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Modern personal identification methods in dentistry

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ABSTRACT

The paper provides a review of relevant studies on the use of digital technology for personal identification in dentistry, as well as the main challenges of their implementation and use in real-world dental practice. Modern aspects of diagnosis and comprehensive planning of identification studies are aimed at improving the efficacy of solving complex medical and legal problems. The use of digital technology in dentistry has improved the accuracy of personal identification, as well as the reliability of forensic evidence. Significant advantages of digital photo and X-ray examinations over conventional techniques, as well as the benefits of digital 3D face reconstruction and dental identification, have been demonstrated. These findings indicate that artificial intelligence technology has the potential to improve identification methods.

At the same time, professional literature demonstrates shortcomings of artificial intelligence-based solutions in terms of discrimination, transparency, accountability, personal privacy, data safety, ethical norms, and other critical aspects. Thus, some authors suggest that the use of intellectual computer systems should be limited or even prohibited when drawing final conclusions and making judgments based on expert examination results. However, leading industry experts are increasingly convinced that the virtual evolution of self-developing artificial intelligence systems designed for independent existence is unavoidable.

According to recent research, the scientific community is increasingly interested in the implementation of innovative digital technology for effective solving of everyday research and practice challenges. Thus, digital technology has the potential to be a valuable tool for solving personal identification tasks and improving the quality of forensic evidence.

Keywords: digital dentistry; personal identification; ChatGPT; artificial intelligence.

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Современные методы идентификации личности в стоматологии

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АННОТАЦИЯ

Представлен обзор актуальных научных исследований применения цифровых компьютерных технологий в практике стоматологической идентификации личности, проанализированы основные проблемы их внедрения и фактического использования. Установлено, что современные аспекты диагностики и комплексного планирования идентификационного исследования направлены на повышение эффективности решения сложных медико-правовых вопросов. Применение цифровых стоматологических технологий позволило повысить результативность процесса идентификации личности человека, а также достоверность предоставляемых судебных доказательств. Показаны существенные преимущества методов цифрового фото- и рентгенологического исследования по сравнению с традиционными, а также достоинства цифровой 3D-реконструкции лица и дентальной идентификации, что свидетельствует о потенциальных перспективах использования технологии искусственного интеллекта с целью оптимизации решения идентификационных задач.

В то же время в специальной литературе есть свидетельства об обнаружении несовершенства интеллектуальных методов, связанного с дискриминацией, прозрачностью, подотчётностью, неприкосновенностью частной жизни, безопасностью данных, этическими нормами и другими важными аспектами. В связи с этим высказываются мнения о необходимости частичного ограничения использования интеллектуальных компьютерных систем для формулирования окончательных выводов и принятия итоговых решений по результатам проведённых экспертных исследований, вплоть до полного отказа. Несмотря на это, ведущие специалисты отрасли всё чаще с настороженностью заявляют о неизбежности виртуальной эволюции саморазвивающихся систем искусственного интеллекта, призванных к автономному экзистенциализму.

По данным современных научных исследований можно отметить рост интереса научного сообщества к вопросам внедрения цифровых инновационных технологий для обеспечения эффективного решения повседневных научных и практических задач. Таким образом, потенциальные возможности успешного применения цифровых технологий для решения задач идентификации личности и повышения качества предоставляемых судебных доказательств остаются весьма многообещающими.

Ключевые слова: цифровая стоматология; идентификация личности; ChatGPT; искусственный интеллект.

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ЭКО • ВЕКТОР

INTRODUCTION

Currently, digital forensic dentistry is a complex interdisciplinary medical science that also functions within the framework of medico-legal relations. Nagi et al. [1] and Gupta et al. [2] explored the paradigm shift in identification studies driven by the ongoing digitalization of forensic dentistry. Modern digital forensic dentistry has revolutionized traditional forensic investigations by enhancing the collection, analysis, and presentation of forensic evidence. It is now routinely used in investigations of mass disasters, earthquakes, and terrorist attacks. Advances in software, digital technologies, computer-aided design and manufacturing systems, electronic dental records, facial reconstruction techniques, and contactless autopsy methods, such as virtopsy, have accelerated and optimized personal identification by enabling the extraction of large volumes of data with reduced error margins [3].

AIM: To review recent publications on the use of artificial intelligence (AI) technologies in dental-based personal identification.

SEARCH METHODOLOGY

A literature search was conducted in Scopus, PubMed, Web of Science, eLIBRARY.RU, and Google Scholar to examine the potential and challenges of using AI technologies for digital personal identification in forensic medicine and dentistry. The search covered the period from 2013 to 2024 and used the following keywords: “digital dentistry,” “personal identification,” “ChatGPT,” and “artificial intelligence.” Today, forensic dentistry is an integral part of forensic medicine, playing a crucial role in identifying deceased individuals when visual recognition or other conventional methods are not feasible. Digital forensics has replaced conventional investigative approaches in terms of evidence collection, analysis, and presentation [4].

Digital forensics can now be defined as the application of computer science and investigative procedures for legal purposes, including the analysis of digital evidence [5]. With improvements in software capabilities, digital technologies are becoming increasingly prevalent in forensic investigations, particularly in assessing the consequences of mass casualty incidents. Moreover, dental radiographs and photographic materials are essential for personal identification and age estimation by comparing antemortem (AM) and postmortem (PM) data following preliminary suspect identification [5].

It is important to emphasize the high level of responsibility borne by forensic dentists, who are legally and ethically accountable for the final interpretation of dental evidence. Like other forensic experts, they must have substantial clinical experience, an appropriate level of medical and legal education, relevant professional certifications, and documented participation in continuing medical education programs. Judicial proceedings require well-reasoned and evidence-based expert opinions supported by verifiable research findings [6]. Therefore, a forensic dentist must be not only an excellent clinician but also knowledgeable in forensic law. Their expertise should include an understanding of the pathogenesis of bite marks and injury patterns in violent encounters, methods for age estimation, and contemporary identification techniques [7]. Furthermore, it is essential to understand the principles of international law, related protocols, and procedures for their implementation, with due regard for ethical standards and deontological principles [8]. Particular attention should be paid to respecting fundamental human rights aimed at protecting individual dignity and integrity, including during investigations of war crimes.

DIGITAL DENTAL PERSONAL IDENTIFICATION

Dental photographic documentation is a key component of comparative identification analysis in postmortem examinations and in the evaluation of suspect dentition against bite marks found on victims [9]. Digital cameras function by capturing an image and converting it into a computerized file via a sensor. These images can then be electronically archived, displayed, edited, printed, transmitted, or published. Balaji et al. distinguish between two types of digital images: raster graphics (e.g., .jpeg, .png, .tiff, .gif, .bmp) and vector images created using illustration software to enable post-processing and quality enhancement [10].

The conventional approach for bite mark photography involves accurate macro-image orientation to document bite mark location, optimal angulation of the camera lens relative to the skin surface, and the use of an ABFO No. 2 scale to assess and adjust for photographic distortions. The latter can be addressed using software such as Adobe Photoshop [11]. Visible light photography is the most common method for documenting bite marks, accounting for reflection, absorption, fluorescence, and light diffusion. Wright et al. reported using infrared and ultraviolet light photography to visualize soft tissue injuries not visible under natural lighting conditions [12]. To maximize the effectiveness of photographic tools, practitioners must have a sound understanding of photographic processes and the application of related computer technologies [13].

Postmortem dental identification relies heavily on the quality of antemortem dental records. However, reports often highlight the poor quality of antemortem clinical data in outpatient dental records. Entries are frequently incomplete, and the descriptive components of diagnostic and therapeutic procedures are routinely abbreviated. In such cases, when the remains of maxillofacial structures are severely fragmented or damaged, reliable identification becomes exceedingly challenging.

Forensic dentists must be well-versed in documentation formats and standards to ensure its potential utility in legal investigations [14]. Improper record keeping is a major contributor to identification errors and inaccurate expert opinions. A digital dental record is now recognized as an official document encompassing the patient's medical and dental history, examination findings, diagnoses, treatment plans, clinical progress, prognoses, and prescriptions. Global disparities in dental record keeping practices remain substantial. While some developing countries still use handwritten paper records, more advanced healthcare systems have adopted digital dental charts (DDCs), which incorporate actual digital images of the dentition and oral cavity and allow for intelligent data editing, sharing, and archiving. Digital dental evidence plays a critical role in Disaster Victim Identification (DVI) in scenarios involving severe disfigurement, where dental hard tissues may be the only viable source of identification. Research emphasizes the unique and histologically stable nature of dental hard tissues, making them a reliable source for authentication. INTERPOL guidelines highlight the importance of maintaining professional confidentiality and personal accountability when handling and storing patient data [15]. The success of digital identification hinges on the accuracy of matching digital radiographs and photographs.

A comprehensive forensic dental analysis can incorporate various features of the dentition and craniofacial anatomy, such as root morphology, maxillary sinus configuration, restoration architecture, and pulp chamber topography [16]. These features offer strong evidence for expert conclusions, contingent upon the quality of antemortem radiographs and other diagnostic records [17]. Depending on the case and investigative needs, useful materials may include diagnostic casts, wax bite templates, acrylic splints, prosthetic devices, orthodontic appliances, and radiographic images [18].

Radiographic data remain a cornerstone of comparative forensic identification. The advent of digital radiography has transformed this domain by enabling rapid retrieval, viewing, editing, and intelligent comparison of AM and PM images. Satellite and internet transmission of digital files to central forensic coordination hubs ensures prompt image delivery with no quality loss. Traditional radiographic exposure and visual comparison with dental records are increasingly viewed as time-consuming and ineffective. According to Lewis et al., the practicality and versatility of digital radiography and digital photography significantly facilitate the process of forensic comparison [19]. The authors also emphasized that in mass disaster situations, digital radiography proves to be far more useful than conventional radiography.

Advanced visualization techniques, including multislice computed tomography and cone-beam computed tomography (CBCT), have significantly reduced PM scan time. DentaScan multiplanar reconstruction further enhances image processing capabilities.

Intraoral scanning, both direct and indirect, has improved the precision of dental imaging [20]. Intraoral 3D scanners allow for reduced reliance on impression trays and materials, thereby enhancing patient comfort and diagnostic efficiency [21]. Modern contact 3D scanners (point-by-point or line-scanning) can analyze dental surfaces using a specialized probe with a steel or sapphire tip. According to experts, the main limitation of such scanners is the prolonged intraoral presence of the probe during point-by-point scanning of complex topographies, particularly concave surfaces. Optical and laser scanners have addressed many challenges associated with occlusal surface scanning. Images captured by a sensor are additionally processed by specialist software, enabling their conversion into 3D models using coordinate triangulation. The high resolution of acquired 3D images allows comparing them with available forensic materials, such as bite marks or photographs [22].

The application of 3D printing in forensic investigations allows for rapid fabrication of physical replicas of anatomical structures, enabling novel solutions to applied research problems. Anthropological assessment of the skull is conducted using computed tomography, whereas digital reconstruction is performed through volumetric imaging based on isotropic voxels: three-dimensional raster elements that represent data values in spatial coordinates. In computer graphics and medical visualization, voxels serve as the three-dimensional equivalent of pixels and provide an alternative to polygonal modeling for accurately depicting anatomical structures. It is well known that 3D printers do not natively interpret medical imaging data in the Digital Imaging and Communications in Medicine (DICOM) format. Instead, the Standard Tessellation Language (STL) format is used, which encodes surface geometry as a set of interconnected triangles, effectively forming

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a digital puzzle. Processing of DICOM images is carried out using specialized computer-aided design (CAD) software. This software enables segmentation of tissue layers by outlining regions of interest (ROIs), which are then converted into refined STL surface models. In the final stage, the generated STL data are transferred to 3D printers, where successive layers of the object are fused together. This process, known as additive layer manufacturing, reconstructs three-dimensional colored models of anatomical structures from sequentially printed 2D slices derived from CT data. Today, 3D printing is widely used in forensic dentistry for criminal case investigations and as evidence in court. It is applied in odontoscopy, palatoscopy, cheiloscopy, bite mark analysis, tongue print analysis, virtual facial reconstruction, sex and age estimation, and assessment of craniofacial trauma. Despite skepticism surrounding the future of digital technologies, the advancement and widespread implementation of intelligent systems are increasingly recognized as essential [22].

Some authors consider AI-based facial reconstruction a viable alternative for contextual assessment when conventional identification methods fail due to severe tissue damage. Notably, this approach does not involve direct evaluation of physical evidence because of its virtual nature [24].

There are diverging views on the relationship between facial morphology and cranial structure, which has led to two opposing theoretical concepts. The first school of thought uses the term “facial approximation,” implying that various facial features can be reconstructed on the same skull [25]. In contrast, proponents of the “facial reconstruction” approach emphasize a unique anatomical correspondence, integrating both scientific and artistic principles.

Currently, both 2D and 3D facial reconstruction methods are employed using analog and digital visualization technologies [26]. Classical manual 3D reconstruction involves sculpting with clay, plastic, or wax directly onto the skull or its replica. This method can follow one of three principal approaches: the American tissue-depth method, the Russian anatomical method, or the combined Manchester method. The American approach, developed by Krogman in 1946 for law enforcement use, involves a comprehensive qualified assessment of facial musculature using needles, radiography, or ultrasonography. Due to its complexity and the need for extensive expert training, as well as the availability of simpler alternatives, its use has declined. The Russian anatomical method, developed by Gerasimov and introduced in Europe in 1971, involved layer-by-layer modeling of soft and hard tissues on the skull. However, it has largely been abandoned due to its labor-intensive nature. As a result, the Manchester method, developed by Nayinis in 1971, has become the predominant manual approach. It considers soft tissue thickness and the alignment of cranial landmarks relative to the Frankfurt horizontal plane [27].

With advances in software, computer-assisted 3D facial reconstruction systems have become particularly relevant, enabling the creation of individualized facial morphology based on skeletal features [28]. The process involves digitizing the skull using laser scanners, video cameras, and dedicated software, which applies markers corresponding to soft tissue depth. Computer-assisted 3D animation systems for virtual sculpting with haptic feedback have been introduced to provide intuitive interaction with the digital model. The integration of computer systems has reduced subjectivity in expert assessments and improved both the speed and accuracy of facial identification. Digitization has simplified virtual facial reconstruction and reduced associated costs [29]. Moreover, it has enabled the generation of realistic image series for facial simulation and further scientific or creative refinement.

According to Verma et al., modern AI-based systems for bite mark analysis are increasingly used as scientifically valid evidence in criminal proceedings [31]. Comparison of bite marks with suspect dentition is traditionally performed via manual tracing and photocopying [11]. However, computer-based overlay techniques are now considered more reliable and accurate. This approach involves scanning, digital processing, and image superimposition using Adobe Photoshop software [11]. Results are interpreted using a scoring system: 0 points for no match, 1 point for slight match, 2 points for moderate match, and 3 points for perfect match. In addition, the Dental Print software (Spain) is reported to generate more precise overlays based on 3D files of suspect digital dental impressions. The use of 3D-printed dental models has further simplified bite mark analysis and significantly reduced the risk of errors.

CHATGPT AND CHALLENGES IN THE APPLICATION OF DIGITAL TECHNOLOGIES

Extensive practical experience has now been gained in the application of ChatGPT and AI in healthcare and medical technologies. As an advanced language model, ChatGPT employs deep learning techniques to generate human-like responses to natural language prompts. It can recognize the nuances and complexities of human language and produce contextually appropriate responses to a wide range of queries. According to Shan et al., ChatGPT is one of the largest publicly available language models that uses deep learning to generate natural language outputs resembling human responses [32]. In forensic medicine, potential applications of ChatGPT range from generating court reports to reduce decision-making time to supporting expert research groups in scientific investigations [33], including comprehensive analytical tasks [34]. Additionally, it has been used to generate automated clinical records summarizing key patient data. These include symptoms, adverse effects, imaging and laboratory findings, drug interactions, treatment regimens, self-diagnosis, and rare disease identification. These tools may enhance patient-provider communication and promote healthcare efficiency [35].

Medical applications of ChatGPT range from identifying potential research topics to assisting professionals in clinical and laboratory diagnosis. It can also support medical students, physicians, nurses, and other healthcare professionals in keeping up with recent advancements and innovations. Another promising application is creating virtual assistants to help patients control their health [36].

Researchers emphasize that, alongside its advantages, the use of AI carries significant drawbacks. Public and academic opinions on the development and large-scale implementation of AI remain divided. Experts note that both public enthusiasm and concern about future prospects are justified and evidence-based. Concerns include job displacement, loss of data privacy and security, information distortion, dehumanization, ethical erosion, and societal depersonalization. AI systems may inherit biases and discriminatory patterns from the training data, reflecting entrenched social prejudices. Such biases are particularly dangerous as they extend beyond individual interactions and can reinforce systemic inequality and discrimination. Moreover, these distortions may result in critical errors during personal identification at all levels [37]. One illustrative example is the use of facial recognition technologies trained on demographically narrow datasets, leading to misidentification, wrongful arrests, and unjust treatment. The lack of transparency in AI decision-making processes complicates logical reasoning, accountability, and the legal admissibility of such data.

Another concern is that overreliance on AI and its overestimation in future workflows could lead to professional dependence. In forensic dental analysis, the limited contextual understanding and domain-specific insight of AI systems pose risks, especially in the interpretation of oral health and pathology, including within legal frameworks. Many researchers also highlight ethical challenges associated with autonomous decision-making in healthcare.

CONCLUSION

Sound forensic dental expert opinions are based on a synthesis of contemporary jurisprudential knowledge, medical computing technologies, craniofacial anatomy, dental morphology and histology, modern digital diagnostics, and accurate clinical data interpretation. Therefore, the legal integration of specialized digital software into personal identification and forensic investigations is both necessary and inevitable. It is anticipated that conventional dental science and forensic practice will undergo fundamental transformation through the widespread implementation of digital technologies in odontology and forensic medicine.

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