Dental implants for forensic identification in incinerations: recommendations from a scoping review

Implantes dentales para la identificación forense en incineraciones: Recomendaciones a partir de una revisión con búsqueda sistemática

Implantes dentários para identificação forense em incinerações: Recomendações de uma revisão de pesquisa sistemática

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Abstract

Forensic odontology (FO) is recognized as one of the primary methods for forensic identification. Although teeth are structures resistant to high temperatures, particular conditions can make them very fragile. Dental implants (DIs), widely used in current oral rehabilitation, are manufactured in alloplastic materials based on titanium, with high thermal resistance. A scoping review is presented to establish the potential use of DIs in forensic identification. Ten articles were identified with a significant presence of Australian researchers and identification models supported not only in the comparison of images, but also in the use of specific software or even in the implementation of serial numbers ensuring their traceability. Although identification through DIs has been proposed as a promising alternative, local realities and the relationship with manufacturing companies have heterogeneously conditioned these possibilities in FO.

Keywords: forensic identification, forensic odontology, dental implants.

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Resumen

La odontología forense (OF) es reconocida como uno de los métodos primarios para identificación forense. Aunque los dientes son estructuras resistentes a altas temperaturas, condiciones particulares pueden fragilizarlos considerablemente. Los implantes dentales (IDs), de gran empleo en la rehabilitación bucodental actual, son fabricados en materiales aloplásticos con base en titanio, de alta resistencia térmica. Se presenta una revisión con búsqueda sistemática para establecer el potencial uso de IDs en identificación forense. Se identificaron 10 artículos con una importante presencia de investigadores australianos y modelos de identificación apoyados no solo en el cotejo de imágenes, sino también en el uso de software específico o incluso en la implementación de números de serie asegurando su trazabilidad. Si bien la identificación mediante IDs se ha propuesto como una alternativa promisoria, las realidades locales y la relación con las empresas fabricantes han condicionado de manera heterogénea estas posibilidades en OF.

Resumo

Odontologia forense (OF) é reconhecida como um dos principais métodos de identificação forense. Embora os dentes sejam estruturas resistentes a altas temperaturas, condições particulares podem torná-los muito frágeis. Os implantes dentários (IDs), amplamente utilizados na atual reabilitação oral, são fabricados em materiais aloplásticos à base de titânio, com alta resistência térmica. Uma revisão de pesquisa sistemática é apresentada para estabelecer o uso potencial de IDs na identificação forense. Foram identificados 10 trabalhos com presença significativa de pesquisadores australianos e modelos de identificação apoiados não só na comparação de imagens, mas também na utilização de softwares específicos ou mesmo na implementação de números de série garantindo sua rastreabilidade. Embora a identificação por meio de IDs tenha sido proposta como uma alternativa promissora, as realidades locais e o relacionamento com as empresas manufatureiras têm condicionado de forma heterogênea essas possibilidades na OF.

Palabras clave: Identificación forense, Odontología forense, Implantes dentales.

Palavras-chave: Identificação forense, Odontologia forense, Implantes dentários.

Introduction

Identification involves a set of procedures used to identify a person or object. One of the meanings of "identify" is to establish whether someone is the person you are looking for, that is, to confirm their individuality by determining the traits or set of qualities that distinguish them from all others and make them the person they are. This makes identification essential in all areas of human relations. It becomes even more critical after death to protect the rights of the families of the deceased and to be certain regarding the causes of death and the final resting place of the body.(1)

Forensic odontology (FO) is one of the three primary methods recognized by INTERPOL for identifying disaster victims. Dental hard structures are the most resistant in nature. Therefore, dentistry continues to provide evidence to help identify victims subjected to heat extremes, trauma, or decomposition. Even when victims are not severely compromised, FO proves to be fast and cost-effective compared to DNA analysis. INTERPOL's Standing Committee on Disaster Victim Identification (DVI) states that forward planning, adequate funding, international cooperation, and standardization are essential to guarantee an effective response. However, every multiple fatality incident response has its peculiarities that require flexibility and advance planning.(2)

Incineration-related disasters are on the rise due to higher global temperatures that lead to a fire-prone environment, more frequent acts of terrorism, and increased high-speed travel. Identifying incinerated victims is an intense and overwhelming task. Fire—depending on its severity and duration—damages or destroys physical evidence such as clothing, documents, tattoos, fingerprints, and hair, and elevated temperatures can even denature DNA.[3]

Dental structures are the hardest structures in the body and, together with some dental materials, they can withstand elevated temperatures and retain their physical shape, providing an excellent way to distinguish individuals. However, the loss of the organic component of human teeth causes shrinkage and cracking, and teeth become very brittle above 1000°C. Other problems of preserving remains include fragmentation, accidental damage during handling or salvage, and exposure to the damaging effects of weather or animal predation.[3]

In this context, achieving definitive identification requires developing appropriate methods, techniques, and resources, which must be implemented by experienced staff with specific knowledge in the medico-legal area. Therefore, it is imperative to organize tasks with an interdisciplinary and highly specialized mindset since the difficulties inherent to this type of scourge pose multiple challenges due to the severe impact on the population affected. The considerable number of intermingled bodies, many of them charred and dismembered, is also relevant because hinders the use of traditional identification methodologies such as fingerprinting and/or visual recognition.[1]

There are various procedures with varying degrees of reliability to confirm the identity of a deceased person. Visual recognition is the most frequently used non-scientific identification procedure. However, it has been shown that the stress associated with the death of a relative or loved one, coupled with postmortem (PM) changes in the deceased, makes visual recognition weak and unreliable. Unsuccessful visual identifications have been reported, often due to the shock and anxiety of the victims' families. A more scientifically rigorous technique is required to confirm their identity when the remains' conditions are considered inadequate for visual recognition.[1]

The scientific methods that allow for reliable identification individualize characteristics that are highly unlikely to appear in more than one individual in a given population. Such features appear when comparing fingerprints, genetic material, and dental information.[4]

Methods of identification of human remains by comparing information depend on the availability of sufficient antemortem (AM) information, sufficient PM material, and a comparison or match between AM and PM data. FO is a specialty that requires specific training and cannot be performed by dentists without such training. Strategies are needed to build FO capacity and resources for managing dead bodies after a mass disaster, along with global guidelines and codes. To this end, Interpol's forms and recommendations have proven to be a good starting point for meeting these requirements.[5]

Argentina has seen some catastrophic events, both natural and anthropic. In some cases, was used as an identification method. Among them, the AMIA bombing in 1994 combined the application of odontology, radiology, and dactyloscopy. A body part containing fragments of both jaws was identified.[6] The 1999 LAPA tragedy was also an emblematic case where FO was applied. Its technical significance was important because the corpses were carbonized, and there were cases of erroneous and cross identifications attributed to faulty or even altered AM records. In the 2011 Líneas Aéreas Sol tragedy in 2011, the dental data obtained were unreliable and incomplete, so identification by this method was not possible. When comparing AM and PM information, it is essential to have radiographic images, study and working models, photographs, and even the patients' prostheses. This is necessary for positive or negative identification. The data recorded in the dental chart must be clear, accurate, and complete. They should be periodically updated to provide as much information as possible.[6]

Since the beginning, humans have been concerned with replacing lost teeth with dental prostheses. The various alternatives sought included the implantation of alloplastic materials. Archaeological findings show that teeth were replaced in the living and the dead to beautify the memory of the deceased.[8] The surgical and prosthetic procedures necessary for this purpose have evolved to cater to the constant need to achieve more effective and satisfactory oral rehabilitation. This is how dental implants (DIs) appear. They are a therapeutic option that provides a firm anchorage to the bone and tissues for the pontics or prosthesis. DIs are alloplastic elements (inert substances that are foreign to the human body) lodged in the bone tissue or underneath the periosteum to preserve natural teeth or replace missing teeth.[8]

The past few years have witnessed major technological and biological advances in implant dentistry, leading to an increasing number of patients treated with this method.[8] The material most frequently used to manufacture DIs has been commercially pure titanium because it has high biocompatibility and is the ideal material for successful long-term osseointegration after functional loading. The biocompatibility of titanium is given by the properties of its surface oxide. Titanium rapidly forms an oxide thickness of 3-5 nm at room temperature when in contact with air or water. The most common oxide is titanium dioxide (TiO_2). This oxide is highly resistant to chemicals, making titanium one of the most corrosionresistant metals and contributing to its biocompatibility. In addition, titanium is strong enough for clinical application.[9] Commercially pure (CP) titanium contains 98.9-99.6% titanium, with a maximum content of various alloying elements: carbon, 0.1%; iron, 0.5%; hydrogen, 0.015%; nitrogen, 0.05%; and oxygen, 0.40%. Titanium has a high melting point (1668°C) and can withstand elevated temperatures without major structural changes.[6]

These characteristics make DIs a potential method to apply in forensic identification considering the implicit resistance of titanium to the most adverse vulnerability conditions.[10]

This systematic scoping review aims to present the state of the art regarding the potential use of conventional DIs for medico-legal purposes and the possible options for implementation in reconstructive or comparative FO or the use of traceable elements in their design. We discuss the applicability of these systems for forensic use in Argentina following current recommendations and standards and considering the local conditions of DI systems' production and supply.

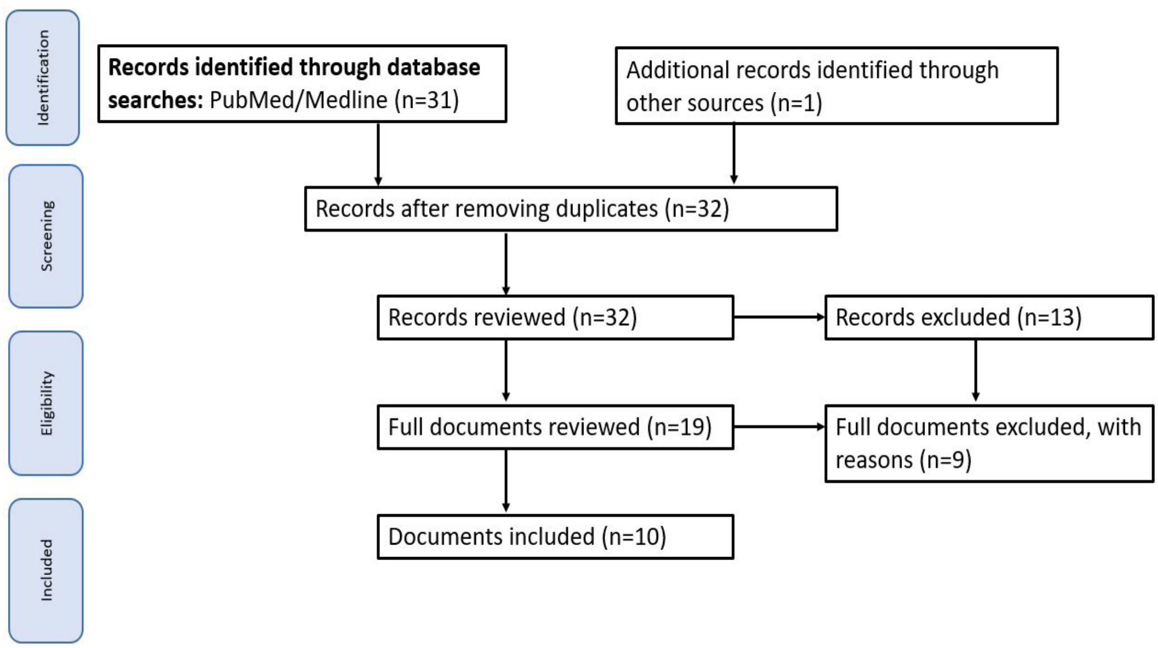
Method

A scoping review was conducted following the methodology proposed by the Joanna Briggs Institute[11] and the PRISMA guidelines.[12] This type of review is considered the suitable methodology when seeking to answer broad research questions and appreciate the nature of the available evidence. Although scoping reviews do not assess the quality of the studies included (unlike systematic reviews), they can identify knowledge gaps, define the scope of systematic reviews, or help develop specific research questions.[13] The specific search strategy included the terms "dental," "implant," "forensic," and "identification" in the PubMed/Medline database. We conducted a complementary search in Google Scholar for full articles in English and Spanish. Original papers on the actual or potential use of DIs for forensic identification were included. Case reports, studies with unconventional (Ad-hoc) implants, secondary sources, letters to the editor, and gray literature were excluded. The documents identified were analyzed independently by two researchers considering the variables: year of publication, country of origin of the authors, and research outcomes.

Results

The search was conducted between 1 and 5 November 2020. Thirty-one articles were identified, of which nine met the inclusion criteria and had the required methodological quality. A subsequent manual search allowed us to include one more publication that met similar criteria, bringing the total number of articles reviewed to ten (Fig. 1).

Fig. 1: PRISMA flow diagram used to conduct the scoping review.



The studies were published between 2006 and 2019. The highest number of publications was recorded in 2010, 2011, and 2014, at a rate of two publications by year. Australia presented the highest frequency of publication and the most considerable number of studies: 5 (50%). This reflects the contributions made by the Forensic Odontology Unit of the University of Adelaide, led by Dr. John W. Berketa and Dr. Helen James. Italy had two studies (20%), followed by Argentina and partnerships between Greece/United Kingdom and Germany/Belgium, each one with one publication each (Table 1).

Table 1: Studies identified in this review

Reference	Authors' country	Outcomes
Michelinakis et al., 2006 [14]	Greece and the United Kingdom	Successful use of implant-recognition software. Eighty-seven implant manufacturers from 21 countries with 231 different implant designs were identified.
Nuzzolese et al., 2008 [15]	Italy	Developing an archive of radiographic images of implants of different brands would create a database to facilitate the identification processes.
Berketa et al., 2010[16]	Australia	The in vitro study made it possible to evaluate the survival of serial numbers in implants.
Berketa et al., 2010[17]	Australia	The use of image-based implant identification software aided the identification of deceased people.
Berketa et al, 2011[18]	Australia	The comparative analysis of implant images and elemental analysis would facilitate positive identification in an in vitro model.
Berketa et al., 2011[19]	Australia	A pilot study with incinerated sheep heads. The detachment of teeth and bone implants was confirmed, and it is recommended that dentists work at the scene. The serial numbers on the implants remained visible.
Berketa et al., 2014[3]	Australia	Even after cremation, the implants were identified, which made it possible to identify the deceased.
De Angelis & Cattaneo, 2014[10]	Italy	The importance of implant radiographs in complex forensic identification scenarios is highlighted, especially if the implants are bone integrated in seriously affected corpses.
Gómez, 2018[6]	Argentina	Radiographic comparison established positive identifications in 54% of the cases, probable identity in 32% of the cases, and possible identity in 14% of the cases. There were no cases of excluded identity. The match percentage was 66% for the category of 5 or more matches and 34% for the category of up to 4 matches; there were no results for images with no matches.
Mansour et al., 2019[20]	Germany and Belgium	The correlation of serial numbers and manufacturer information and the traceability of the implants in cross-reference with complementary data on the biological profile would facilitate forensic identification.

These studies show various proposed identification models. The first model is based on the support of radiographic images, in some cases recording morphological data corresponding to different brands[15,18] or to the intraosseous positions of implants.[3,10] In this case, specific software proved extremely useful to facilitate comparisons.[14,27] The second hinges on the support of serial or lot numbers etched on the surface of the implants. In this case, the Australian team reports that StraumannTM (Waldenburg, Switzerland) is the only brand available in the market that includes etched, incineration-resistant serial numbers.[16,19]

All the studies proved the resistance of the DIs to incineration. Although identification methodologies are promising, all studies recommend that this issue be addressed in new lines of research. This would make it possible to standardize methods and ensure the traceability of prosthetic devices. It is also necessary to communicate effectively with brands and commercial companies to guarantee the above.

Discussion

The use of DIs in daily dental practice has increased significantly because professionals tend to gravitate towards implant surgery and rehabilitation and because patients have more information on the subject, which forces dentists to train to meet this demand. The current application of this dental practice and the increasing demand raises the likelihood of finding implants in deceased victims and that they be detected on PM radiographs.[6]

The studies identified in this review show that the tests performed on the implants manufactured with type IV titanium did not show noticeable macroscopic changes. It was also observed that there was a characteristic microstructure and a variation in the thickness of the titanium oxide layer (on the rim) at each temperature evaluated (200°C, 800°C, and 1000°C). This would make it possible to identify the temperature to which each implant was exposed. It is recommended that the identification code be etched at a depth of more than 1 mm because the code used in that research disappeared when reaching 1000°C. Therefore, titanium DIs can be used as forensic identification elements even after incineration.[12]

It is essential to consider that the fragmentation caused by thermal violation caused teeth to burst and be ejected in incineration cases. The implants became detached too. According to some authors, this reinforces the need for dentists to be involved in the scene and debris removal phase of the investigation. Personnel unaccustomed to identifying tooth structures may overlook the recovery of small DIs and other dental restorative materials, which could be critical to identify the deceased. Recovery and radiographic examination of debris from the area around the head in incineration cases will easily locate implants that have become detached from the body.[14]

Imaging supports for comparative identification further underscore the importance of having relevant AM information. The increased demand clearly enhances the chances of having live radiographs of individuals with DIs. However, it will depend on the actions and good habits of the treating professional that must preserve these images. Although the articles identified in this review describe techniques based on manual and automated comparison of radiographic images, it is well known that comparison is only possible if precious AM information is available. The literature has repeatedly presented the difficulties caused by the lack of records or records that have been tampered with or are not updated, which is even worse.[21] It has already been reported that it is necessary to keep dental records (adapting the nomenclature and graphic records of the implants)[22] and all the relevant imaging information with better identification quality.[23]

Studies conducted by the University of Adelaide team have shown the way serial numbers are effective for comparative identification.[16,19] Comparing serial numbers has already been recommended by INTERPOL for other substrates.[2] Its application in DIs has created elevated expectations. These studies confirm that serial numbers inside implants resist incineration up to 1125ºC, so working with companies to implement these systems will help create a novel approach to identifying deceased persons.[13] The huge contributions of the Australian team led by Dr. John Berketa and Dr. Helen James have greatly facilitated a thorough approach to addressing this need.

It could be interpreted that the University of Adelaide team is intensely interested in this area because the country is vulnerable to devastating fires. As of 27 January 2020, massive fires spurred by record temperatures and months of severe drought have burned over 10 million hectares causing animal and human losses.[24]

This background reflects an objective reality: local conditions and collaboration between universities and security and risk control forces are critical to provide viable research responses and results. Dr. Berketa recently published a study on gelling agents to preserve burned teeth within alveoli for forensic processing purposes. This has been implemented successfully in the field.[25] On a smaller scale, over 190 thousand hectares were affected by fires in the province of Córdoba, Argentina, in October 2020: a record figure in the last 20 years.[26] However, actual forensic practice and the potential link with dental implantology remain utopic.

The well-known economic difficulties Argentina has faced for at least 20 years, the fact that critical issues have been neglected, and the need to provide prosthetic solutions to the entire community have led to research and technological development in dental implantology. Dental implants are now locally produced, making them much more accessible to the general public.[27] This entails a significant improvement in the supply and acquisition of DIs. However, the heterogeneity of systems, the inevitable local replication of foreign versions at a lower cost, or even the undesired (but real) effect of "home" production of devices without the necessary health approval make it almost impossible to use DIs as a forensic tool, at least as far as traceability is concerned. The FDI has recommended including traceable elements in DIs[28] following the standards of the International Organization for Standardization (ISO),[29] and dentists should register them. However, the scarce literature found, and the specific situation of Argentina make the effective implementation of this resource almost impossible. Paradoxically, Argentina is one of the countries with the lowest scientific productivity in periodontics and DIs in Latin America,[30] but it has one of the most developed titanium implant markets in the region.[31] Therefore, learning about technology transfer and the creation of applied research projects through science-business partnership programs seems to be the logical starting point to include traceable elements in DIs.

Madea[32] mentions that case reports are considered low in the hierarchy of evidence-based medicine because of their anecdotal nature and because the information they provide is not as complex as that of experimental studies, which is why they were excluded from this review. However, we agree with this author that medico-legal case reports are valuable because they show peculiarities in injury patterns, innovative procedures or because they simply increase the knowledge in a specific area.[32] We admit that excluding case reports may be a limitation of this review. However, our results allow us to pose new research questions.[13] These questions include collecting real field applications of dental implant-based identifications, and they not only represent a potential new line of study but also provide the possibility of fostering a solid area of innovation and technology transfer, as well as pushing the boundaries of forensic odontology in its permanent evolution.

García Sánchez and Vicente González, report in Zamora (Spain) in 2018[33] the identification of a corpse found near a riverbank. The person had not been reported missing. The person was in an advanced putrefaction state, with partial skeletonization and loss of facial features. In the absence of other potentially identifying elements, a stomatologist extracted four of the many implants the person had on both jaws. This proved that they were Straumann™ implants, which, as we have seen above, are the only ones that include etched serial numbers. These numbers were analyzed with optical microscopy, and the implants were measured with an electronic calibrator. The resulting information was cross-checked with the product sales records of the company and then cross-checked with the records of the dental clinics in the community. A positive match focused the investigation on one individual, who was finally identified and confirmed by genetic testing.[33] This was a moment when the utopia became a reality. We are not that far away.[34]

Conclusions

The best identification method must positively compare available information to that obtained from human remains. Recent research in the area has suggested including traceable elements in DIs. Although less useful for identification purposes, comparing radiological images (periimplant bone, superstructure) and using databases associating implant morphology with commercial brands or geography can be invaluable for forensic identification, provided that adequate clinical records are available. Although the serial production of DIs makes it challenging to identify them, traceable numbers would help forensic identification. Although the FDI has recommended including traceable elements in DIs (following ISO standards), and dentists should keep their records, the scarce literature on the subject seems to show a lack of knowledge of the considerable identification potential of this strategy. In Argentina, implementing innovation and technology transfer policies may result in considerable progress opportunities given the local conditions of scientific production and manufacturing of DIs.

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