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Unveiling the enigma: Exploring implants in forensic odontology - A survey among dental students and practitioners

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Abstract:
Forensic odontology contributes to human identification and the interpretation of dental evidence in legal investigations. Therefore, it is of interest to assess the awareness, knowledge and training gaps regarding forensic odontology and dental implants among 550 dental students and professionals, with a 98% response rate. Overall, 72% were aware of forensic odontology, 81% understood its role in human identification and 53% were aware of dental implants in forensic contexts. Only 14% had received formal training, while 83% supported greater emphasis on forensic odontology in dental education. Thus, data shows the need for structured education, workshops, seminars and hands-on training on forensic odontology and the forensic application of dental implants.

Keywords: Dental implants, forensic odontology, knowledge, survey, training

Background:
Forensic odontology is an important branch of forensic science that applies dental knowledge to legal investigations, particularly in the identification of unknown individuals and human remains **[1]**. Dental identification is especially valuable when remains are decomposed, burned, fragmented, or otherwise severely disfigured, making conventional methods of identification difficult or impossible **[2]**. Dental records, radiographs, restorations, tooth morphology and other individual dental characteristics can provide reliable evidence for establishing identity and may also assist in age estimation and other forensic assessments **[3]**. The increasing use of advanced restorative procedures has further expanded the range of dental features that may be relevant to forensic investigations **[4]**. Dental implants have become an established treatment option for replacing missing teeth and restoring oral function and aesthetics **[5]**. Their widespread use has created an additional source of potentially valuable forensic information, as implants may possess distinctive characteristics related to their material, dimensions, design, surface configuration and manufacturer **[6]**. Implant-supported restorations may also be documented through clinical records and radiographic images, which can provide useful antemortem information for comparison with postmortem findings **[5]**. However, the forensic significance of dental implants is not always adequately recognized or incorporated into routine dental documentation and identification procedures **[7, 8].** Therefore, it is of interest to evaluate the awareness, knowledge, perceptions and training gaps regarding forensic odontology and the forensic application of dental implants among dental students and practitioners.

Methodology:
This study analyzed the perception, awareness and knowledge of dental students and practitioners regarding the role of dental implants in forensic odontology using a cross-sectional survey design. The questionnaire assessed the dental community's understanding of the applications of forensic implants for the identification of human remains from a judicial perspective, offering a better idea of the knowledge of dental implants among dental practitioners who are representatives of odontological medical expert activity. Participants comprised all dental students and practitioners in dental schools, dental clinics and private practices, providing a balanced representation across varying levels of academia and clinical practice, including undergraduate dental students, graduate dental students (*e.g.,* dental residents or specialists) and practitioners in the field (dentists and forensic odontologists), enabling knowledge assessment at varying stages of experience and expertise. The sample size was calculated according to the population of dental students and practitioners in the selected geographical area, yielding 550 subjects, which statistically ensures a 95% confidence level with a margin of error of 5%; the sample was stratified to guarantee sufficient proportions from each type of dental practitioner and participants were recruited from dental schools and private dental clinics accordingly. Inclusion criteria comprised current dental students enrolled in an accredited dental school at both undergraduate and postgraduate levels, licensed dental professionals including general dentists, specialists and forensic odontologists, participants aged 18 years or older and informed consent to engagement conditions. Exclusion criteria ruled out non-dental professionals (e.g., administrative staff, non-dental healthcare professionals) and invalid data, *i.e.,* responses that were incomplete or inconsistent. Convenience sampling was used, with dental schools and clinics contacted to invite their members to participate, enabling data retrieval from a diverse population with differing forensic odontology knowledge and experience; participants were recruited across academic levels (undergraduate, graduate, residency) and from both urban and rural settings to accommodate regional differences in education and practice. Data were collected through a self-administered online survey disseminated via institutional email, social media platforms and institutional networks; the first section gathered general demographic information (age, sex, profession, years of experience, geographic location), the second assessed professional background and exposure to forensic odontology, the third evaluated knowledge of the role of implants in forensics and any training received in identifying and documenting implants in forensic cases and the fourth assessed educational needs regarding whether forensic odontology, specifically dental implants, should be part of the curriculum or continuing education. An expert panel of forensic odontologists, experienced dental educators and survey design specialists reviewed the questionnaire for content clarity, accuracy and relevance and a pilot study of about 30 people was conducted to identify design flaws such as confusing questions or technical

problems; reliability was assessed using Cronbach's alpha, with 0.7 considered an acceptable limit. Descriptive and inferential statistical methods were used to analyze data from the online survey: demographic characteristics and responses to closed-ended questions were summarized using frequencies, percentages, means and standard deviations; chi-square tests and dependent t-tests explored relationships between variables (*e.g.*, years of experience and knowledge of implants); and thematic analysis was used to analyze qualitative data from open-ended questions to identify common themes around awareness of dental implants in forensic contexts and the need for further training. The study complied with ethical principles established by IRB and ethical committees; all participants were informed that participation was voluntary and anonymous, informed consent was obtained, responses were kept confidential and used only for research and all identifying information was removed from the dataset.

Results:

A total of 550 dental students and practitioners participated in the survey, resulting in a response rate of 98%. The gender distribution of the survey participants was as follows: 56% (308 participants) were male, while 44% (242 participants) were female. The participants' professional backgrounds were diverse, with 32% (176 participants) being undergraduate dental students, 132 participants (24%) being graduate dental students, including specialists and residents and 154 participants (28%) being general practitioners; additionally, 55 participants (10%) were specialists, such as orthodontists and periodontists, while 33 participants (6%) were forensic odontologists. The participants' years of experience were distributed as follows: 165 participants (30%) had 0-2 years of experience, 137 participants (25%) had 3-5 years, 110 participants (20%) had 6-10 years and 138 participants (25%) had 11+ years of experience; regarding geographic location, 358 participants (65%) were based in urban areas, while 192 participants (35%) were from rural areas. The survey results revealed that 396 participants (72%) of respondents were aware of forensic odontology, while 154 participants (28%) were not. In terms of familiarity with forensic applications, 445 participants (81%) were knowledgeable about the role of forensic odontology in identifying human remains, 358 participants (65%) were familiar with its use in determining age, sex and ancestry, 264 participants (48%) had knowledge of bite mark analysis and 423 participants (77%) understood the importance of dental records matching. Regarding training in forensic odontology, 99 participants (18%) had received formal training, 247 participants (45%) had informal exposure through case studies or seminars and 204 participants (37%) had no training in this field. The results showed that 291 (53%) participants were aware of using dental implants in forensic identification, whereas 259 (47%) participants were unaware. Regarding encounters with forensic cases involving dental implants, 154 participants (28%) reported encountering them and 396 participants (72%) reported not encountering them. Regarding subjects' perceived importance of dental implants in forensic investigations, 176 participants (32%) thought dental implants were essential, 247 participants (45%) thought them somewhat necessary and 127 participants (23%) believed they were of no importance. Regarding implant identification proficiency, 66 participants (12%) were very familiar, 220 participants (40%) were somewhat familiar and 264 participants (48%) were not familiar. Furthermore, only 77 participants (14%) had previously received training on using dental implants for forensic purposes, with 473 participants (86%) having received no training on the subject. Results indicated that 457 participants (83%) agreed, while 93 participants (17%) disagreed, that forensic odontology should receive greater emphasis in dental curricula. Regarding continuing education, 391 participants (71%) expressed interest in further training on the forensic applications of dental implants, whereas 159 participants (29%) did not. In terms of preferred learning formats, workshops and seminars were favored by 264 participants (48%), online courses by 149 participants (27%) and hands-on practical training by 137 participants (25%) **(Table 1)**. Of the survey's questions, some measured differences in awareness based on professional experience: of undergraduates, 95 participants (54%) acknowledged that dental implants played a role in forensic odontology and 40 participants (23%) noted that they had undergone specific training in forensic odontology; graduate students and residents had significantly greater awareness, with 82 participants (62%) having heard of the forensic role of implants and 40 participants (30%) having informal exposure to implants through seminars or case studies; and forensic odontologists had the most significant awareness of the forensic role of dental implants, with 33 participants (100%) aware and 30 participants (91%) having formal training in this area.

Table 1: Preferred learning format for continuing education on forensic applications of dental implants

Preferred learning format	Participants (%)
Workshops and seminars	264 (48%)
Online courses	149 (27%)
Hands-on practical training	137 (25%)

Discussion:

Here, we examine the overall survey need for extra education on forensic odontology focusing on dental implants. The results of the current study reveal that, to a large extent, participants agreed that forensic odontology should be integrated more thoroughly into dental education. The majority (83%) were in favor, believing that forensic odontology deserves more emphasis within dental curricula, with only 17% disagreeing. This aligns with the increasing awareness in dental and forensic communities of the need for forensic odontology to be a fundamental aspect of all dental education. About 71% of participants stated that they wanted to be educated more on the forensic applications of dental implants; this reflected the need for legal training in the field as dental implants were getting an ever-increasing role in forensic examinations. Respondents favored interactive and hands-on practical training, seminars and workshops when asked about the preferred learning mode, agreeing more with the learning approach that engages them than traditional methods. It also reflects a recent direction within

healthcare education, in which learning techniques more likely to promote retention and application of knowledge have become the goals. Differences in knowledge/awareness of the role of dental implants in forensic odontology across levels of professional experience were also investigated. Awareness was relatively low among undergraduate students of dentistry, where only 54% recognized dental implants can also have a forensic utility. In comparison, 62% of graduate students and 100% of forensic odontologists had a much higher awareness of the forensic applications of implants. These findings indicated that the level of professional experience and specific training in forensic odontology largely determines the extent of an individual's knowledge on this fundamental topic. Compared to the greater awareness of worldwide research perspectives among specialists, the relatively low awareness among undergraduate students highlights an essential gap in dental education. This issue is particularly worrying due to the growing use of dental implants in forensic identification, indicating the importance of including this subject in general dental education. The survey indicated that knowledge gaps were evident and that there was a significant lack of formal training regarding dental implants in forensic settings. Moreover, only 14% had received formal training in the forensic applications of dental implants, compared to 86% of participants who reported receiving no formal training. Such lack of training is alarming because dental professionals are usually among the first responders in situations requiring forensic analysis (for instance, in mass disasters or criminal investigations). Advanced forensic training for dental professionals, such as analysis in the identification of dental implants, would ensure that professionals are competent in providing aid to forensic investigators. The findings corroborate previous studies urging more forensic odontology content in dental curricula. For instance, Rathod *et al.* (2017) raised issues associated with dental professionals not receiving adequate training in forensic odontology, similar to the issues raised in the current study **[9].** Similarly, Emam (2024) emphasizes the critical need for expanding forensic odontology education so that dental professionals have the knowledge they need to assist in disaster victim identification, in which dental implants play an ever more important role **[10].** The results of this survey support the insightful recommendations given by Sebastian *et al.* (2023), arguing for reform in dental curricula to include a more comprehensive coverage of forensic odontology **[11]**. Deepalakshmi *et al.* (2014) also describe the potential role of dental implants as a critical tool in forensic investigations, noting that accurate identification and analysis of dental implants requires specialized training **[7]**. This survey's results, particularly the observation that most participants (86%) had no formal training on the forensic potential of dental implants, support the implementation of curricular changes and targeted training initiatives. Indeed, the current study found that most responding clinicians wished to have more education on the forensic applications of dental implants, supporting a previous call for dental professionals to undergo training to complete forensic examinations Kabra *et al.* **[12]**.

Conclusion:

Dental implants are increasingly valuable in forensic odontology, highlighting the need for enhanced practitioner education, standardized identification protocols and interdisciplinary collaboration. Integrating Artificial Intelligence (AI) and Augmented Reality (AR) can improve implant identification, radiographic analysis, database matching and practical forensic training. International databases, ethical guidelines and structured training programs are essential to strengthen identification accuracy and facilitate cross-border forensic investigations.

Limitations:

Although this study gives preliminary insights into awareness and perception of dental implants in forensic odontology, it has limitations. First, the convenience sampling method used, though practical, may limit the generalizability of the results. Another limitation was that this sample predominantly represents individuals from urban settings, meaning that dentists working in rural areas, where access to forensic odontology training and resources may vary, could be under-represented. Furthermore, the self-reported nature of the data may lead to response biases, like social desirability or recall bias, as participants may have perceived themselves as having extensive experience or knowledge in forensic odontology focusing on the role of dental implants, leading to a possible overestimation of the results. Additionally, the study found a significant lack of formal training on the forensic applications of implants, which is troubling considering that many dental professionals are often some of the first responders in forensic investigations; however, this limitation is only relative to the survey sample and may not reflect the broader dental community appropriately. Finally, innovation in dental implants and forensic odontology is occurring relatively rapidly and current education practices may be unable to keep up, potentially leaving some practitioners unable to adopt oral implantology practices in their workplace and they may need continuing professional development in the area.

Future perspectives:

The future of forensic odontology and the integration of AI in forensic odontology with dental implants is inevitable and possible within VR and AR **[13].** By automating the comparison of dental records and the accuracy of implant identification, AI can potentially transform mutations and spur the development of new forensic investigations **[14, 15].** When combined with VR and AR, these technologies can serve as immersive and interactive training platforms for dental professionals to train their ability to identify implants and conduct forensic scenarios. These innovations may help to upskill forensic cases with more aimed efforts from dental experts and more competent and efficient enhancements **[16, 17].** Besides, the study highlights the importance of curriculum reforms recognizing forensic odontology as an integral segment of dental education. The curriculum should include AI-powered educational tools, virtual case studies and hands-on simulations to adequately prepare

dental students and practitioners to meet the forensic challenges of dental implants head-on. Integrating the input of dental clinicians, forensic practitioners and technology developers will be necessary for the evolution of the field so that forensic odontology keeps up with the increasing implementation of dental implants in criminal investigations and disaster victim identification. Moreover, international standards must be outlined for implant identification and documentation in forensic fields, as well as specific training programs emphasizing dental implants. Such initiatives might fill the existing gaps in knowledge and ensure that dental professionals are well-trained to handle similar forensic cases in the future.

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