuable advantage in determining the nature of the injury and distinguishing accidental injuries from intentional injuries.

Dynamic Properties: The dynamic nature of periodontal tissues further increases their value in trauma assessment. Unlike many other tissue types, periodontal tissues continuously regenerate and adapt to changes in the oral environment and mechanical stress. As a result, these tissues exhibit a degree of plasticity that provides insight into when injury occurs (13). Investigators can infer whether the injury occurred recently or in the past by examining the phase of tissue response and repair.

Dental Evidence Support: Periodontal tissues are unique to each individual; therefore, they can provide an additional layer of evidence to corroborate dental records and assist in identifying unknown remains (14). The condition of periodontal tissue, and dental characteristics can offer a multifaceted approach to identity verification.

Potential Advances: Recent advances in histological and molecular techniques have further expanded the possibilities of periodontal tissue analysis. Immunohistochemistry and molecular markers can improve the accuracy and specificity of injury assessment and the time of death by providing additional information about tissue changes (15).

Examples of periodontal tissue use in forensics

The practical application of periodontal tissue analysis in forensic trauma assessment is perhaps best elucidated through case studies and real-life examples. These examples highlight the tangible benefits and insights that can be gained from the microscopic examination of periodontal tissue in various forensic settings.

Literature review gives data on different aspects of periodontal tissue use in forensics. From human identification using samples of cellular cementum (16) and bone trabecular patterns (17) to the histomorphometric analysis of fibroblast density (18) and the use of incremental lines of cementum for age identification (19) periodontal tissues have already shown potential in human identification.

Research has provided evidence for the differentiation of ante mortem-peri mortem dental trauma from post-mortem dental trauma using the morphology, extension, location of the injuries, and characterization of the impact (20).

Forensic case report presentation showed that forensic analysis of alveolar bone can distinguish violent attack from self-inflicted trauma resulting in tooth loss using multi-slice computed tomography (MSCT) and imaging reconstruction technology (21). Cone beam computed tomography (CBCT) with digital technologies 3D reconstruction and 3D printing also showed to be effective in the forensic odontology with process of forensic tooth reconstruction of missing tooth by using the intra-alveolar morphology of the dental socket (22).

These studies illustrate the various applications and benefits of periodontal tissue analysis in forensic assessment. Whether facilitating human identity, the nature of trauma, distinguishing between accidental and intentional injuries, or ante-mortem/post-mortem dental trauma, periodontal tissue analysis is a valuable tool in forensic analysis.

Methods of analysis

Analysis of periodontal tissues in the context of forensic trauma assessment requires a multidisciplinary approach that combines knowledge of forensics, pathology, dentistry, and histology. The methods used in this process extract valuable information from these tissues while preserving the integrity of the evidence. Advances in histological and molecular techniques have expanded the possibilities of periodontal tissue analysis in the forensic evaluation of trauma.

The following table describes the methods and tools used to analyze periodontal tissues in forensic cases (Table 1).

In addition to the challenges and limitations associated with the methods and tools used to analyze periodontal tissues in forensic cases, other important aspects need to be considered. Individual variations in periodontal tissues can complicate their analysis (23).

Table 1. Methods and tools used to analyze periodontal tissues in forensic cases.

	METHODS AND TOOLS	MAIN CHARACTERISTICS	ADVANTAGES	CHALLENGES AND LIMITATIONS
1	Periodontal tissue sample collection and preservation (24,25,34)	Collection of periodontal tissues during autopsy or examination of the victim's remains. Immediate fixation in formalin or a similar preservative solution.	Immediate fixation immobilizes cellular structures and prevents further tissue deterioration.	Careful extraction is crucial to minimize contamination during collection, handling, storage of samples and tissue damage. Tissue handling protocols are required to reduce errors.
2	Histological examination (9,18,19,25,26)	Preparation of thin tissue sections followed by staining with specialized dyes.	Can reveal cellular changes such as inflammation, hemorrhage, and other cellular alterations.	Careful preparation and staining are crucial for minimizing contamination and tissue section damage. It may be difficult to verify the staining accuracy. The post-mortem environment can introduce changes in periodontal tissues that may be misconstrued as trauma-related. The interpretation may be influenced by the expertise and subjectivity of the forensic expert, emphasizing the need for standardization.
3	Immunohisto chemistry (IHC) (15,30,32)	Employs antibodies to identify specific proteins or markers in periodontal tissues.	Can detect the presence of particular substances or pathogens that may be relevant to the trauma case. Can provide insights into the nature of injuries, such as identifying the presence of bacteria or foreign materials in tissues.	Availability of antibodies. Experience of pathologist. Antigenicity loss in paraffin sections. The training and expertise required for periodontal tissue analysis are specialized and may not be uniformly accessible.
4	Molecular analysis (16,31,33,34)	Polymerase chain reaction (PCR) can be applied to periodontal tissues to extract DNA or RNA.	This analysis can help identify potential pathogens, confirm the identity of the individual, or detect substances that may be related to the trauma. Molecular analysis can be especially valuable in cases where traditional histological methods may not yield conclusive results.	Possible errors in sampling. Contamination of the samples. The training and expertise required for periodontal tissue analysis are specialized and may not be uniformly accessible.
5	Radiography (21,22,27,28,29)	Radiographic techniques, such as dental X-rays, cone beam computed tomography (CBCT) and multi-slice computed tomography (MSCT), are employed to examine the dentition and surrounding periodontal tissues.	Can reveal structural changes in the alveolar bone, fractures, or dental anomalies that may be associated with trauma. Radiography complements histological and molecular analyses, providing a comprehensive view of dental and periodontal features. Possible use for forensic tooth reconstruction using the intra-alveolar morphology of the dental socket.	Technical errors in radiography. Variability in radiological analysis. Forensic tooth reconstruction provides good results with minimum errors.

Each person's response to trauma may differ, and the extent of histological changes may vary among individuals. To reduce the possible effects of this aspect, establishing normative data and reference standards for periodontal tissue analysis is a complex task, as it requires accounting for these individual variations.
In some cases, the sample size of available periodontal tissues may be limited, especially in decomposed or skeletonized remains (24). This limitation can affect the comprehensiveness of the analysis. During traumatic events, periodontal tissues may be severely damaged during traumatic events, reducing the amount of tissue available for examination. Post-mortem changes can further obscure accurate estimation of the time of injury.
The use of specialized techniques for the analysis of periodontal tissues, such as histology (25,26) radiology (27-29) immunohistochemistry (15,30) and molecular analysis (31), may be expensive and not available in all forensic laboratories, limiting their widespread application. In addition, the use of these techniques requires specialized training and expertise required for periodontal tissue analysis and may not be uniformly accessible. With the possible use of different techniques, standardizing procedures, quality assurance measures, and reporting guidelines are essential to ensure reliability and credibility. Ethical principles and legal regulations governing the handling and analysis of human tissue must be followed.
Due to the overall challenges and limitations, periodontal tissue analysis should be used in conjunction with other forms of forensic evidence to provide a comprehensive assessment. Interpretation of findings from periodontal tissues should be considered alongside other investigative aspects. Acknowledging these challenges and limitations is vital for the responsible and accurate use of periodontal tissue analysis in forensic trauma assessment. Rigorous training, quality control, and expert collaboration in relevant disciplines are essential to mitigate these challenges and ensure the meaningful interpretation of periodontal tissue findings in legal contexts. This recognition of nuances underscores the importance of maintaining the highest standards in forensic science.

Future implications and research

The use of periodontal tissues in the forensic evaluation of trauma is a dynamic and evolving field. As scientific and technological advances continue to reshape the forensic landscape, this section explores future implications and promising areas of research to further improve the application of periodontal tissue analysis.
The future of periodontal tissue analysis in forensic trauma assessment is likely to see significant advances in molecular techniques. DNA and RNA analysis could become even more accurate and sensitive, allowing the identification of specific pathogens, chemicals, or substances associated with trauma (34). With this, integration of advanced imaging technologies, such as 3D imaging and micro-computed tomography (micro-CT), could provide a more complete view of periodontal tissues by visualization of anatomical and structure changes, fractures, and microfractures, improving the quality of trauma assessment.
The creation of a broad reference database that includes histological specimens and molecular profiles of periodontal tissues could provide a valuable resource for forensic experts. Extensive validation studies are needed to establish the reliability and accuracy of periodontal tissue analysis for different types of trauma, which would include studies with a variety of trauma scenarios and different conditions to determine the robustness and limitations of the methods. Ethical and legal considerations are important, reminding us of the responsibility that comes with the post-mortem analysis of human remains.
Future research should explore the possibility of integrating periodontal tissue analysis with other forms of forensic evidence, such as DNA analysis, dental records, radiographs, and macroscopic assessment of lesions.

Conclusion

The application of periodontal tissue analysis in the forensic assessment of trauma represents an exciting avenue for improving the accuracy and completeness of investigations. Periodontal tissues and their responses to different types and durations of injury, as manifested by histological changes and unique features, provide a valuable perspective on the nature and timing of injury. The application of periodontal tissue analysis is not without challenges and limitations: contamination risks, post-mortem changes, and interpretation of histological results require meticulous attention.
Individual variations in tissue response and limited sample sizes in some cases require continued research and the establishment of reference standards. The future implications of

periodontal tissue analysis have great potential with advances in molecular analysis, integration of imaging technology, and development of reference databases. Successful use of periodontal tissues in trauma assessment requires interdisciplinary collaboration and analyses of periodontal tissues among forensic pathologists, pathologists, periodontists, and histologists.

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Declaration of Interest
None

Author Contributions
Z. H. – wrote and reviewed the manuscript; I. P. – supervised and reviewed the manuscript.

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