Maximisation of postmortem information for identification of severely incinerated victims

John William Berketa

Forensic Odontology Unit

School of Dentistry

University of Adelaide

A thesis submitted for the degree of Doctor of Philosophy

at the University of Adelaide

December 2015

Contents

Table of Contents

Abstract

The identification of victims of incineration events can be an intensive and daunting task as the usual comparison methods, including visual, fingerprint, and DNA, may not be possible due to the destruction of postmortem tissue. Dental comparison may also not be possible due to damage and further loss of what remains of the fragile dental tissues.

The aim of this thesis is to provide knowledge and practical suggestions to assist the identification of deceased persons through the successful recognition, retrieval, stabilisation and treatment of postmortem information from incinerated human remains together with prosthetic devices and materials within them to facilitate more successful identification outcomes.

The stabilisation of fragile dental remains was the first step in successful retrieval of information and following pilot studies; non-volatile Clag™ paste solution stabilising agent was identified as the material of choice. Further testing on sheep heads, then trials on human mandibles, produced positive results. An alternative of using a plain flour solution is also offered where Clag™ paste is unavailable. In parallel studies for cases where dentition would not be available, the retrieval of numerical data from the most commonly placed hip and knee incinerated implants was investigated and the use of information from cochlear implants, dental implants and gold alloy analysis were also considered.

This research has proposed practical suggestions that have already been placed into practice to maximise postmortem information of severely incinerated victims.

Declaration

I certify that this work contains no material which has been accepted for the award of any other degree or diploma in my name, in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text. In addition, I certify that no part of this work will, in the future, be used in a submission in my name, for any other degree or diploma in any university or other tertiary institution without the prior approval of the University of Adelaide and where applicable, any partner institution responsible for the joint-award of this degree.

I give consent to this copy of my thesis when deposited in the University Library, being made available for loan and photocopying, subject to the provisions of the Copyright Act 1968.

The author acknowledges that copyright of published works contained within this thesis resides with the copyright holder(s) of those works.

I also give permission for the digital version of my thesis to be made available on the web, via the University's digital research repository, the Library Search and also through web search engines, unless permission has been granted by the University to restrict access for a period of time.

Acknowledgements

I would like to firstly thank my supervisors Lindsay Richards, Helen James and Neil Langlois; and my other co-authors Ellie Simpson, Paul Pigou, Stephen Graves, Grace O'Donohue and Yen-Liang Liu. All have given me great encouragement and support. I also wish to thank the University of Adelaide Forensic Odontology Unit, Forensic Science South Australia (FSSA) and their staff, the Australian Orthopaedic Association National Joint Replacement Registry (AOANJRR), Denice Higgins and Victor Marino at the University of Adelaide, Michele Bayly-Jones at South Australian Coroner's office, Wesley Fisk Ray Last Laboratory at the University of Adelaide, Richard Duddy at Legal Risk University of Adelaide, John Wells and Robert Pitt at Adelaide Cemeteries Authority, Adam Kenny and Bryan Elliott at Centennial Park Crematorium, Ken Neubauer at Adelaide Microscopy, Robert Morrisey, Ken Naismith at South Australian police (SAPOL), the Australian Dental Research Foundation (ADRF), Paul Mitchell at Stryker Corporation, Kevin Roberts at DePuy Corporation, Chris Price and Shane Nicholls at Smith and Nephew Corporation and the Cochlear Ltd., Advance Bionics and Med-El companies. Most of all I would like to thank my great loves: my wife Lindy and my two sons Jack and Sam for their love and support throughout this long process.

Chapter 1

1.1 Introduction

Fire is the rapid oxidation of a material in an exothermic chemical process of combustion, where heat, light, and various reaction products are released. Fires start when a flammable or a combustible material, in combination with a sufficient quantity of an oxidizer such as oxygen gas or another oxygen-rich compound is exposed to a source of heat or ambient temperature above the flash point for the fuel/oxidizer mix, and is able to sustain a rate of rapid oxidation that produces a chain reaction. This is commonly called the fire tetrahedron. Fire cannot exist without all of these elements in place and in the right proportions (1, 2).

Fire has been present on earth dating back to 440 million years ago when oxygen became more prevalent (3). Fire has been shown to be vital to the life and development of humans. The control of fire by early humans was a turning point in evolution. It allowed humans to cook food, leading to improved nutrition, and obtain warmth in plunging global temperatures (3). Fire also allowed the expansion of human activity into the dark and provided protection from predators and insects. The temperatures produced by fire allowed forging of weapons from copper, bronze and, eventually, iron. Disposal of bodies by cremation in burial rituals dates from the Neolithic period (2).

In addition to the positive benefits of fire to humans there are hazards. The effect of fire on human tissue ranges from skin burns to almost total destruction in the cremation process, depending on the proximity to the fire, temperature and duration of the heat (2). Temperatures reached from fires have been reported to be as high as 1350°C in a tunnel fire (4). House fires are usually lower than 900°C (5-7) although this is dependent upon ventilation and fuel

[8]. The roof of a burning car may reach over 1000°C [1,7] and temperatures in the 2009 Victorian bushfires were estimated to be over 1000°C [9]. High-speed train, aircraft and terrorist bombings may produce various degrees of burning and temperatures depending upon the type and amount of fuel load and are therefore difficult to measure consistently.

The effect on human tissue varies dependant not only on these temperatures but also the duration of exposure. The scale for burn injury to human remains was classified by Crow and Glassman in 1996 [10]. The skin and hair are the first tissues to be effected by heat, the skin might tighten then split, followed by rupture of the abdominal cavity with the prolapse of intestinal loops. The muscles will contract and the tongue will extrude giving some protection and support to the teeth [2, 11].

With intense heat, combustion and pyrolysis create physical changes to the bone and teeth [1]. There is loss of moisture and organic material such as collagen creating shrinkage up to 37% over 1000°C [12] leading to cracking, deformation and fragmentation of bone. The colour of bone will change from a grey black charred appearance to a blue white appearance due to increased crystallinity from approximately 645°C [13].

The teeth, although containing less moisture than bone, also contract. The facial soft tissues will initially protect the teeth, however the orbicularis muscle (being thin and circular) will retract due to the denaturing of protein. Most often the anterior teeth will experience more burning than the posterior teeth [2, 7, 14]. As the fire continues the entire tissues of the face will burn exposing the posterior teeth to the radiation heat. Research by Sandholzer et al. concluded that the average volumetric shrinkage in teeth ranged between 4.78% (at 400 °C) and 32.53% (at 1000°C). The major increase in shrinkage occurs between 700°C and 800°C, with no significant statistical difference between lower temperature groups [15]. Tooth colour will change from grey brown to blue-white to white when no organic material remains [7, 16-18]. Tooth morphology is generally well preserved even at high temperatures, in contrast to burned bone [15]. However, burnt teeth become extremely fragile and enamel may separate from the dentine [7,19] with deep fissures observed at 800°C. These fissures are most noticeable between restorations and dentine [17, 19, 20] and the crown may totally separate from their root bases [2, 9, 16]. Roots will either remain within the sockets of the fragile alveolar bone or drop out depending upon forces acting upon them such as gravity, accidental damage by fire fighters and scene recovery officers, falling debris or vibration from movement [21-23].

Following the death of a human, identification is required for legal and ethical reasons [24-26]. The identification of an individual is fundamental in our society and is based on law to have scientific proof before death certificates are issued. Death certificates are required to allow the disposal of the body by cremation or burial, the estate to be finalised, the possible resolution of child custody, life policies to be paid out, for remarriage to occur and assist legal authorities with criminal prosecutions [27]. The identification also allows closure to friends and relatives of the deceased. Without certainty of identification, the bereaved could spend a lifetime wondering if their loved one was in fact the victim. The constant wondering does not allow grief resolution and may precipitate chronic grief and depression [28].

Methods of identification should be scientifically sound, reliable, applicable under field conditions and capable of being implemented within a reasonable time frame [29]. The primary means of identification for those not able to be viewed for visual identification are fingerprint analysis, comparative dental analysis and deoxyribonucleic acid (DNA) analysis

[29]. Unique serial numbers from medical implants may also be reliable identifiers in proving identity [29,30]. Secondary means of identification include circumstantial evidence, medical findings, tattoos, facial superimposition, anthropological profiling as well as property and clothing [29, 30]. These secondary means of identification are ordinarily not sufficient as a sole means of identification, although depending on the circumstances there might be some exceptions [29, 30].

Victims from fires present difficult problems of identification and the phrase “burnt beyond recognition” is still being coined both in the media and in scientific papers [31, 32]. Victims of incinerations can be from a variety of incidents such as motor vehicle accidents [11, 33-41], wildfires or bushfires [23, 42-45], aircraft accidents [11, 46-53], train collisions [54], ship fires [55-57], funicular fire [58], terrorist bombings [59-61], suicides [33] and building fires [41, 51, 57, 62-64]. The increasing temperature of the earth’s climate [65-67] creating more fuel for bushfires/wildfires, increasing high speed travel [68] and political instability are generating more chances of these incidents occurring. Also following homicides some perpetrators deliberately try to destroy the evidence by incinerating the body [41, 69-73]. Incineration events globally continue to frustrate forensic scientists in their ability to bring about conclusive information leading to the identification of severely incinerated bodies [2, 11, 14, 55, 74-76].

At severe incineration events, fire will damage or destroy physical evidence such as clothing, documents, tattoos, fingerprints, and hair [2], leaving DNA and dental comparison as the only possible primary methods for identification depending upon temperature and damage to the tissues. As temperatures rise within incineration incidents, there is a breakdown of the organic components and a subsequent increase in the degradation of DNA for sample testing. Cattaneo et al. concluded that DNA was not amplifiable in experimentally burnt human compact bones when heated to 800–1200°C for 20 minutes, as well as in charred bones obtained from actual forensic cases [77]. Imaizumi et al. found that no amplification was found in the specimens burnt at 250°C or higher in bone [78] and Fredericks et al. concluded that no DNA targets were amplified from bovine bone heated to 210 to 250°C [79]. As fire requires the combination of fuel, oxygen and a high temperature to be active [1], if a person is discovered flat against a non-combustible material the tissue already burnt might act as a barrier to oxygen penetration and as an insulator to the deep tissues even though it appears that a victim is totally incinerated. In such situations DNA might be retrieved from these deeper tissues [80]. The dental pulp of a third molar might be an excellent source of DNA [69]. Continuing research on testing for DNA might make improvements on the sensitivity of DNA testing and recent reports suggest that cementum might be the best source of DNA, although testing using incinerated teeth is still required to confirm this in incineration events [81, 82].

The lack of visual and DNA information in severe incinerations highlights dental comparison as an important method for identification. Forensic odontology has been used for identification of incinerated victims for a considerable period of time. As early as 1869 victims of a boat fire on the Ohio river were identified by dentists [57]. In 1898 Amoedo wrote a thesis titled "L'art Dentaire en Médecine Légale" based on the dental identification of many victims in an incineration mass casualty fire event at the Charite de la Bazar, Paris in 1897 [57]. Since the publication of his thesis the use of forensic odontology has extended throughout the world and many published articles where dental evidence has proven to be successful in identification of incinerated victims [9, 11, 23, 33-40, 43-54, 56-58, 62, 63, 74]. However there are difficulties with regards to odontological identification which requires comparison of dental records from treatment during life (antemortem records) with the findings at postmortem. There may be lack of antemortem information (due to poor record keeping and sourcing of records) and in the case of severe incineration there is often a lack of postmortem information.

Conventional dental comparison utilises the dental restorations placed during life discovered within incinerated remains as the main method of dental comparative analysis [14, 43, 45, 46, 50, 52, 54, 55, 73, 83]. Dental radiography of the retrieved dentition can ascertain conditions not easily detectable in burnt oral tissues such as tooth coloured restorations, endodontic restorations, impacted teeth, retained roots, implants, fracture hardware and bony pathology [14, 51, 84-87]. The anatomy of tooth crowns and roots, and morphological relationships between teeth are important identification tools, and become more so when no restorative work is present. Dental implants are becoming more popular as a form of dental treatment for tooth replacement [88]. They are usually composed of commercially pure titanium, titanium alloy, zirconium or a combination of either material [89, 90]. They have a high melting point [91, 92] and the detection of dental implants can aid in identification of by identifying the type, make, and sizes of the implants, as well as their position within the oral cavity [73, 93].

Where there are few or no teeth, or few distinguishing features in the teeth, other methods of identification may be utilised. Mastoid processes air cells, nasal sinuses and frontal sinus morphological comparisons could be applied [72, 94-103]; however, this may be susceptible to error [104, 105] especially if there has been bone shrinkage and warping.

Postmortem information collection of dental information starts at the scene of the incident. A fire scene is always treated as a crime scene until there is sufficient evidence to contradict that presumption. Any interference cannot be undone and care must be taken not to introduce contamination, such as accelerants that may interfere with subsequent investigation. When severely incinerated human remains are involved detection and recognition of information to assist identification is a key component of the investigation. It is often evident from images taken at a scene that dental postmortem information may be lost transporting the remains to the mortuary for examination [21-23]. Cracking is usually observed on the outer surface of exposed dentition closest to the heat source as this is where the dehydration begins first, with further cracking emanating from the pulpal chamber at higher temperatures [16]. However the cracks in the incinerated bone and the teeth will increase if there is uneven support on either side of the cracks when any force is applied either in lifting the remains or transporting them. By adhering the two sides of the crack together it inhibits the crack progressing further into either the bone or tooth. Also the loss of organic material such as the periodontal ligament may allow single rooted teeth to fall out of their sockets. Adhering the tooth roots to the surrounding alveolar bone will assist in maintaining its correct anatomical position.

Loss of restorations and disruption to the normal anatomical arrangement with the separation of teeth from the alveolar bone requires anatomical recognition of the tooth segment and opinion on from where individual teeth, roots or segments of teeth have originated rather than the certainty of the teeth retaining their anatomical position. Methods to minimise these scenarios of displaced dentition have been reported [7, 76]. Plastic bubble wrap can protect the head by acting as a shock absorber during transportation [51] and wrapping or bagging will keep the dental evidence to the confined head area [21]. Mincer et al. reported a number of methods cited by odontologists to stabilise incinerated human remains. Cyanoacrylate and poly vinyl acetate (PVA) were the most common choices, with almost 25% of surveyed odontologists using these materials [76]. To stabilise anthropological specimens, Grevin advocated the use of a glue gun [106], Fairgrieve [2] suggest the use of PVA water based glue whilst Mayne Correia and Beattie [107] also suggested soaking bone fragments in water diluted PVA for 1 minute to stabilise them. These methods would not be practical or desirable with incinerated dental remains at a scene.

The carefully controlled placement onto the exposed teeth of non-radiopaque materials such as cyanoacrylate adhesive or transparent nail polish will produce positive stabilising results [7, 53]. They also allow forensic odontologists to obtain radiographs without further damage to the teeth [7, 51, 76]. If a large amount of cyanoacrylate is flowed onto the face the separation of the mandible for a subsequent intra-oral examination may not be easily controlled due to the strength of the glue. There is also the risk that any glue, if not completely dry, will stick to prematurely applied wrapping materials.

Materials that require precise placement also require recognition of which structures to treat. In many instances scene attendance by forensic odontologists is not the norm. This may be due to remote distances, and insufficient resources or manpower. Multiple concurrent scenes in a bushfire scenario would overstretch many departments. A less precise method, which can be applied to the face by non-dentists, may be valuable.

In severe incineration cases contact materials require extremely careful touching of the fragile ashened dental structures. Use of a spray has been suggested to avoid direct contact with the fragile tissues, however spraying of cyanoacrylate is not advisable as an occupational health issue for scene officers. Micro droplets may form invisible solid particles of cured cyanoacrylate, as it sets with moisture [108], get trapped behind the eyelids, cause abrasive damage, are difficult to see and to remove [109].

A major issue with use of many possible stabilisation materials, including cyanoacrylate and hair lacquer, is the introduction to the scene of volatile chemicals which have a similar profile to fire accelerants. This may interfere with investigations either at the scene or subsequently at the mortuary into how the fire was caused.

Restorations are frequently missing at the postmortem examination. With high temperatures, amalgam restorations may melt above 1000°C [11, 19, 110, 111] and composite resins begin to change shape at approximately 800° [110] to 900°C [11] but can (due to the fissure cracking of the dentine), fall out after 400°C [111, 112]. Acrylic resin has a lower melting point and may ignite in direct contact with fire [11]. Botha reports that gold alloy will melt between 870°C to 1070°C [11] and Merlati et al., reported that all gold alloys tested had melted at 1100°C [111]. Endodontic gutta percha will tend to honeycomb [19] and boil out between 615°C to 815°C [11, 19]. Porcelain has a high melting point temperature with a melting point of 1370°C [11]. If there is a suspicion that a restoration has fallen out, detection by scanning electron microscopy (SEM) might be able to detect the striations of bur markings where a restoration was once in place [2, 111].

Other medical information could be pre-existing bone pathology or foreign bodies which might assist identification [113, 114] and medical implants or devices that might be retrieved. Jewellery, piercings, penile nodules, pacemakers, orthopaedic plates, screws, rods, intraocular lenses, spinal devices, skull caps, gastric bypass clips, surgical wires, staples, metallic stents and implants such as knees, hips, shoulder, ankle devices and penile nodules might be found [24, 115-129]. Computer tomography scanning of burnt bodies is therefore highly advisable to assess what objects might be present and their position within the charred remains [34, 113, 115, 130-132].

1.1a Summary

The natural human tissues and man-made artifacts utilised for identification are all affected by severe incineration. What might be available for identification following severe incineration is listed in Table1.

Table 1. Postmortem available for identification following severe incineration

Postmortem information	Comment
Visual – Eyes, hair, tattoos,	Lost at high temperatures.
Ridge analysis- fingerprints	Lost at high temperatures.
DNA	Degraded at high temperatures- could be scavenged from deep insulated tissues or teeth.
Dental restorations comparison	Could be dislodged or altered in form at high temperatures. Possible elemental analysis.
Dental anatomy comparative analysis	Crowns could be dislodged. Some cracking of roots and could also be dislodged.
Bone structure analysis- frontal sinus, mastoid processes	Due to shrinkage - bone deformation, distortion and cracking. Unreliable.
Dental implants	Not serial numbered, position in relation to anatomical structures could be useful to match antemortem information.
High melting point medical devices without numbers	Position in relation to anatomical structures could be useful to match antemortem information.
High melting point medical numbered devices	Accepted by Interpol if unique serial number(29), however numbers could be severely charred, oxidized and unretrievable.

From the list above current methods of identifying severely incinerated victims are: dental information from restorations and tooth morphology, medical implants with serial numbers, matching dental implants and other medical devices to antemortem information and elemental analysis of dental restorative materials. However there are problems as mentioned earlier with each method and gaps in the knowledge to identify ways of maximising the postmortem information available.

1.1b Aims and Objectives

The general aims of this research were to address the following research questions:

1. Are published methods of stabilisation valid and appropriate?
2. What new methods could be used to provide useful data for identification?
3. What training would assist scene officers and odontologists to maximise data from incinerated human remains?

In order to achieve the aims, the following specific objectives were formulated:

1. To review stabilisation methods for dental tissue and restorations and develop new methods to limit the loss of information.
2. To validate that dental implants can remain stable even under high temperature assault so that information can then be matched to antemortem records.
3. To investigate and create a predictable method of retrieving numbered data from medical implants.
4. To investigate the method of elemental analysis on gold alloys.
5. To formulate a training protocol to instigate suggested protocols.

1.2 Scope of thesis

This thesis is presented as nine chapters containing an introductory chapter, a published literature review chapter with an expanded literature review, a further six chapters of which five contain published or accepted or draft for publication papers and a conclusion chapter. All have the specific aim of maximising postmortem information of incinerated material for examination, but highlight different ways in which this may be accomplished. There are three central themes: stabilising incinerated remains to maximise the potential for a conventional dental comparison, use of other data and techniques to enhance available postmortem information, and training in recognition, handling and examination of incinerated remains to extract maximum postmortem information for examination. Each chapter contains an introduction and background research leading to the published paper or prepared manuscript. A conclusion chapter summarises this body of research. Publishing choices have resulted in alternate English spellings (United Kingdom and United States) for some words throughout this thesis.

Chapter 1 introduces the effects and consequences of fire on humans, and discusses postmortem problems of incineration cases. Reasons for embarking on this study and research aims are outlined.

Chapter 2 presents a published review of the researched literature on maximising postmortem oral-facial data to assist identification following severe incineration. Following this publication, the scope of research was expanded to include medical implants that could be used for identification and training requirements for scene officers and forensic odontologists. Further reviews of the literature are included to incorporate these topics.

Chapter 3 looks at the problems of stabilisation. Methods to stabilise teeth have been published but data to show effectiveness of maintaining the integrity of teeth within bone was not available. Personal case experience also suggested that scene retrieval personnel did not routinely apply stabilising agents in South Australia. On discussion with the state's police officers involved in scene recovery they indicated concerns about lack of time and skill needed to accurately identify dental material and painstakingly apply the most commonly recommended material, cyanoacrylate glue. They also expressed concern about volatile vapors emitted from any stabilising agent, which would compromise investigations if testing for fire accelerants were required. I therefore considered what attributes were desirable for an ideal stabilising material and method. Essential characteristics were that it firstly was effective and would not lead to further loss of information; it wouldn't interfere with either visual or radiographic examination; it would not contain human DNA; it would be nontoxic and easily applied to a large area; and it would be readily available, stable and reasonable cost. Given the limitations of the published methods, I looked to developing a material to fulfill these traits.

Chapters 4-7 are concerned with other data and techniques to assist identification and include research on dental implants, the characteristic of dental alloys, cochlear implants, and artificial hips and knees. In many cases, the position within the bone and angulations relative to anatomical structures is sufficient to give weight to implants as identification features. I have previously published data on recognition of dental implant brand. Chapter 4 explores the effect of incineration on implants embedded within bone. Colour and dimensional changes were investigated and the question posed "Would it be possible in a blind study to identify an individual from just implants and its burnt superstructure?"

Chapter 5 investigates the possibility of increasing postmortem knowledge by SEM and elemental analysis of dental materials. Even if a gold crown has melted in a severe incineration, the elements of the alloy should still be present. Two theories were tested to increase the possibility of establishing identity. Firstly, could a laboratory be traced from analysis of dental alloy used for gold crown construction, and could this knowledge assist in tracking the identity of an incinerated individual where no circumstantial evidence is available to hint at who the victim might be? Secondly, could alloy analysis be used to confirm the identity against laboratory records when, due to the ferocity of the fire, there is very little other postmortem evidence available?

During recovery of incinerated human remains it is standard practice to collect debris from around the head. A device that is increasing in availability, but on which there was no published data, is the cochlear implant. These are attached to the outside of the cranium around the mastoid process and could easily detach once the overlying skin has been vaporised by fire. The appearance of a burnt rectangular or circular object with wires attached may be misinterpreted as a piece of jewellery or hardware structure. Chapter 6 documents the appearance of such devices following incineration. This gives scene officers and odontologists valuable information to recognise such devices. The mere presence of such a devise considerably narrows the field of missing persons. The ability to retrieve from the incinerated body of the device a unique serial number would significantly enhance the postmortem data.

An extension of the work on dental and cochlear implant oxide layers and inner chambers for serial numbers lead to research documented in Chapter 7 on retrieval of serial numbers from other medical implants. Hips and knees were chosen as the medical implants to study, as they are the most common prostheses implanted. Studies were undertaken to determine the location of the serial number, if data numbers could be retrieved from totally charred hips or knee implants, and the best materials and methods to facilitate this process

Issues of training for scene retrieval personnel were addressed in Chapters 3 and 6, but I also felt that a training exercise for odontologists could be created at minimal cost. Chapter 8 describes the development of the exercise material and procedures.

Chapter 9 discusses further literature since the articles were published, further findings, and the successful implementation of my studies to actual casework. Limitations and further research recommendations are also suggested.

An Appendix summarises further publications during my candidature, awards received, collaborations established, presentations given and future presentations planned.

1.3 References

1. DeHaan JD. Kirks fire investigation. 5th ed. Upper Saddle River: Brady; 2002.
2. Fairgrieve SI. Forensic Cremation: Recovery and Analysis. Boca Raton: CRC Press; 2007.
3. Pausas JG, Keeley JE. A burning story: The role of fire in the history of life. Bioscience. 2009;59(7):593-601.
4. Lonnermark A, Ingason H. Gas temperatures in heavy goods vehicle fires in tunnels. Fire Safety J. 2005;40:506-27.
5. Lilly DG. Temperature measurements in a small house fire. Paper presented at: Energy Conversion Engineering Conference; 1996.
6. Kahn SA, Patel JH, Lentz CW, Bell DE. Firefighter burn injuries: predictable patterns influenced by turnout gear. J Burn Care Res. 2012;33(1):152-6.

7. Berman GM, Bush MA, Bush PJ, Freeman AJ, Loomis PW, Miller RG. Dental identification. In: Senn DR, Weens RA, editors. Manual of forensic odontology. Boca Raton: CRC; 2013. p. 75-127.

8. Lilly DG. Estimating fire growth and temperatures in structural fires. Paper presented at: AIAA, Aerospace Sciences Meeting; 1997; Reno.

9. Lain R, Taylor J, Croker S, Craig P, Graham J. Comparative dental anatomy in Disaster Victim Identification: Lessons from the 2009 Victorian Bushfires. Forensic science international. 2011;205(1-3):36-9. DOI: 10.1016/j.forsciint.2010.06.008.

10. Glassman DM, Crow RM. Standardization model for describing the extent of burn injury to human remains. Journal of forensic sciences. 1996;1(152-4).

11. Botha CT. The dental identification of fire victims. Journal of forensic odonto-stomatology. 1986;4(2):67-75.

12. Thompson TJ. Heat-induced dimensional changes in bone and their consequences for forensic anthropology. Journal of forensic sciences. 2005;50(5):1008-15.

13. Shipman P, Foster G, Schoeinger M. Burnt bones and teeth: an experimental study of color, morphology, crystal structure and shrinkage. Journal of archaeological science 1984;11:307-25.

14. Delattre VF. Burned beyond recognition: systematic approach to the dental identification of charred human remains. Journal of forensic sciences. 2000;45(3):589-96.

15. Sandholzer MA, Baron K, Heimel P, Metscher BD. Volume analysis of heat-induced cracks in human molars: A preliminary study. Journal of forensic dental sciences. 2014;6(2):139-44.

16. Sandholzer MA, Walmsley AD, Lumley PJ, Landini G. Radiologic evaluation of heat-induced shrinkage and shape preservation of human teeth using micro-CT. Journal of forensic radiology and imaging. 2013;1(3):107-11.

17. Bagdey SP, Moharil RB, Dive AM, Thakur S, Bodhade A, Dhobley AA. Effect of various temperatures on restored and unrestored teeth: A forensic study. Journal of forensic dental science. 2014;6(1):62-6.

18. Muller M, Berytrand MF, Quatrehomme G, Bolla M, Rocca JP. Macroscopic and microscopic aspects of incinerated teeth. Journal of forensic odonto-stomatology. 1998;16(1):1-7.

19. Savio C, Merlati G, Danesino P, Fassina G, Menghini P. Radiographic evaluation of teeth subjected to high temperatures: experimental study to aid identification processes. Forensic science international. 2006;158(2-3):108-16. DOI: 10.1016/j.forsciint.2005.05.003.

20. Hughes CE, White CA. Crack propagation in teeth: A comparison of perimortem and postmortem behavior of dental materials and cracks. Journal of forensic sciences. 2009;54(2):263-6.

21. Hill AJ, Lain R, Hewson I. Preservation of dental evidence following exposure to high temperatures. Forensic science international. 2011;205(1-3):40-3. DOI: 10.1016/j.forsciint.2010.08.011.

22. Hinchliffe J. Forensic odontology, part 3. The Australian bushfires - Victoria state, February 2009. British dental journal. 2011;210(7):317-21. DOI: 10.1038/sj.bdj.2011.239.

23. Hill AJ, Hewson I, Lain R. The role of the forensic odontologist in disaster victim identification: lessons for management. Forensic science international. 2011;205(1-3):44-7. DOI: 10.1016/j.forsciint.2010.08.013.

24. Schuliar Y, Knudsen P. Role of forensic pathologists in mass disasters. Forensic science, medicine, and pathology. 2012;8(2):164-73.

25. Hinchliffe J. Forensic odontology, part 2. Major disasters. British dental journal. 2011;210:269-74.

26. Berketa JW, James H, Lake AW. Forensic odontology involvement in disaster victim identification. Forensic science, medicine, and pathology. 2012;8(2):148-56. DOI: 10.1007/s12024-011-9279-9.

27. Cordner SM, Woodford N, Bassed R. Forensic aspects of the 2009 Victorian Bushfires Disaster. Forensic science international. 2011;205(1-3):2-7. DOI: 10.1016/j.forsciint.2010.08.008.

28. Bonanno GA, Kaltman S. The varieties of grief experience. Clinical psychology review. 2001;21(5):705-34.

29. Interpol. Interpol DVI guide. 2014. Available from: http://www.interpol.int/News-and-media/Publications

30. Goodwin WH, Simmons T. Disaster victim identification. In:Encyclopedia of forensic sciences. Waltham: Academic Press 2012.

31. Dawid AP, Mortera J, Vicard P. Object-oriented Bayesian networks for complex forensic DNA profiling problems. Forensic science international. 2007;169(2-3):195-205.

32. Brysiewicz P. The lived experience of losing a loved one to a sudden death in KwaZulu-Natal, South Africa journal of clinical nursing. 2008;17(2):224-31.

33. Campobasso CP, Dell'Erba AS, Belviso M, Di Vella G. Craniofacial identification by comparison of antemortem and postmortem radiographs: two case reports dealing with burnt bodies. American journal of forensic medicine and pathology. 2007;28(2):182-6. DOI: 10.1097/PAF.0b013e31806195cb.

34. Thali MJ, Yen K, Plattner T, Schweitzer W, Vock P, Ozdoba C, et al. Charred body: Virtual autopsy with multi-slice computed tomography and magnetic resonance imaging. Journal of forensic sciences. 2002;47(6):1326-31.

35. Bennett JL, Benedix DC. Positive identification of cremains recovered from an automobile based on presence of an internal fixation device. Journal of forensic sciences. 1999;44(6):1296-8.

36. Ligthelm AJ. The identification of 2 victims of fire. Journal of forensic odonto-stomatology. 1983;1(2):93-9.

37. Purves JD. Dental identification of fire victims. Forensic science. 1975;6(3):217-9.

38. Ruwanpura R, Vidanapathirana M, Ranasinghe S, Hettiarachchi MW, J., Seneviratne S, Dhahanayaka K, et al. Identification of Severely Burnt Bodies Due to Post Collision Fire: Bus –Truck Collision at Induruwa, Southern Sri Lanka. journal of forensic research. 2012. DOI: 10.4172/2157-7145.1000143.

39. Titsas A, Kieser JA. Odontological identification in two high-impact, high-temperature accidents. Journal of forensic odonto-stomatology. 1999 ;17(2):44-6.

40. Valenzuela A, Martin-de las Heras S, Marques T, Exposito N, Bohoyo JM. The application of dental methods of identification to human burn victims in a mass disaster. International journal of legal medicine. 2000;113(4):236-9.

41. Fanton L, Jdeed K, Tilhet-Coartet S, Malicier D. Criminal burning. Forensic science international. 2006;158:87-93.

42. Moritz MA, Parisien M-A, Battlori E, Krawchuk MA, Van Dorn J, Ganz DJ, et al. Climate change and disruptions to global fire activity. Ecosphere. 2012;3(6). DOI: 10.1890/ES11-00345.1.

43. Bastiaan RJ. Dental identification of the Victorian bushfire victims. Australian dental journal. 1984;29(2):105-10.

44. Bassed R, Leditschke J. Forensic medical lessons learned from the Victorian Bushfire Disaster: recommendations from the Phase 5 debrief. Forensic science international. 2011;205(1-3):73-6. DOI: 10.1016/j.forsciint.2010.06.026.

45. Cardoza AR. Dental forensic identification in the 2003 Cedar Fire. Journal of the California Dental Association. 2004;32(8):689-93.

46. Bonavilla JD, Bush MA, Bush PJ, Pantera EA. Identification of incinerated root canal filling materials after exposure to high heat incineration. Journal of forensic sciences. 2008;53(2):412-8. DOI: 10.1111/j.1556-4029.2007.00653.x.

47. Nambiar P, Jalil N, Singh B. The dental identification of victims of an aircraft accident in Malaysia. International dental journal. 1997;47(1):9-15.

48. Barsley RE, Carr RF, Cottone JA, Cuminale JA. Identification via dental remains: Pan American Flight 759. Journal of forensic sciences. 1985;30(1):128-36.

49. Brannon RB, Morlang WM. The crash of LOT flight 007: dental identification. Journal of forensic sciences. 2002;47(6):1323-5.

50. Dumancic J, Kaic Z, Njemirovskij V, Brkic H, Zecevic D. Dental identification after two mass disasters in Croatia. Croatian medical journal. 2001;42(6):657-62.

51. Griffiths CJ, Bellamy GD. Protection and radiography of heat affected teeth. Forensic science international. 1993;60(1-2):57-60.

52. Stene-Johansen W, Solheim T, Sakshaug O. Dental identification after the Dash 7 aircraft accident at Torghatten, Northern Norway, May 6th, 1988. Journal of forensic odonto-stomatology. 1992;10(1):15-24.

53. Bush M, Miller R. The crash of Colgan Air flight 3407 : Advanced techniques in victim identification. Journal of the American Dental Association (1939). 2011;142(12):1352-6.

54. Chapenoire S, Schuliar Y, Corvisier JM. Rapid, efficient dental identification of 92% of 13 train passengers carbonized during a collision with a petrol tanker. American journal of forensic medicine and pathology. 1998;19(4):352-5.

55. Solheim T, Lorentsen M, Sundnes PK, Bang G, Bremnes L. The "Scandinavian Star" ferry disaster 1990--a challenge to forensic odontology. International journal of legal medicine. 1992;104(6):339-45.

56. Jakobsen J, Remvig P. Identification of victims after a fire on the ferry "Scandinavian Star". Tandlaegebladet. 1991;95(8):325-30.

57. Hill IR, Keiser-Nielsen S, Vermylen Y, Free E, de Valck E, Tormans EeBIRH, 1984. L'Art dentaire en Medecine Legale in Forensic Odontology - Its Scope and History. Marshgibbon: Ian R. Hill; 1984.

58. Labovich MH, Duke JB, Ingwersen KM, Roath DB. Management of a multinational mass fatality incident in Kaprun, Austria: a forensic medical perspective. Military medicine. 2003;168(1):19-23.

59. Ubelaker DH, Owsley DW, Houck MM, Craig E, Grant W, Woltanski T, et al. The role of forensic anthropology in the recovery and analysis of Branch Davidian Compound victims: recovery procedures and characteristics of the victims. Journal of forensic sciences. 1995;40(3):335-40.

60. Taylor J. Development of the Australian Society of Forensic Odontology disaster victim identification forensic odontology guide. Journal of forensic odonto-stomatology. 2009;27(2):56-63.

61. Colvard MD, Lampiris LN, Cordell GA, James J, Guay A, Lee M, et al. The dental emergency responder: Expanding the scope of dental practice. Journal of the American Dental Association (1939). 2006;137(4):468-73.

62. Petersen KB. A hotel fire. International dental journal. 1975;25(3):172-8.

63. Taylor PT, Wilson ME, Lyons TJ. Forensic odontology lessons: multishooting incident at Port Arthur, Tasmania. Forensic science international. 2002;130(2-3):174-82.

64. Eckert WG. The medicolegal and forensic aspects of fires. American journal of forensic medicine and pathology. 1981;2(4):347-57.

65. Pechony O, Shindell DT. Driving forces of global wildfires over the past millennium and the forthcoming century. Proceedings of the National Academy of Sciences of the United States of America. 2010;107(45):19167-70. DOI: 10.1073/pnas.1003669107.

66. Byard RW, Gilbert JD, Kostakis C, Heath KJ. Circumstances of Death and Diagnostic Difficulties in Brushfire Fatalities. Journal of forensic sciences. 2012. DOI: 10.1111/j.1556-4029.2012.02083.x.

67. Johnston FH. Bushfires and human health in a changing environment. Australian family physician. 2009;38:720-4.

68. Muthusubramanian M, Limson KS, Julian R. Analysis of rugae in burn victims and cadavers to simulate rugae identification in cases of incineration and decomposition. Journal of forensic odonto-stomatology. 2005;23(1):26-9.

69. Sweet DJ, Sweet CH. DNA analysis of dental pulp to link incinerated remains of homicide victim to crime scene. Journal of forensic sciences. 1995;40(2):310-4.

70. Tümer AR, Akçan R, Karacaoğlu E, Balseven-Odabaşı A, Keten A, Kanburoğlu Ç, et al. Postmortem burning of the corpses following homicide Journal of forensic and legal medicine. 2012;19(4):223-8.

71. Porta D, Poppa P, Regazzola V, Gibelli D, Schillaci DR, Amadasi A, et al. The importance of an anthropological scene of crime investigation in the case of burnt remains in vehicles - 3 case studies. American journal of forensic medicine and pathology. 2013;34(3):195-200.

72. Owsley DW, Ubelaker DH, Houck MM, Sandness KL, Grant WE, Craig EA, et al. The role of forensic anthropology in the recovery and analysis of Branch Davidian Compound victims: techniques of analysis. Journal of forensic sciences. 1995;40(3):341-8.

73. De Angelis D, Cattaneo C. Implant Bone Integration Importance in Forensic Identification. Journal of forensic sciences. 2015;60(2):505-8.

74. Andersen L, Juhl M, Solheim T, Borrman H. Odontological identification of fire victims--potentialities and limitations. International journal of legal medicine. 1995;107(5):229-34.

75. Johanson G, Saldeen T. Identification of burnt victims with the aid of tooth and bone fragments. Journal of forensic medicine. 1969;16(1):16-25.

76. Mincer HH, Berryman HE, Murray GA, Dickens RL. Methods for physical stabilization of ashed teeth in incinerated remains. Journal of forensic sciences. 1990;35(4):971-4.

77. Cattaneo C, DiMartino S, Scali S, Craig OE, Grandi M, Sokol RJ. Determining the human origin of fragments of burnt bone: a comparative study of histological, immunological and DNA techniques. Forensic science international. 1999;102(2-3):181-91.

78. Imaizumi K, Taniguchi K, Ogawa Y. DNA survival and physical and histological properties of heat-induced alterations in burnt bones. International journal of legal medicine. 2014;128(3):439-46.

79. Fredericks JD, Ringrose TJ, Dicken A, Williams A, Bennett P. A potential new diagnostic tool to aid DNA analysis from heat compromised bone using colorimetry: A preliminary study. Science and justice. 2015;55(2):124-30.

80. Meyer HJ. The Kaprun cable car fire disaster--aspects of forensic organisation following a mass fatality with 155 victims. Forensic science international. 2003;138(1-3):1-7.

81. Higgins D, Austin JJ. Teeth as a source of DNA for forensic identification of human remains: a review. Science and justice. 2013. DOI: 10.1016/j.scijus.2013.06.001.

82. Higgins D, Kaidonis J, Austin J, Townsend G, James H, Hughes T. Dentine and cementum as sources of nuclear DNA for use in human identification. American journal of forensic science. 2011:287-95. DOI: 10.1080/00450618.2011.583278.

83. Senn DR, Weems RA. Manual of forensic odontology. Manual of forensic odontology. 5th ed. Boca Raton: CRC Press; 2013.

84. Farrell WL. Forensic identification of burn victims. Journal of the American Dental Association. 1979;99(1):51-6.

85. Johanson G, Saldeen T. A new method for the radiological detection and identification of fragments of teeth and bone recovered from burnt victims. Journal of forensic medicine. 1969;16(1):26-8.

86. Martin-de las Heras S, Valenzuela A, Villanueva E, Marques T, Exposito N, Bohoyo JM. Methods for identification of 28 burn victims following a 1996 bus accident in Spain. Journal of forensic sciences. 1999;44(2):428-31.

87. Morlang WM. Mass disaster management. In: Stimson PG, Mertz CA, editors. Forensic dentistry. Boca Raton: CRC; 1997. p. 185-236.

88. Iqbal MK KS. A Review of Factors Influencing Treatment Planning Decisions of Single-tooth Implants versus Preserving Natural Teeth with Nonsurgical Endodontic Therapy. Journal of endodontics. 2008;34:519-29.

89. Chiapasco M. Titanium–zirconium alloy narrow-diameter implants (Straumann Roxolid®) for the rehabilitation of horizontally deficient edentulous ridges: prospective study on 18 consecutive patients. Clinical oral implant research. 2012;23(10):1136.

90. Browne M, Gregson PJ. Surface modification of titanium alloy implants. Biomaterials. 1994;15(11):894-8.

91. Van Noort R. Titanium: the implant material of today. Journal of material science. 1987;22:3801-11.

92. Donachie MJJ. Titanium: A Technical Guide. 2nd ed. Materials Park: ASM International; 2000.

93. Berketa JW, Hirsch RS, Higgins D, James H. Radiographic recognition of dental implants as an aid to identifying the deceased. Journal of forensic sciences. 2010;55(1):66-70. DOI: 10.1111/j.1556-4029.2009.01226.x.

94. Marlin DC, Clark MAS. Identification of human remains by comparison of frontal sinus radiographs: a series of four cases. Journal of forensic sciences. 1991;36(6):1765-72.

95. Angyal M, Derczym K. Personal identification on the basis of antemortem and postmortem radiographs. Journal of forensic sciences. 1998;43(5):1089-93.

96. Nambiar P, Naidu MDK, Subramaniam K. Anatomical variability of the frontal sinuses and their application in forensic identification. Clinical anatomy. 1999;12:16-9.

97. Quartrehomme G, Fronty P, M. S, Grevin G, Bailet P, Ollier A. Identification by frontal sinus pattern in forensic anthropology. Forensic science international. 1996;83:147–53. 1996;83:147-53.

98. Kullman L, Ekland B, Grundin R. Value of the frontal sinus in identification of unknown persons. Journal of forensic odonto-stomatology. 1990;8(1):3-10.

99. Cox M, Malcolm M, Fairgrieve S. A new digital method for the objective comparison of frontal sinuses for identification. Journal of forensic sciences. 2009;54(4):761-72.

100. Reichs KJ. Quantified comparison of frontal sinus patterns by means of computed tomography. Forensic science international. 1993;61:2-3.

101. Kirk NJ, Wood RE, Goldstein M. Skeletal identification using the frontal sinus region: a retrospective study of 39 cases. Journal of forensic sciences. 2002;47(2):318–23.

102. Yoshino M, Miyasaka S, Sato H, Seta S. Classification system of frontal sinus patterns by radiography. Its application to identification of unknown skeletal remains. Forensic science international. 1987;34(4):289-99.

103. Culbert WL, Law FM. Identification by comparison of roentgenograms of nasal accessory sinuses and mastoid processes. Journal of American Medical Association. 1927;88(21):1634-6.

104. Cameriere R, Ferrante L, Mirtella D, Rollo F, Cingolani M. Frontal sinuses for identification: quality of classifications, possible error and potential corrections. Journal of forensic sciences. 2005;50(4):770-3.

105. Christensen AM. Testing the reliability of frontal sinuses in positive identification. Journal of forensic sciences. 2005;50(1):18-22.

106. Grevin G, Bailet P, Quatrehomme G, Ollier A. Anatomical reconstruction of fragments of burned human bones: a necessary means for forensic identification. Forensic science international. 1998;96(2-3):129-34.

107. Mayne Correia P, Beattie O. A critical look atmethods for recovering, evaluating, and interpreting cremated human remains. In: Haglund W SM, editors., editor. Advances in forensic taphonomy: Method, theory, and archaeological perspectives. Boca Raton: CRC 2002.

108. Clark TF. Cyanoacrylate glue burn in a child--lessons to be learned. Journal of plastic reconstruction and aesthetic surgery. 2011;64(7):e170-3.

109. Safety Data Sheet cyanoacrylate adhesive. 2015 [cited 2015 13 Feb]. Available from: http://ge-iic.com/files/fichas%20productos/cianoacrilato.pdf.

110. Merlati G, Savlo C, Danesino P, Fassina G, Menghini P. Further study of restored and un-restored teeth subjected to high temperatures. Journal of forensic odonto-stomatology. 2004;22(2):34-9.

111. Merlati G, Danesino P, Savio C, Fassina G, Osculati A, Menghini P. Observations on dental prostheses and restorations subjected to high temperatures: experimental studies to aid identification processes. Journal of forensic odonto-stomatology. 2002;20(2):17-24.

112. Rossouw RJ, Grobler SR, Phillips VM, van WKTJ. The effects of extreme temperatures on composite, compomer and ionomer restorations. Journal of forensic odonto-stomatology. 1999;17(1):1-4.

113. Hatch GM, Dedouit F, Christensen AM, Thali MJ. RADid: A pictorial review of radiologic identification using postmortem CT. Journal of forensic radiology and imaging. 2014;2(2):52-9.

114. Kahana T, Hiss J. Suprapelvic and pelvic phleboliths—a reliable radiographic marker for positive identification. Journal of clinical forensic medicine 2002;9:115-8.

115. Eckert WG, James S, Kathis S. Investigation of cremations and severely burned bodies. American journal of forensic medicine and pathology. 1988;9(3):188-200.

116. Isaacs TW, Margolius KA, Chester GH. Postmortem identification by means of a recovered intraocular lens. American journal of forensic medicine and pathology. 1997;18(4):404-5.

117. Simpson EK, James RA, Eitzen DA, Byard RW. Role of orthopedic implants and bone morphology in the identification of human remains. Journal of forensic sciences. 2007;52(2):442-8. DOI: 10.1111/j.1556-4029.2006.00370.x.

118. Wilson RJ, Bethard JD, DiGangi EA. The use of orthopedic surgical devices for forensic identification. Journal of forensic sciences. 2011;56(2):460-9. DOI: 10.1111/j.1556-4029.2010.01639.x.

119. Maples WR. Forensic anthropology. In: Stimson PG, Mertz AM, editors. Forensic dentistry. Boca Raton: CRC; 1997. p. 65-81.

120. Scott AL, Congram D, Sweet D, Fronseca S, Skinner M. Anthropological and radiographic comparison of antemortem surgical records for identification of skeletal remains. Journal of forensic sciences. 2010;55(1):241-4.

121. Murray LA, Caiach S. Confirmation of identity by a metallic knee prosthesis in a severely burnt body. Journal of clinical forensic medicine. 1998;5(1):8-9.

122. Grabherr S, Stephan BA, Buck U, Nather S, Christe A, Oesterhelweg L, et al. Virtopsy – Radiology in forensic medicine. Imaging decisions MRI. 2007;11(1):2-9.

123. Takeshita H, Nagai T, Sagi M, Chiba S, Kanno S, Takada M, et al. Forensic identification using multiple lot numbers of an implanted device. Medicine, science, and the law. 2014;54(1):51-3. DOI: 10.1177/0025802413498860

124. Silva RH, Franco A, Mendes SDSC, Picoli FF, Marinho DEA. Human identification through the patella—Report of two cases. Forensic science international. 2014;238:e11-e4. DOI: 10.1016/j.forsciint.2014.02.025.

125. Matoso RI, de Novaes Benedicto E, de Lima SHR, Prado FB, Daruge E, Júnior ED. Positive identification of a burned body using an implanted orthopedic plate. Forensic science international. 2013;229(1): 168.e1–.e5.

126. Wilcher G. Artificial Penile Nodules – A Forensic Pathosociology Perspective. Medicine, science, and the law. 2006;46(4):349-56.

127. Makinae H, Numata N, Kitaoka H, Daimon M, Yamamoto T, Amano A. Use of pacemaker programmers for disaster victim identification. Forensic science, medicine, and pathology. 2013;9(4):551-3.

128. Sidler M, Jackowski C, Dirnhofer R, Vock P, Thali M. Use of multislice computed tomography in disaster victim identification—Advantages and limitations. Forensic science international. 2007;169(2-3):118-28.

129. Fleischman JM. Radiographic identification using midline medical sternotomy wires. Journal of forensic sciences. 2015;60:S3-10. DOI: 10.1111/1556-4029.12610.

130. Blau S, Robertson S, Johnstone M. Disaster Victim Identification: New Applications for Postmortem Computed Tomography. Journal of forensic sciences. 2008;53(4):956-61. DOI: doi: 10.1111/j.1556-4029.2008.00742.x.

131. Woisetschlager M, Lussi A, Persson A, Jackowski C. Fire victim identification by post-mortem dental CT: radiologic evaluation of restorative materials after exposure to high temperatures. European journal of radiology. 2011;80:432-40.

132. Hinchliffe J. Forensic odontology, Part 1. Dental identification. British dental journal. 2011;210(5):219-24.

Chapter 2

A review of the literature

2.1 Introduction

This chapter incorporates three parts, The first section contains a peer reviewed published paper which reviews the literature on maximising postmortem oral-facial data to assist identification following severe incineration The second section reviews other non-cranial postmortem information that could be used for identification of severe incinerated victims. The third section is a paper reviewing the literature regarding training for the identification of severely incinerated victims.

2.2 Maximizing postmortem oral-facial data to assist identification following severe incineration

Published as: Berketa, J.W. Maximizing postmortem oral-facial data to assist identification following severe incineration. *Forensic Science Medicine Pathology.* (2014) 10:(2) 208-216.

(Sole author)

Berketa, J.W. (2014) Maximizing postmortem oral-facial data to assist identification following severe incineration. *Forensic Science, Medicine and Pathology*,10(2), 208-216.

NOTE: This publication is included in the print copy of the thesis held in the University of Adelaide Library.

It is also available online to authorised users at:

http://dx.doi.org/10.1007/s12024-013-9497-4

2.3 A review of post-cranial facial postmortem data to assist identification following severe incineration.

Following severe incineration, with the loss of identifying features such as visual, fingerprint, and DNA, there could be also being situations where no oral-facial information is available. The victim could be edentulous, the incineration is extremely severe or that there has been irretrievable accidental or deliberate damage to the oral-facial tissues. Fortunately, other parts of the body might reveal sufficient information to allow identification. There could be bony pathology (1-9), calluses from earlier bone fractures (4, 10, 11), aesthetic insertions (12, 13) or medical devices (13-21).

There have been identifications of burnt bodies utilising bony information, but severe incineration will deform and warp bone so care should be exercised (22-26). Following the World Trade Center attacks on 11th of September 2001 one of the deceased fire-fighters was identified by comparison of congenital malformations of his cervical vertebrae and a piece of jewellery. However, DNA results matched a different person who also had malformation of the same two vertebrae (4).

Metallic objects of high melting points should survive an incineration event. A Computer Tomography (CT) scan may reveal medical implants or devices (27). Items that could survive are jewellery such as rings and watches (28), body piercings (studs, chains or rings), heart pacemakers (18), orthopaedic plates used to stabilise healing fractures (19), rods also used for healing bone fractures, screws used by themselves or in combination with plates and rods (4), spinal devices such as Harrington rods or dens supports (4, 21), gastric bypass clips, surgical wires (17), staples (29), metallic stents, implants such as knees (20, 30), hips (30), shoulder (21), ankle devices and penile nodules [12, 31] might be found [4, 10, 12, 14, 17, 20, 21, 27, 32-35]. The CT scanning of burnt bodies is therefore highly advisable to assess what objects might be present and also the indication of position within the charred remains would speed up recovery of these devices [13, 15, 33, 36-38].

The most common medical device are bone healing plates (traumatic fixation devices) [30]. They are usually metallic flat plates or chain structures made from alloys, such as cobalt–chromium–molybdenum, stainless steel, or titanium [30] fastened with nails, screws, bolts, nuts and washers. Some plates do have numbering upon them [4, 19, 30], and Mataso et al. [19] published an article where they were successful in identifying a burnt victim where the numbering was quite easily read. I have noticed that rods utilized for healing may also have numbers along their shafts.

Takeshita et al. [34] published an article where an intramedullary nail inserted within a right femur allowed identification as there were multiple parts and lot numbers, resulting in extremely low probability of the same combination of lot numbers being present in multiple individuals. The numbering may not be a unique serial number, but as the screws may also have lot numbers etched on their heads, the combination of specific numbers of screws, the orientation and sizes of screws together with these lot numbers may add substantial weight to a victim's identification if corresponding antemortem records are located. This case confirmed the use of multiple lot numbers of implantable devices in forensic identification [34].

Simpson et al. [4] presented a case where, although there was no lot numbers, the matching of antemortem radiographs to postmortem radiographs of two metal Harrington rods connecting the T4 to L3 vertebrae was sufficient to establish identification. Also, in the same article, a case where an orthopaedic plate fixed to the left ulna by six screws aided substantially to identity being established [4].

Total or partial arthroplasty accounts for the next most common reason for implanted devices. Total arthroplasty is the replacement of an entire joint complex. Usually there is more than one part with a total hip replacement consisting of the acetabulum and femoral head being replaced by metal and/or plastic (polymer) components. Partial arthroplasty is the replacement of a part of the joint complex. For example, a partial knee replacement consists of the replacement of only one or both condyles of the tibia, the femoral component or the patella. Arthroplasty parts are typically constructed of metals such as stainless steel, titanium, cobalt/chromium, and ceramics for the sturdy sections, with possibly polymer parts where friction is involved. There could be multiple different manufacturers within the same joint replacement, which can complicate the individuation process yet if this combination is unusual this would add more weight to the reconciliation process. Arthroscopic implants are recognizable following cremations or situations of extreme burning because the implant main shaft sections are usually quite large, have an obvious shape (compared to screws, nails, bolts and plates that can be confused with building material debris) and they maintain their morphological shape enough for easy identification amongst the rubble [(30)].

Any information obtained from an implanted prosthesis requires matching with antemortem data. In America, the Safe Medical Devices Act (SMDA) of 1990 and the FDA Food and Drug Administration (FDA) requires implant manufacturers to have the ability to track devices to patients through the purchasing physician/hospital in case of device flaws and/or failure [(30)]. The Australian Orthopaedic Association National Joint Replacement Registry (AOANJRR) fully implemented a registry across the country in 2002 to track arthroscopic implants [(39)]. The American Association of Orthopedic Surgeons (AAOS) instituted its own tracking system for joint replacements in 2004 [(30)]. Many hospitals or medical care groups hold their own database for joint replacements [(39)], although the surgeons' notes will be the best source of the identification because the serial number of the appliance, the part number, and the manufacturer information should be in these records [30].

Owing to both the increase in length of life of people in the developed nations and the obesity epidemic throughout the western world, hip and knee replacements account for most of the joint replacement devices [30, 39]. In a case report by Murray and Caiach [20], a victim was severely burnt, yet identification was confirmed by matching the serial numbers on a knee prosthesis with the joint serial number and with co-existing anatomical abnormalities of the suspected victim [20]. In a case reported by Simpson et al. [4] radiographs of a right hip prosthesis were corresponded with antemortem radiographs of the occupier of the premises, believed to be the deceased, and together with a calcified uterine fibroid noted in both pre and postmortem radiographs, this substantiated the identification of the victim [4].

Published cases where other devices have assisted in identification are; Blau et al. reported that following a plane crash the fragmented partially burnt remains were CT scanned revealing a ring and two screws [15], Siva et al. [35] published two cases which fixation wires in patellas allowed identification, Bennett and Benidix [14] reported that an EBI osteostimulator was utilised for homicide identification case where the victim was burnt, Hinchcliff [37] mentions the use of breast implant serial numbers for identification, Scott et al. [29] reported on a surgical clip and seven staples discovered on skeletal remains which helped identify a person that had been missing for almost a decade; and Makinae et al. reported on the use of pacemaker programs in successfully identifying a victim of 2011 tsunami in Japan [18].

The previous reports highlight the successful use of medical devices in bringing about successful identification of victims. However, the discovery of a medical implant within human remains does not always establish positive identification. The lack of individual identifiers on devices limits the identification of deceased individuals from medical records. They either are not uniquely serial numbered or the damage to the device from the incident, which created the death of the victim, has limited the data available for reconciliation. This may occur with severe incineration where the soft tissue has failed to insulate the device sufficiently that the device is damaged, charred or oxidized. There appears to be a gap in the literature regarding the retrieval of data from implanted devices where there has been charring or oxide build up obscuring the numbering and/or the manufacturer's logo. There needs to be a successful method developed and then tested so that valuable information hidden beneath the buildup on implanted devices is successfully revealed.

2.3a References

1. Beggan C, Towers M, Farrell M, Jaber K. Spinal diastematomyelia: A means of identification of charred remains. Journal of forensic and legal medicine. 2014;21:5-8.

2. Kahana T, Goldin L, Hiss J. Personal identification based on radiographic vertebral features. American journal of forensic medicine and pathology. 2002;23(1):36-41.

3. Kahana T, Hiss J. Suprapelvic and pelvic phleboliths—a reliable radiographic marker for positive identification. Journal of clinical forensic medicine 2002;9:115-8.

4. Simpson EK, James RA, Eitzen DA, Byard RW. Role of orthopedic implants and bone morphology in the identification of human remains. Journal of forensic sciences. 2007;52(2):442-8. DOI: 10.1111/j.1556-4029.2006.00370.x.

5. Rich J, Tatarek N, Powers RH, Brogon BG, Lewis BJ, Dean DE. Using pre- and post-surgical foot and ankle radiographs for identification. Journal of forensic sciences. 2002;47(6):1319-22.

6. Sudimack JR, Lewis BJ, J. R, Dean DE, Fardal PM. Identification of decomposed human remains from radiographic comparisons of an unusual foot deformity Journal of forensic sciences. 2002;47(1):218-20.

7. Hulewicz B, Wilcher GW. The use of thoracolumbar and hip joint dysmorphism in identification. Journal of forensic sciences. 2003;48(4):842-7.

8. Dean DE, Tatarek NE, Rich J, Brogdon BG, Powers PR. Human identification from the ankle with pre- and postsurgical radiographs. Journal of clinical forensic medicine. 2005;12:5-9.

9. Hogge JP, Messmer JM, Fierro MF. Positive identification by post-surgical defects from unilateral lambdoid synostectomy: a case report. Journal of forensic sciences. 1995;40(4):688-91.

10. Grabherr S, Stephan BA, Buck U, Nather S, Christe A, Oesterhelweg L, et al. Virtopsy – Radiology in Forensic Medicine. Imaging decisions MRI. 2007;11(1):2-9.

11. Herrmann NP, Bennett JL. The differentiation of traumatic and heat-related fractures in burned bone. Journal of forensic sciences. 1999;44(3):461-9.

12. Badiadka KK, Vasu S, D'Souza DH. Artificial penile nodules' as a tool for identification: A case report. Journal of the South India Medicolegal Association. 2010;2:28-30.

13. Thali MJ, Yen K, Plattner T, Schweitzer W, Vock P, Ozdoba C, et al. Charred body: Virtual autopsy with multi-slice computed tomography and magnetic resonance imaging. Journal of forensic sciences. 2002;47(6):1326-31.

14. Bennett JL, Benedix DC. Positive identification of cremains recovered from an automobile based on presence of an internal fixation device. Journal of forensic sciences. 1999;44(6):1296-8.

15. Blau S, Robertson S, Johnstone M. Disaster Victim Identification: New Applications for Postmortem Computed Tomography. Journal of forensic sciences. 2008;53(4):956-61. DOI: doi: 10.1111/j.1556-4029.2008.00742.x.

16. Durão CH, Pinto R, Riberio C, Vieira D. Importance of a national arthroplasty register for identification by medical examiner. Revista Brasileira de Ortopedia. 2012;47(5):651-5.

17. Fleischman JM. Radiographic identification using midline medical sternotomy wires. Journal of forensic sciences. 2015;60:S3-10. DOI: 10.1111/1556-4029.12610.

18. Makinae H, Numata N, Kitaoka H, Daimon M, Yamamoto T, Amano A. Use of pacemaker programmers for disaster victim identification. Forensic science, medicine, and pathology. 2013;9(4):551-3.

19. Matoso RI, de Novaes Benedicto E, de Lima SHR, Prado FB, Daruge E, Júnior ED. Positive identification of a burned body using an implanted orthopedic plate. Forensic science international. 2013;229(1): 168.e1–.e5.

20. Murray LA, Caiach S. Confirmation of identity by a metallic knee prosthesis in a severely burnt body. Journal of clinical forensic medicine. 1998;5(1):8-9.

21. Sidler M, Jackowski C, Dirnhofer R, Vock P, Thali M. Use of multislice computed tomography in disaster victim identification—Advantages and limitations. Forensic science international. 2007;169(2-3):118-28.

22. Bohnert M, Rost T, Faller-Marquardt M, Ropohl D, Pollak S. Fractures of the base of the skull in charred bodies--post-mortem heat injuries or signs of mechanical traumatisation? Forensic science international. 1997;87(1):55-62.

23. Tsokos M. Heat-induced post-mortem defect of the skull simulating an exit gunshot wound of the calvarium. Forensic science, medicine, and pathology. 2011;7(2):227-8.

24. Thompson TJ. Heat-induced dimensional changes in bone and their consequences for forensic anthropology. Journal of forensic sciences. 2005;50(5):1008-15.

25. Cameriere R, Ferrante L, Mirtella D, Rollo F, Cingolani M. Frontal sinuses for identification: quality of classifications, possible error and potential corrections. Journal of forensic sciences. 2005;50(4):770-3.

26. Shipman P, Foster G, Schoeinger M. Burnt bones and teeth: an experimental study of color, morphology, crystal structure and shrinkage. Journal of archaeological science. 1984;11:307-25.

27. Schuliar Y, Knudsen P. Role of forensic pathologists in mass disasters. Forensic science, medicine, and pathology. 2012;8(2):164-73.

28. Park DK, Park KH, Ko JS, Kim YS, Chung NE, Ahn YW, et al. The role of forensic anthropology in the examination of the Daegu subway disaster (2003, Korea). Journal of forensic sciences. 2009;54(3):513-8. DOI: 10.1111/j.1556-4029.2009.01027.x.

29. Scott AL, Congram D, Sweet D, Fronseca S, Skinner M. Anthropological and radiographic comparison of antemortem surgical records for identification of skeletal remains. Journal of forensic sciences. 2010;55(1):241-4.

30. Wilson RJ, Bethard JD, DiGangi EA. The use of orthopedic surgical devices for forensic identification. Journal of forensic sciences. 2011;56(2):460-9. DOI: 10.1111/j.1556-4029.2010.01639.x.

31. Wilcher G. Artificial Penile Nodules – A Forensic Pathosociology Perspective. Medicine, science, and the law. 2006;46(4):349-56.

32. Maples WR. Forensic anthropology. In: Stimson PG, Mertz AM, editors. Forensic dentistry. Boca Raton: CRC; 1997. p. 65-81.

33. Eckert WG, James S, Kathis S. Investigation of cremations and severely burned bodies. American journal of forensic medicine and pathology. 1988;9(3):188-200.

34. Takeshita H, Nagai T, Sagi M, Chiba S, Kanno S, Takada M, et al. Forensic identification using multiple lot numbers of an implanted device. Medicine, science, and the law. 2014;54(1):51-3. DOI: 10.1177/0025802413498860

35. Silva RH, Franco A, Mendes SDSC, Picoli FF, Marinho DEA. Human identification through the patella—Report of two cases. Forensic science international. 2014;238:e11-e4. DOI: 10.1016/j.forsciint.2014.02.025.

36. Woisetschlager M, Lussi A, Persson A, Jackowski C. Fire victim identification by post-mortem dental CT: radiologic evaluation of restorative materials after exposure to high temperatures. European journal of radiology. 2011;80:432-40.

37. Hinchliffe J. Forensic odontology, Part 1. Dental identification. British dental journal. 2011;210(5):219-24.

38. Hatch GM, Dedouit F, Christensen AM, Thali MJ. RADid: A pictorial review of radiologic identification using postmortem CT. Journal of forensic radiology and imaging. 2014;2(2):52-9.

39. Huang T, Wang W, George D, Mao X, Graves S. What can we learn from AOANJRR 2014 annual report? Annals translational medicine. 2015;3(10):131.

2.4 A review of the literature regarding training for the identification of severely incinerated victims.

Forensic odontology knowledge can be gained by reading the many well-written textbooks and encyclopedias worldwide [1-8]. Also many courses are offered in teaching forensic odontology, both university postgraduate training through a Graduate Diploma, Masters or PhD program and also through a College system. However, forensic odontology cannot simply be carried out by dentists without specialty training [9]. Untrained and inexperienced personnel can cause delays and compromise victim identification [10]. During the South Asian tsunami of 2004, a principal error component reported was due to inexperience of the operators [11]. Brannon and Kassler also suggested that advanced planning and training of all dental personnel can eliminate most of the problems that occur in dental disaster victim identification [10]. A review by De Winne comments that the world is still poorly prepared to handle major disaster incidents not just in so-called underdeveloped countries, but also in well-organized and industrialised countries such as the United States of America with the example of hurricane Katrina in New Orleans in August 2005[12].

Therefore, to be competent in forensic odontology there needs to be supervised hands on casework. Explaining a skill verbally is not the most effective way to promote either the amount of material retained nor the length of time for which it is retained [13]. The "see one, do one, teach one" combines the benefits of different learning styles. The process involves trainees in seeing or learning the skill, doing it themselves, and then teaching the skill to another person. Maximum learning results are obtained when the learner goes through these activities [13] Unfortunately, with forensic odontology, it is difficult to predict if there will be sufficient real life casework to gain sufficient practical experience nor would it be ethical to create casework purely as a teaching exercise.

Mock victim identification exercises are a way of introducing training where there is a lack of steady casework available. In Vancouver Canada, to provide a prepared team of dental members training, a mock disaster exercise (Operation: DENT-ID) is conducted annually in association with the British Columbia Coroners Service and the British Columbia Forensic Odontology Response Team. The exercise enables areas of strength and weakness to be identified as well as assuring the authorities that the dental team is appropriately trained (14).

In cases of severe incineration, the level of skill required to manage the postmortem information correctly is greater due to the fragility of incinerated remains and the possible lack of material available. I was unable to discover any reported literature where mock training in the forensic odontological identification of severely incinerated victims has been reported. Similarly, scene police officers that are tasked in recovering the remains of these severely incinerated victims do not have freely available published articles or manuals for referral. The training communicated to me is hands on training and incorporated within the general topic heading of processing the victims. The requirements and difficulties of forensic odontologists in such cases need to be communicated to scene officers so that a specific training regime is set for these circumstances. Although training exercise will not duplicate a real life situation, the need to prepare for such events as realistic as possible utilising animal tissues is likely to assist forensic odontologists, scene officers and ultimately the reconciliation process.

2.4a References

1. Senn DR, Weems RA. Manual of forensic odontology. Manual of forensic odontology. 5th ed. Boca Raton: CRC Press; 2013.

2. Gustafson. Forensic odontology. London: Staples Press; 1966.

3. Stimson PG, Mertz AC. Forensic dentistry. Baton Rouge: CRC; 1997.

4. Bowers CM. Forensic dental evidence. First ed. Amsterdam: Elsevier Academic Press; 2004.

5. Clark DH. Practical forensic odontology. Oxford: Wright; 1992.

6. Dayal PK, Srinivasan SV, Paravatty RP. Textbook of forensic odontology. Hyderabad: Paras; 1998.

7. Fixott RH. The dental clinics of North America. Philadelphia: W.B.Saunders; 2001.

8. Goodwin WH, Simmons T. Disaster Victim identification. In:Encyclopedia of forensic Sciences. Waltham: Academic Press 2012.

9. Nuzzolese E, Vella G. Future project concerning mass disaster management: a forensic odontology prospectus. International dental journal. 2007;57(4):261-6.

10. Brannon RB, Kessler HP. Problems in mass disaster dental identification: a retrospective review. Journal of forensic sciences. 1999;44(1):123-7.

11. Kieser JA, Laing W, Herbison P. Lessons learned from large-scale comparative dental analysis following the South Asian tsunami of 2004. Journal of forensic sciences. 2006;51(1):109-12.

12. De Winnie J. Preparing for major incidents. Forensic science international. 2006;159:S9-S11.

13. Coughlin CN. See one, do one, teach one: Dissecting the use of medical education's signature pedagogy in the law school curriculum. Georgia State University Law Review. 2009;26(2):Article 4.

14. Pretty IA, Webb DA, Sweet D. The design and assessment of mock mass disasters for dental personnel. Journal of forensic sciences. 2001;46:74-9.

Chapter 3

Use of a non-volatile agent to stabilize severely incinerated dental remains

3.1 Introduction

Evidence of loss of dental postmortem information from the scene to the mortuary is a continuing problem. In for example the 2009 Australian Victoria bushfires, due to separation of tooth fragments (leading to loss of postmortem information), the forensic odontologists were required to give opinions with minimal information on which to base a reconciliation decision. It was evident from the images taken at the scene that a substantial amount of dental postmortem information was lost transporting the remains to the mortuary for examination [(1-3)]. This lack of postmortem information continues to frustrate odontologists and anthropologists [(4-10)]. Similarly, in motor vehicle incinerations, quite often retrieval of the victim leads to the loss of postmortem information. Images taken at the scene (Figure 1.) highlight useful dental data such as the missing 24 tooth, however recovery at the mortuary of recognisable tooth structures are minimal as shown in Figure 2. Reconstruction of fractured sections of tooth (Figure 3.) and bone material introduces possible errors and loss of certainty. If the teeth have been avulsed, replacement into the sockets requires verification of placement position utilising radiographs at the mortuary.

Figure1. Portrait image of incinerated deceased showing retained roots and the 24 missing.

Figure 2. Dental information recovered of the same case as Figure 1.

Figure 3. Reconstruction of fractured dental information.

Clearly there was a lack of use of stabilisation agents and/or lack of knowledge in handling of incinerated dental remains by scene officers.

3.2 Background Research

Chapter 2 highlighted methods to stabilise dental remains. To provide evidence and information for scene officers to utilise stabilising agents, I tested various materials mentioned by Mincer et al. [9], but excluded dental materials that would not be readily available in supermarkets or general hardware stores to the scene officers in rural locations. I utilised cigarette ash, as an extreme example of what could be achieved. I discovered that brushing on materials would destroy some of the ash structure and that materials that could be sprayed were a better proposition. Hair spray would give a fine mist yet wasn't as strong as clear enamel gloss spray. When sprayed at a distance, sufficient retention was achieved to hold not only the cigarette but also the ash in its form even when the tile it was resting on was turned upwards as can be seen in Figure 4.

Figure 4. The bottom cigarette and its ash are seen remaining in situ when sprayed with the tile turned up.

With this initial success, I devised and supervised a postgraduate study into stabilisation of incinerated sheep mandibles, utilising a commercially prepared clear lacquer gloss spray available in a ready to use spray can. This study has been recently published [11]. However during presentation of the results, police scene officers pointed out their extreme reluctance to use the product. Their concern was that volatile vapors emitted from any stabilising agent might compromise a scene if testing for accelerants was required. As crime scene investigators, they were reluctant to contaminate their own and/or pathologist's investigations and would therefore not use the product routinely. Testing for volatiles can be sampled at the scene but also later at the mortuary especially beneath the body. I devised a pilot study to determine the extent of spread with a paint spray and various methods such as clear plastic pipes, to limit the contamination spread. Unfortunately, in ideal conditions, such as good access and no wind, there was still a spread of aerosols of greater than 55 centimetres (Figure 5).

Figure 5. Stone model of a head sprayed with containment device allowing measurement of aerosol radius.

It was clear that a method to stabilise the incinerated remains utilising a non-volatile agent needed to be developed (and tested) that would be accepted by scene officers and forensic pathologists. The following published article that describes the various materials I tested for stabilisation, the subsequent testing of initially successful products on sheep mandibles, and the results following testing on human dental tissue.

3.2a References

1. Hill AJ, Hewson I, Lain R. The role of the forensic odontologist in disaster victim identification: lessons for management. Forensic science international. 2011;205(1-3):44-7. DOI: 10.1016/j.forsciint.2010.08.013.

2. Hill AJ, Lain R, Hewson I. Preservation of dental evidence following exposure to high temperatures. Forensic science international. 2011;205(1-3):40-3. DOI: 10.1016/j.forsciint.2010.08.011.

3. Hinchliffe J. Forensic odontology, part 3. The Australian bushfires - Victoria state, February 2009. British dental journal. 2011;210(7):317-21. DOI: 10.1038/sj.bdj.2011.239.

4. Andersen L, Juhl M, Solheim T, Borrman H. Odontological identification of fire victims--potentialities and limitations. International journal of legal medicine. 1995;107(5):229-34.

5. Botha CT. The dental identification of fire victims. Journal of forensic odonto-stomatology. 1986;4(2):67-75.

6. Delattre VF. Burned beyond recognition: systematic approach to the dental identification of charred human remains. Journal of forensic sciences. 2000;45(3):589-96.

7. Fairgrieve SI. Forensic Cremation: Recovery and Analysis. Boca Raton: CRC Press; 2007.

8. Johanson G, Saldeen T. Identification of burnt victims with the aid of tooth and bone fragments. Journal of forensic medicine. 1969;16(1):16-25.

9. Mincer HH, Berryman HE, Murray GA, Dickens RL. Methods for physical stabilization of ashed teeth in incinerated remains. Journal of forensic sciences. 1990;35(4):971-4.

10. Solheim T, Lorentsen M, Sundnes PK, Bang G, Bremnes L. The "Scandinavian Star" ferry disaster 1990--a challenge to forensic odontology. International journal of legal medicine. 1992;104(6):339-45.

11. Berketa J, Fauzi A, James H, Lake AW, Langlois N. The utilization of a commercial gloss spray in stabilization of incinerated dental structures. Journal of forensic and legal medicine. 2015;33:76-9.

3.3 Manuscript

Published as: Berketa, J. James, H. Langlois, N. Richards, L. Use of a non-volatile agent to stabilize severely incinerated dental remains. *Forensic Science Medicine Pathology*. Available online (2015) DOI 10.1007/s12024-015-9670-z.

Statement of Authorship

Title of Paper	Use of a non-volatile agent to stabilize severely incinerated dental remains.
Publication Status	⦿ Published, ○ Accepted for Publication, ○ Submitted for Publication, ○ Publication style
Publication Details	John Berketa, Helen James, Neil Langlois, Lindsay Richards and Paul Pigou. Forensic Science, Medicine, and Pathology. available online at 10.1007/s12024-015-9670-z

Author Contributions

By signing the Statement of Authorship, each author certifies that their stated contribution to the publication is accurate and that permission is granted for the publication to be included in the candidate's thesis.

Name of Principal Author (Candidate)	John Berketa		
Contribution to the Paper	Designed, performed analysis on all samples, interpreted data, wrote manuscript and acted as corresponding author		
Signature		Date	8 04 2015

Name of Co-Author	Helen James		
Contribution to the Paper	Supervised work and manuscript evaluation.		
Signature		Date	8 04 2015

Name of Co-Author	Neil Langlois		
Contribution to the Paper	Supervised work, ethics application assistance and manuscript evaluation.		
Signature		Date	8th April 2015

Name of Co-Author	Lindsay Richards		
Contribution to the Paper	Supervised work and manuscript evaluation.		
Signature		Date	08 04 2015

Name of Co-Author	Paul Pigou		
Contribution to the Paper	Chromatogram supervision, review and editing of manuscript		
Signature		Date	8/4/2015

Berketa, J. James, H. Langlois, N. Richards, L. Use of a non-volatile agent to stabilize severely incinerated dental remains. *Forensic Science, Medicine and Pathology*,11(2), 228–234.

NOTE: This publication is included in the print copy of the thesis held in the University of Adelaide Library.

It is also available online to authorised users at:

http://dx.doi.org/10.1007/s12024-015-9670-z

Chapter 4

A study of osseointegrated dental implants following cremation

4.1 Introduction

A dental implant is a prosthetic device, usually cylindrical in design, that is inserted into either or both the upper or lower jawbone, onto which an artificial tooth, crown or bridge or denture can be anchored. Dental implants are typically constructed from titanium or more recently some manufacturers are constructing their implants from zirconia or a combination of titanium and zirconia [1, 2]. The placement of implants has become widespread throughout the world and Gaviria et al. state that in 2010 in the United States of America, about 100,000-300,000 dental implants are placed per year [3]. Coupled with the properties of dental implants such as high melting points, high resistance to corrosion and robustness, the likelihood of implants present in the deceased in the future would likely increase.

4.2 Background Research

During my postgraduate forensic odontology study, which began in 2006, my research project was in my special interest of dental implants. I could foresee that they would become a more popular form of treatment with the use and the number of companies manufacturing them would likewise multiply and would be another good source of postmortem information. I researched the history of dental implants and devised a sieving system using the shape, threaded or non-threaded, tapering, flange shape and apex as morphological markers when analysing dental implants radiographically [4]. Differences of the groove patterns in the apex and the use of 5mm stainless steel balls (Ref. 6034321 D3352, Sirona™, Charlotte, USA) to analyse the dimensions of the implant were highlighted [4] and a blind study involving 200 images of dental implants was conducted and published [5].

In 2009 I was asked to assist with dental implant recognition following the Victorian bushfires. Even though I was confident in providing an opinion, it occurred to me that the effect of severe heat on the implant might affect the morphology of the implant and I decided to expand my research into testing dental implants when exposed to high temperatures.

A review of the literature at that time provided no information on possible changes such as warping, sagging and oxide build up on implants following severe heat exposure. Commercially pure titanium and titanium alloy dental implants have a melting point greater than 1650˚C [6] Although the melting point of titanium metal is much greater than the reported temperatures of fires [7-9], metals may sag (creep) at a much lower temperature than their melting point. Sagging in metals occurs when T > 0.3–0.4TM for metals where T is the temperature and TM is the melting temperature in degrees Celsius minus 272.15 [6]. It was important to test implants to ascertain if the sagging might be of such magnitude that the individual features of the implants would no longer be recognisable radiographically. In a controlled laboratory study, implants from the most popular brands were radiographed in predetermined position, heated in a porcelain furnace to 1125°C and changes documented[10]. Utilising Photoshop® CSV2 (Adobe® San Jose, USA), an image subtraction technique showed that there was a slight increase in size due to the build-up of an oxide crust yet the individual features of grooves and threads were still recognisable.

An unusual finding of this study was the gold-like colouring of the commercially pure implants compared to the 3i™ titanium implant which remained a grey colouring. I decided to analyse the crust layers of the heated implants to determine what was in the oxide layers. Scanning Electron Microscopy and Energy Dispersive X-ray Analysis (SEM/EDAX) revealed that the gold colouring observed was pure titanium and oxygen, yet the grey oxide layer seen on the 3i™ implants contained titanium, aluminium and oxygen with no vanadium detected [(10)].

During my research with implants and contact with company executives I was informed that the Straumann™ company (Basel, Switzerland) had begun to place batch numbers within the chambers of their dental implants. Matching the batch numbers to the notes of the surgeons would increase the weight of evidence linking the identification of that victim. The number of Straumann™ implants with the same batch number varies from 24 to 2400 [(11)] and although this needs to be taken into the context of world distribution, ideally companies producing implants etch an individual serial number within each implant.

It became apparent that when the Straumann™ implants were incinerated, the oxide layer obscured the batch number and that various chemical treatments to remove the oxide layer to reveal the batch number was unsuccessful. However, dental implants usually have a healing screw or an abutment sealing the chamber. When an abutment was attached before incineration to 1125˚C, the lack of oxygen within the chamber restricted the oxidation so that the numbers could be read when the abutment was removed. Following the laboratory research, I decided to test the effect of incineration of implants in an animal study. Ideally it would have been beneficial to place implants within live sheep, wait three months for osseointegration, then conduct the study. However, due to the high cost and animal ethics considerations, it was decided to test implants initially within mandibles of adult sheep sourced from the abattoir.

As in the previous study [11] radiographic images of the implants taken before the firings were compared to the images taken after the firings utilising the computer software Adobe® Photoshop® CS. SEM/EDAX was again utilised for analysis. Results obtained indicated that the batch number within the Straumann™ implant was again still clearly visible whilst elemental analysis detected bone elements, serum salts as well as titanium. Of significance compared to the earlier research was that the pure titanium implants did not exhibit the gold or straw colour but a grey appearance. This led me to studying the various oxide layers on metallic implants together with advice from Professor Valerie Linton from the Mechanical Engineering Department of the University of Adelaide and Simon Cox a professional forensic fire investigator. It became clear that if oxygen availability is limited then the excessive oxide layers seen in the gold colouring would not be present. This limited pilot study was promising but the next logical step would be to examine dental implants that have been osseointegrated in human bone. What would be the effect of human tissue being burnt on these implants, what colour changes would be observed? What dimensional changes would occur? Do the recovered implant dimensions correspond to the stated manufacturer's size parameters? Would it be possible in a blind study to identify an individual from just implants and its burnt superstructure? These questions needed to be answered to increase the knowledge of incinerated implants.

Due to strict human ethics restrictions and lack of facilities such as a body farm, it took time to plan and satisfy the university's authorities to receive permission to conduct the next logical step in my study of dental implants. It was not until the end of the following year when I could utilise the bodies donated for dissection anatomy tuition for examination and ultimately find a suitable cadaver for human osseointegration study. This study can be read in the following manuscript.

4.2a References

1. Kohal RJ, Weng D, Bächle M, Strub JR. Loaded custom-made zirconia and titanium implants show similar osseointegration: An animal experiment. Journal of periodontology. 2004;75:1262-8.

2. Sennerby L, Dasmah A, Larsson B, Iverhed M. Bone tissue responses to surface-modified zirconia implants: A histomorphometric and removal torque study in the rabbit. Clinical implant dentistry and related research. 2005;7:13-20.

3. Gaviria L, Salcido JP, Guda T, Ong JL. Current trends in dental implants. Journal of the Korean Association of Oral and Maxillofacial Surgeons. 2014;40(2):50-60.

4. Berketa JW. Implant recognition as an aid to identifying the deceased. In: Adelaide Uo. Forensic Odontology Unit collection. Adelaide2007. p. 1-135.

5. Berketa JW, Hirsch RS, Higgins D, James H. Radiographic recognition of dental implants as an aid to identifying the deceased. Journal of forensic sciences. 2010;55(1):66-70. DOI: 10.1111/j.1556-4029.2009.01226.x.

6. Ashby MF, Jones DRH. Engineering Materials. An Introduction to Their Properties and Applications. First, ed. Oxford: Pergamon; 1980.

7. DeHaan JD. Kirks fire investigation. 5th ed. Upper Saddle River: Brady; 2002.

8. Lilly DG. Temperature measurements in a small house fire. Paper presented at: Energy Conversion Engineering Conference; 1996.

9. Kahn SA, Patel JH, Lentz CW, Bell DE. Firefighter burn injuries: predictable patterns influenced by turnout gear. Journal of burn care and research. 2012;33(1):152-6.

10. Berketa JW, James H, Marino V. Dental implant changes following incineration. Forensic science international. 2011;207(1-3):50-4. DOI: 10.1016/j.forsciint.2010.08.025.

11. Berketa JW, James H, Marino V. Survival of batch numbers within dental implants following incineration as an aid to identification. Journal of forensic odonto-stomatology. 2010;28(1):1-4.

4.3 Manuscript

Published as: Berketa, J.W. James, H. Langlois, N.E.I. Richards, L.C. A study of osseointegrated dental implants following cremation. Australian Dental Journal. (2014) 59:(2) 149-55.

Statement of Authorship

Title of Paper	A study of osseointegrated dental implants following cremation.
Publication Status	⦿ Published, O Accepted for Publication, O Submitted for Publication, O Publication style
Publication Details	Berketa J. W. , James H., Langlois N.E. I. & Richards L. C. (2014). A study of osseointegrated dental implants following cremation. Australian Dental Journal, 59(2), 149-55.

Author Contributions

By signing the Statement of Authorship, each author certifies that their stated contribution to the publication is accurate and that permission is granted for the publication to be included in the candidate's thesis.

Name of Principal Author (Candidate)	John Berketa		
Contribution to the Paper	Designed, synchronized study, interpreted data, wrote manuscript and acted as corresponding author		
Signature		Date	8 .04. 2015

Name of Co-Author	Helen James		
Contribution to the Paper	Supervised work and manuscript evaluation.		
Signature		Date	8 04 · 2015

Name of Co-Author	Neil Langlois		
Contribution to the Paper	Supervised work and manuscript evaluation.		
Signature		Date	8^ April 2015

Name of Co-Author	Lindsay Richards		
Contribution to the Paper	Supervised work, ethics application assistance and manuscript evaluation.		
Signature		Date	08 04 2015

Berketa, J.W. James, H. Langlois, N.E.I. Richards, L.C. (2014) A study of osseointegrated dental implants following cremation. *Australian Dental Journal*, 59(2), 149-55.

NOTE: This publication is included in the print copy of the thesis held in the University of Adelaide Library.

It is also available online to authorised users at:

https://doi.org/10.1111/adj.12170

Chapter 5

Gold analysis

5.1 Introduction

During my scanning electron microscopy (SEM) elemental analysis (EDAX) of the superstructures in the previous chapter to ascertain if the framework was either a titanium or gold alloy superstructure, I was curious to investigate the actual gold content. If a gold crown had melted in a severe incineration, the elements of the alloy should still be present. I considered two research questions. Firstly, if a particular laboratory only used a specific dental alloy or if the period of time during which given alloys were available was known, this could assist in tracking the identity of an incinerated individual where no circumstantial evidence is available to hint at who the victim might be? Secondly, if antemortem records are available could the alloy analysis be used to confirm the identity against laboratory records where, due to the ferocity of the fire, there is very little other postmortem evidence available? A similar study by Bush et al. investigated the recognition of composite resins (1) and in cremated individuals using a portable X-ray fluorescence (XRF) unit (2) as they predicted that the ability to distinguish resin brands could aid in positive identification of burn victims. Similarly, Aboshi et al. evaluated porcelain crowns by wave dispersive X-ray microanalyser (EDX). Their preliminary study showed that surface analysis by EDX may have great potential for identifying the composition, and thereby the manufacturers of dental porcelain, which in turn may assist dental identification (3).

Following discussions with my supervisors it was decided to conduct elemental analyses of gold crowns that required recementing from patients in Adelaide as a sample base. This chapter describes my study, the lack of success in matching the alloy contents to the published manufacturers contents and reasons for the limitations in this study.

5.1a References

1. Bush MA, Bush PJ, Miller RG. Detection and classification of composite resins in incinerated teeth for forensic purposes. Journal of forensic sciences. 2006;51(3):636-42. DOI: 10.1111/j.1556-4029.2006.00121.x.

2. Bush MA, Miller RG, Prutsman-Pfeiffer J, Bush PJ. Identification through X-ray fluorescence analysis of dental restorative resin materials: a comprehensive study of noncremated, cremated, and processed-cremated individuals. Journal of forensic sciences. 2007;52(1):157-65. DOI: 10.1111/j.1556-4029.2006.00308.x.

3. Aboshi H, Takahashi T, Komuro T. Component analysis of dental porcelain for assisting dental identification. Journal of forensic odonto-stomatology. 2006;24(2):36-41.

5.2 Manuscript

Prepared as a draft for publishing

All that glitters is not gold

Introduction

Following severe incineration of a victim of a fire, the destruction of tissues may lead to the need to utilise information not normally investigated. Postmortem information collected may include dental gold alloy restorations, whether intact or in a deformed state. In 1973, Rotzsher et al. suggested that analysis of dental alloy may narrow choices to help establish the identity of a victim. They further proposed that manufactures add one or two tracer elements to signature their product [1]. The short half-life of suggested tracer elements and cost involved prohibit this as a reasonable suggestion. However, the proliferation of many dental alloy companies and products today provides differential diagnostic possibilities. If a particular laboratory only used a specific dental alloy this could assist in tracking the identity of an individual. Bush et al. have previously investigated the recognition of composite resins [2] and in cremated individuals using a portable X-ray fluorescence (XRF) unit [3] and Aboshi et al. have evaluated porcelain crowns by wave dispersive X-ray microanalyser (EDX) [4]. In a homicide case in Japan, a comparative analysis of porcelain found at the scene and porcelain removed from the suspect's abutment tooth, was analysed by scanning electron microscopy (SEM) and electron probe X-ray microanalysis (EPMA) with the elemental composition of each sample said to be identical [5].

The aim of this study was to conduct elemental analyses of gold alloys from patients and to compare the analyses against provided information from dental alloy companies to see if matches could be made.

Methods

Scanning electron microscope (SEM) aluminum alloy mounts with carbon conductive tabs within a single mounted storage tube (Figure 1) were utilised to collected gold alloy dust from gold coloured crowns that have been dislodged from patients. A diamond encrusted flat fissure bur was utilized within a high speed handpiece to obtain the gold dust specimens to limit metal contamination.

Samples were analysed utilizing a XL30 FEGSEM (Phillips, Amsterdam, The Netherlands) with EDAX EDS. Images with an example seen in Fig. 2 were obtained at 2500x in backscatter electron imaging (BSE) mode using a 20kV beam and elemental analysis was for 20 seconds at spot size 3.

An internet search on the web was performed to source information regarding the content of dental alloys from major dental alloy suppliers to dental technicians. Elephant Dental Alloys [(6)] and Aurident Inc. [(7)] provided charts for comparison. Dale Dental Company [(8)] and Argen Dental [(9)] provided search engines for comparison. Results were rounded to the nearest percent, and a plus one and minus one degree of error was accepted. Discussions with dental technicians in regard to techniques and alloys used were also documented.

Results

The results of the analyses of the alloys are tabulated in Table 1.

Elements are listed in the first row, with the percentages listed below.

Au	**Ag**	**Cu**	**Pd**	**In**	**Ti**	**C**	**O**	**Ga**	**N**	**Cr**	**Sr**
11.2	14.94	6	40.92	26.94							
12.03	21.46	10.73	33.1	22.68							
16.03	27.35	7.04	23.36	16.23		9.98					
23.98	31.25	11.47	18.93	14.37							
25.98	62.57	11.45									
28.74	56.01	7.79				7.46					
28.89	64.06	7.05									
58.75	5.12	15.65	9.75			10.72					
59.35			27.79			11.17		1.69			
62.09	8	14.58				15.33					
62.33	9.64	11.92	16.11								
63.01	18.12	9.99				5.99			2.89		
66.84	6.93	6.77			19.46						
68.9	9.09	16.56	4.23							1.23	
69.29	6.94	15.39				8.38					
69.99	10.9	19.11									
70.9	13.97	15.13									
71.59	10.7	17.71									
71.9	10.52	11.71	5.86								
72.11	7.96	13.36				6.57					
72.66	13.64	13.7									

73.25		12.29				14.17				
73.85	17.58	8.57								
75.02	12.24	12.74								
77.15	6.55	4.92				9.32	1.37			
77.4	12.21	7.53								2.86
77.8	12.71	9.49								
78.29	8.44	7.48	5.79							
78.38	11.8	9.82								
80.51	9.27	5.66	4.56							
82.83	9.28	5.03					2.86			
90.09	9.86				0.05					
91.81						8.18				
95.48	3.53	0.99								

Comparison with the internet charts and search engines of the dental alloy providers yielded only two possible matches with samples 26 and 27. Both could be Argen DAPcast 77 or Argen LWO77 or Aurident AM dental alloy.

Discussion

A more accurate measurement would be possible utilizing electron probe analysis [174] although sample preparation would be more difficult and require preparation in the form of a polished block. The failure to produce only two matches from a sample base of 33 samples suggest either possible overheating of the alloys during original crown production, creating a inhomogeneous mix, or that a broader sample base may be required. Multiple testing of different sites and samples with an average range would reflect a more accurate result and testing by an expert in the field of metallurgy is also recommended. Also the habit amongst technicians to re-utilize old sprues and buttons from previous castings to minimize costs creates mixing, which could add different compositions of elements to the final alloy casting.

With the advent of globalization and faster courier services, no longer would it be logical to assume that a local technician cast the alloy under investigation as it might have been cast interstate or even overseas thereby making it difficult to track the dental technician.

The American Dental Association requires that alloys classified as high-gold content must have at least 40% gold by weight and at least 60% noble metal content. In England and Scotland the National Health Service regulations specify the alloys that may be used in cast restorations in dentistry and the use of non-precious alloys is only permissible in full-coverage restorations and resin-retained bridges (11). The policing of the regulations may prove a difficult and expensive exercise and of note is that the Australian Dental Association does not specify a full "gold " crown as item 618 in their schedule but simply define the item as a full metal crown (12).

Recently, IdentAlloy® (Glastonbury, CT, USA), provides dentists and laboratories with a way to verify and record the content of the restoration materials they select. Laboratories obtain certificates from participating manufacturers and suppliers and they include the appropriate certificate with each case sent to dentists. Materials manufacturers and suppliers qualify for the program once they agree to conform to rigid requirements for compliance with material specifications. This makes the certificates invaluable not only for labs and dentists but also for forensic investigations. In 2013, 20.7 million certificates were issued, and if this trend of verification increases and adopted world wide, with appropriate regular auditing reviews of the certification processes, the investigation into the type of alloy recovered postmortem would be justified.

There have been references in the literature regarding the melting point of gold alloys suggesting the temperature that a fire event occurred [13, 14]. The broad range of gold and other elements within modern alloys suggests that this subjective assessment may no longer be valid unless an extremely thorough assessment and testing by a specialist metallurgist of the alloy is conducted.

Conclusion

The proposition that gold alloy discovered postmortem may lead to the laboratory source and hence a dentist should not be assumed.

Acknowledgements

Ken Neubauer Adelaide Microscopy

Fig. 1 Scanning electron microscope aluminum alloy mount with carbon conductive tab within a single mounted storage tube

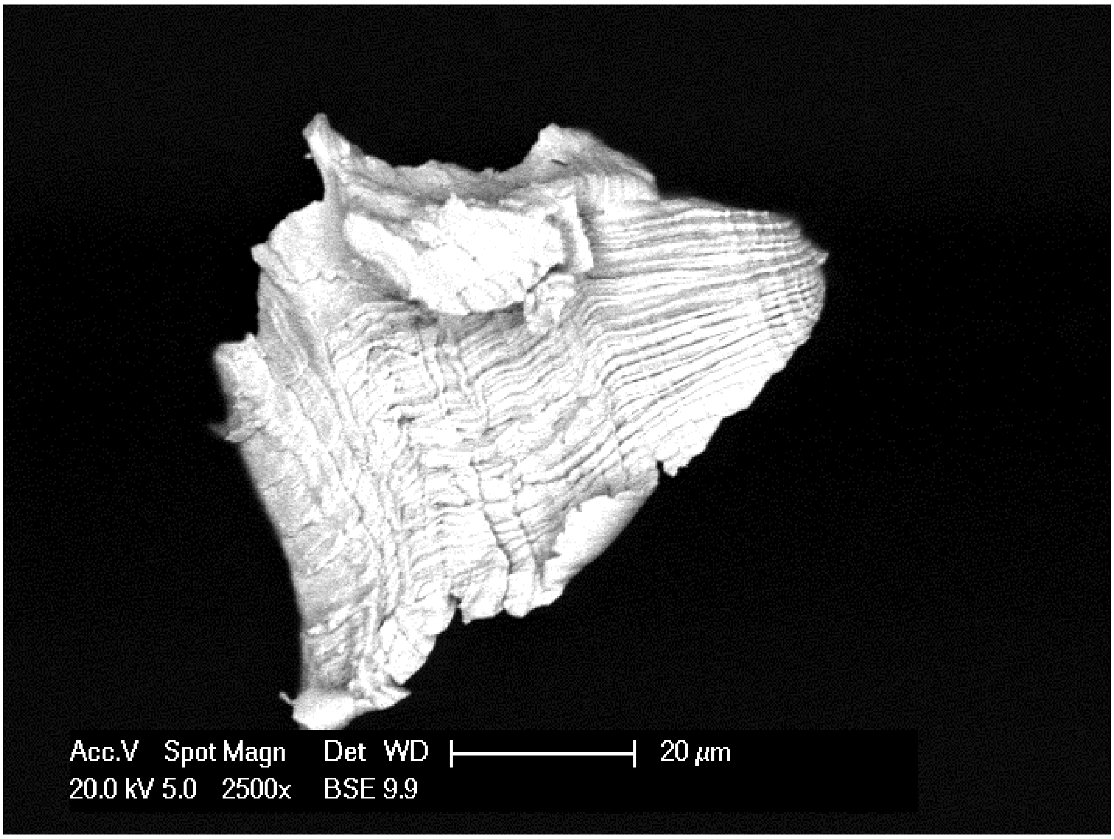

Fig. 2 Image of gold alloy dust particle

References

1. Rötzscher K, Mende S, Flachowsky J, Geisler M, Wehran H-J. Neutron activation analysis of dental metals with regard to forensic odontology Journal of radioanalytical and nuclear chemistry. 2007;15(1):317-28.

2. Bush MA, Bush PJ, Miller RG. Detection and classification of composite resins in incinerated teeth for forensic purposes. Journal of forensic sciences. 2006(3):636-42. DOI: 10.1111/j.1556-4029.2006.00121.x.

3. Bush MA, Miller RG, Prutsman-Pfeiffer J, Bush PJ. Identification through X-ray fluorescence analysis of dental restorative resin materials: a comprehensive study of noncremated, cremated, and processed-cremated individuals. Journal of forensic sciences. 2007;52(1):157-65. DOI: 10.1111/j.1556-4029.2006.00308.x.

4. Aboshi H, Takahashi T, Komuro T. Component analysis of dental porcelain for assisting dental identification. Journal of forensic odonto-stomatology. 2006;24(2):36-41.

5. Suzuki K, Hanaoka Y, Minaguchi K, Inoue M, Suzuki H. [Positive identification of dental porcelain in a case of murder]. Nihon hoigaku zasshi= The Japanese journal of legal medicine. 1991;45(4):330-40.

6. Elephant dental technical data. 2014. Available from: http://www.elephant-dental.nl/uploads/BR_E_Alloys%20-%20Technical%20Data.pdf

7. Aurident Inc. 2014. Available from: http://www.aurident.com/casting-golds

8. Dale dental alloys. 2014. Available from: http://portal.daledental.com/public/alloys/default.asp?search=1

9. Christensen AM. Testing the reliability of frontal sinuses in positive identification. Journal of forensic sciences. 2005;50(1):18-22.

10. Reed SJB. Electron microprobe analysis. 2nd ed. Cambridge: Cambridge University; 1975.

11. Beddis HP, Ridsdale L, Chin JS, Nixon PJ. An audit of the quality of base metal cast restorations provided within the restorative department of a UK dental institute. British dental journal. 2014;217(E11). DOI: 10.1038/sj.bdj.2014.855.

12. Association AD. The Australian Schedule of Dental Services and Glossary Tenth Edition. 2013. Available from: http://www.ada.org.au/app_cmslib/media/lib/1303/m538110_v1_10th%20edition%20schedule%20and%20glossary_web.pdf

13. Senn DR, Weems RA. Manual of forensic odontology. 5th ed. Boca Raton: CRC Press; 2013.

14. Botha CT. The dental identification of fire victims. Journal of forensic odonto-stomatology. 1986 Dec;4(2):67-75.

Chapter 6

Cochlear implants in the forensic identification process

6.1 Introduction

When scene officers attend an incineration event and recover an incinerated victim, it is advisable to also gather the material around the head [1, 2]. Valuable postmortem information such as loose crowns, roots, dental implants, and restorative structures may fall through the ashes and be lost to the identification process unless it is collected at the scene. Forensic odontologists or scene officers collecting this debris might locate a cochlear implant.

Cochlear implants are metallic or ceramic cases containing electronic hardware to stimulate sound to the cochlear in deaf people. They are attached to the outside of the cranium around the mastoid process and could easily detach once the overlying skin has been vaporised by fire. The appearance of a burnt rectangular or circular object with wires attached may be misinterpreted as a piece of jewellery or hardware structure.

Although becoming popular, no literature had been published regarding the use of cochlear implants for identification, yet the postmortem information provided by a cochlear implant could prove to be significant. I was interested to compare what changes occurred in these implants compared to dental implants and whether serial numbers would be readable following cremation due to the charring and oxidisation. As the cochlear implants are expensive and the intellectual property is well guarded, the companies were reluctant to physically pass on any implants. Fortunately I was able to get four implants cremated by the companies and supervised the image taking. The results are presented in the following published paper.

6.1a References

1. Hill AJ, Lain R, Hewson I. Preservation of dental evidence following exposure to high temperatures. Forensic science international. 2011 Feb 25;205(1-3):40-3. DOI: 10.1016/j.forsciint.2010.08.011.

2. Bowers CM. Forensic dental evidence. First ed. Amsterdam: Elsevier Academic Press; 2004.

6.2 Manuscript

Published as: Berketa, J. James, H. Langlois, N. Richards, L. Cochlear implants in the forensic identification process. *Forensic Science Medicine Pathology.* (2013) 9:(3) 422-26.

Statement of Authorship

Title of Paper	Cochlear implants in the forensic identification process
Publication Status	⦿ Published, O Accepted for Publication, O Submitted for Publication, O Publication style
Publication Details	Berketa J. W. , James H., Langlois N.E. I. & Richards L. C. (2013). Cochlear implants in the forensic identification process. Forensic Sci Med Pathol 9:422–426

Author Contributions

By signing the Statement of Authorship, each author certifies that their stated contribution to the publication is accurate and that permission is granted for the publication to be included in the candidate's thesis.

Name of Principal Author (Candidate)	John Berketa		
Contribution to the Paper	Designed, synchronized study, interpreted data, wrote manuscript and acted as corresponding author		
Signature		Date	8 04.2015

Name of Co-Author	Helen James		
Contribution to the Paper	Supervised work and manuscript evaluation.		
Signature		Date	8 04 15

Name of Co-Author	Neil Langlois		
Contribution to the Paper	Supervised work and manuscript evaluation.		
Signature		Date	8th April 2015

Name of Co-Author	Lindsay Richards		
Contribution to the Paper	Supervised work and manuscript evaluation.		
Signature		Date	08 04 2015

Berketa, J. James, H. Langlois, N. Richards, L. (2013) Cochlear implants in the forensic identification process. *Forensic Science, Medicine and Pathology*, 9(3), 422-426.

NOTE: This publication is included in the print copy of the thesis held in the University of Adelaide Library.

It is also available online to authorised users at:

http://dx.doi.org/10.1007/s12024-013-9439-1

Chapter 7

The utilization of incinerated hip and knee prostheses for identification

7.1 Introduction

The University of Adelaide's Forensic Odontology Unit works in unison with Dr Ellie Simpson, who is in charge of anthropological issues at the Forensic Science Centre of South Australia. To understand the roles of other forensic scientists and prepare us for collaborative teamwork during my postgraduate studies in forensic odontology I was instructed to attend the subjects of Comparative Anatomy and Applied Anatomy provided by the Medical School of the university. Whilst this training is clearly insufficient to qualify me as an expert in anthropology, the foundation knowledge and subsequent casework with Dr Simpson has broadened my knowledge in other areas of the body. Following my research of the oxide layers and inner chambers with dental and cochlear implants I was encouraged to investigate if incinerated body implants could also be used for identification.

After dental implants, knees and hips are the most common type of prostheses implanted. The Australian Orthopaedic Association National Joint Replacement Registry (AOANJRR) began in 1999. Their records until 2013 indicate that there are (in an Australian population of approximately 23 million) at least 588,000 Australians alive with either a hip or knee implant. Records also show that 29.6% of these recipients have more than one implant. The popularity of these implants is not restricted to Australia as globally they are becoming extremely popular.

Similarly to dental and cochlear implants, they have high melting points and their macroscopic features are retained following cremation yet become charred and oxidised. Also the chambers inside hip implants are similar to dental implant chambers but on a much larger scale. As in dental implants, the numbers are at the base of the chamber, the air and hence the oxygen for oxidation is limited and many implants are made from titanium.

There have been articles highlighting the use of prostheses in identification [1-7] as well as a specific book by Branovacki looking at morphological shapes of femoral implants from 1938-2008 [8], however no study has been published detailing if data numbers could be retrieved from totally charred hips or knee implants or the best materials and methods to facilitate this process. Although orthopaedic surgeons and company representatives were obviously knowledgeable of the identification numbering, the forensic community I contacted were lacking this knowledge. Importantly, if implants were investigated without prior knowledge, damage by acids or severe sectioning might negate any chance of retrieving the identification data.

Hips and knees were chosen as the medical implants to study as they are the most common prostheses implanted in Australia. I was therefore able to source sufficient osseointegrated implants to form a study from revised operations from the Royal Adelaide Hospital orthopaedic unit. These were used to study the position of the data, to conduct pilot incinerations and to test the many formulations of chemicals and physical materials to reveal the numbers. The findings from hip and knee joints implants may be able to be utilised for other medical joint implants, although further testing would be required to confirm the results.

As well as ethical issues that had to be addressed, there were complexities that required professional legal opinions. Interpretation of the Transplantation and Anatomy Act 1983, permission from the Coroners office, Births Deaths and Marriages office, crematorium and access to confidential data of the AOANJRR all had to be in place for this study to occur. A requirement imposed by the Ray Last laboratory was that they would not reveal the identity of the bodies. Therefore, a protocol had to be devised to enable testing of the use of the prosthesis identification numbers through the records of the AOANJRR. It was determined that the AOANJRR would be asked, to provide the names corresponding to batch numbers. The names were then provided to the Ray last laboratory, who indicated how many matched with their donor list.

Similarly to the dental implant research, I received permission to utilise the bodies donated for dissection anatomy, which I am grateful for, but statistical numbers were, therefore, limited. A considerable amount of trial and work included testing and critical evaluation of methods to remove oxide layers obscuring implant numbers and retrieving the identification numbers from the prostheses. This chapter presents the published paper and is a synopsis of that work.

7.1a References

1. Bennett JL, Benedix DC. Positive identification of cremains recovered from an automobile based on presence of an internal fixation device. Journal of forensic sciences. 1999;44(6):1296-8.

2. Isaacs TW, Margolius KA, Chester GH. Postmortem identification by means of a recovered intraocular lens. American journal of forensic medicine and pathology. 1997;18(4):404-5.

3. Murray LA, Caiach S. Confirmation of identity by a metallic knee prosthesis in a severely burnt body. Journal of clinical forensic medicine. 1998;5(1):8-9.

4. Simpson EK, James RA, Eitzen DA, Byard RW. Role of orthopedic implants and bone morphology in the identification of human remains. Journal of forensic sciences. 2007;52(2):442-8. DOI: 10.1111/j.1556-4029.2006.00370.x.

5. Wilson RJ, Bethard JD, DiGangi EA. The use of orthopedic surgical devices for forensic identification. Journal of forensic sciences. 2011;56(2):460-9. DOI: 10.1111/j.1556-4029.2010.01639.x.

6. Silva RH, Franco A, Mendes SDSC, Picoli FF, Marinho DEA. Human identification through the patella—Report of two cases. Forensic science international. 2014;238:e11-e4. DOI: 10.1016/j.forsciint.2014.02.025.

7. Takeshita H, Nagai T, Sagi M, Chiba S, Kanno S, Takada M, et al. Forensic identification using multiple lot numbers of an implanted device. Medicine, science, and the law. 2014;54(1):51-3. DOI: 10.1177/0025802413498860

8. Branovacki G. Ortho Atlas: Hip Arthroplasty US Femoral Implants 1938–2008 Chicago: Ortho Atlas Publishing, ; 2008.

7.2 Manuscript

Published as: Berketa, J.W. Simpson, E.Graves, S. O'Donohue,G. Liu,Y The utilization of incinerated hip and knee prostheses for identification. *Forensic Science Medicine Pathology.* (2015) 11:(3) 432-7.

Statement of Authorship

Title of Paper	The utilization of incinerated hip and knee prostheses for identification.
Publication Status	◉ Published, ○ Accepted for Publication, ○ Submitted for Publication, ○ Publication style
Publication Details	Berketa J. W. , Simpson E, Graves S., O'Donohue G. and Yen-Liang L. (2015). The utilization of incinerated hip and knee prostheses for identification. Forensic Sci Med Pathol

Author Contributions

By signing the Statement of Authorship, each author certifies that their stated contribution to the publication is accurate and that permission is granted for the publication to be included in the candidate's thesis.

Name of Principal Author (Candidate)	John Berketa		
Contribution to the Paper	Designed and coordinated study, performed analysis on samples, interpreted data, wrote manuscript and acted as corresponding author		
Signature		Date	

Name of Co-Author	Ellie Simpson		
Contribution to the Paper	Assistance with analysis on samples, provision of work space, anthropological consultant and manuscript evaluation		
Signature		Date	

Name of Co-Author	Stephen Graves		
Contribution to the Paper	Orthopaedic consultant and manuscript evaluation.		
Signature		Date	30/3/15

Name of Co-Author	Grace O'Donohue		
Contribution to the Paper	Statistical analysis of registry data and manuscript evaluation.		
Signature		Date	2/4/15

Name of Co-Author	Liu Yen-Liang		
Contribution to the Paper	Statistical analysis of registry data and manuscript evaluation.		
Signature		Date	2/4/15

Berketa, J.W., Simpson, E., Graves, S., O'Donohue,G. & Liu,Y. (2015). The utilization of incinerated hip and knee prostheses for identification. *Forensic Science Medicine Pathology, 11*(3), 432-437.

NOTE: This publication is included in the print copy of the thesis held in the University of Adelaide Library.

It is also available online to authorised users at:

http://dx.doi.org/10.1007/s12024-015-9677-5

Chapter 8

The use of incinerated pigs heads in dental identification simulation

8.1 Introduction

To maximise postmortem information, it is vital to create and maintain an appropriate protocol and quality control, with the enforcement of that protocol through Standard Operating Procedures [(1)].

Although all types of casework in forensic odontology are demanding, incineration cases offer the most challenges in examination of extremely fragile remains. A mistake in procedure can result in damage to teeth and irretrievable loss of data prior to documentation. Literature recommends photography and radiography prior to charting; a reversal of the usual order of examination due to the need to visually document, and cautions of the fragility of the tissues [(2-7)]. There is, however, no substitute for practical experience in examination of incinerated remains.

During my candidature I devised and supervised a training exercise designed to simulate a disaster where victims were severely incinerated to prepare for such events. Handling and processing severely incinerated heads identifies flaws, weaknesses, and adds the “do one” in the “see one, do one, teach one” approach to improve skills[(8)]. Criteria considered when developing this resource module were: ethical issues, ease of preparation and cost. Religious sensitivities of foreign odontologists and students might also be a factor in choosing animal heads for training.

Ethical restrictions on human tissues for training necessitate the use of animal heads for cremation and subsequent examination. Pigs (*Sus Scrofa*) heads are usually readily available, do not necessitate the sacrifice of an animal if sourced from an abattoir, are inexpensive and similar in size to human heads. They are an omnivore rather than herbivore and the enamel and dentine from swine and human teeth share structural similarities [(9)]. Pigs' heads would seem to be an ideal animal model for such a training exercise but produced unexpected results. This study has been accepted for publication and can be read in this chapter.

8.1a References

1. Lake AW, James H, Berketa JW. Disaster victim identification: quality management from an odontology perspective. Forensic science, medicine, and pathology. 2012;8(2):157-63. DOI: 10.1007/s12024-011-9286-x.

2. Bowers CM. Forensic dental evidence. First ed. Amsterdam: Elsevier Academic Press; 2004.

3. James H, Taylor J. Australasian and multinational disaster victim identification. 2nd ed. Bowers CM, editor. Burlington: Academic Press; 2011.

4. Fairgrieve SI. Forensic Cremation: Recovery and Analysis. Boca Raton: CRC Press; 2007.

5. Griffiths CJ, Bellamy GD. Protection and radiography of heat affected teeth. Forensic science international. 1993;60(1-2):57-60.

6. Delattre VF. Burned beyond recognition: systematic approach to the dental identification of charred human remains. Journal of forensic sciences. 2000;45(3):589-96.

7. Senn DR, Weems RA. Manual of forensic odontology. Manual of forensic odontology. 5th ed. Boca Raton: CRC Press; 2013.

8. Coughlin CN. See one, do one, teach one: Dissecting the use of medical education's signature pedagogy in the law school curriculum. Georgia State University Law Review. 2009;26(2):Article 4.

9. Lopes FM, Markarian RA, Sendyk CL, Duarte CP, Arana-Chavez VE. Swine teeth as potential substitutes for in vitro studies in tooth adhesion: a SEM observation. Archives of oral biology. 2006;51(7):548-51. DOI: 10.1016/j.archoralbio.2006.01.009.

8.2 Manuscript

Proof edited for publication as: Berketa, J.W. James, H. Langlois, N.E.I. Richards, L.C. The use of incinerated pigs heads in dental identification simulation. *Journal of Forensic Odonto-Stomatology*. November 2015

Statement of Authorship

Title of Paper	**The use of incinerated pig heads in dental identification simulation**
Publication Status	☐ Published ☒ Accepted for Publication ☐ Submitted for Publication ☐ Unpublished and Unsubmitted work written in manuscript style
Publication Details	**John Berketa, Helen James, Neil Langlois, Lindsay Richards. Journal of Forensic Odonto – Stomatology.**

Principal Author

Name of Principal Author (Candidate)	**John Berketa**		
Contribution to the Paper	**Designed, collected samples, supervised incinerations and examinations, interpreted data, wrote manuscript and acted as corresponding author.**		
Overall percentage (%)	**90**		
Certification:	**This paper reports on original research I conducted during the period of my Higher Degree by Research candidature and is not subject to any obligations or contractual agreements with a third party that would constrain its inclusion in this thesis. I am the primary author of this paper.**		
Signature		**Date**	15/9/15

Co-Author Contributions

By signing the Statement of Authorship, each author certifies that:

the candidate's stated contribution to the publication is accurate (as detailed above);

permission is granted for the candidate in include the publication in the thesis; and

the sum of all co-author contributions is equal to 100% less the candidate's stated contribution.

Name of Co-Author	**Helen James**		
Contribution to the Paper	**Supervised work and manuscript evaluation**		
Signature		**Date**	18.09.15

Name of Co-Author	Neil Langlois		
Contribution to the Paper	Supervised work and manuscript evaluation		
Signature		Date	15th Sep 2015

Please cut and paste additional co-author panels here as required.

Name of Co-Author	Lindsay Richards		
Contribution to the Paper	Supervised work and manuscript evaluation		
Signature		Date	15 09 15


I-O-F-O-S

JOURNAL of FORENSIC ODONTO-STOMATOLOGY

VOLUME 33 Number 2 July 2015

SECTION IDENTIFICATION

The Use of Incinerated Pig Head in Dental Identification Simulation

John Berketa[1], Helen James[1], Neil Langlois[1], Lindsay Richards[1]

[1]University of Adelaide, Adelaide, Australia

Corresponding author: johnberketa@hotmail.com

The authors declare that they have no conflict of interest.

ABSTRACT

Purpose: The aim of this exercise was to simulate a disaster victim identification scenario to allow training in documentation of postmortem incinerated remains and reconciliation of dental data.

Method: Varying number of restorations were placed in ten pig heads. The teeth and restorations were charted, with the restorations radiographed and documented, creating an ante-mortem data set. The following day the heads were cremated. Following cooling and recording they were transported for a post-mortem examination by trained specialist odontologists who were not involved in the initial antemortem phase. Recordings included the charting of teeth, restorations, lost teeth, and radiographs to simulate a post-mortem examination. A reconciliation of postmortem to antemortem information was attempted.

Results: There was an unacceptable amount of error in the postmortem examination of the heads. The errors related mainly to avulsed teeth and incorrect opinion of which charted surfaces the restorations were placed upon. Also noted were a considerable number of root fractures occurring beneath the crestal bone. This observation does not mimic the evidence observed in human incinerated teeth where the crowns tend to fracture off the roots at the dentin-enamel junction.

Conclusion: The use of incinerated pig (Sus Scrofa) heads is not an ideal model for forensic odontology training in disaster victim identification. Differences in both anatomy and behavior following exposure to heat were shown to hamper documentation and subsequent comparison to antemortem data.

***KEYWORDS*:** Forensic odontology, identification, incineration, pig heads, stabilization.

INTRODUCTION

The identification of deceased victims is required for legal and ethical reasons. [1] The process of identification in a severe fire event may be extremely difficult and prolonged due to damage or destruction of physical evidence such as clothing, documents, tattoos, fingerprints, and hair; [2] furthermore DNA may be unobtainable [3] As the dental structures are the most resilient structures of the body [4, 5] they are commonly utilized as the identifying method of choice in severely incinerated cases. However, the loss of water and organic component causes shrinkage and cracking of the teeth and supporting bone [6, 7] consequently any minor force can fracture the brittle teeth and bones or cause teeth to be dislodged. This causes disruption of bony features and loss of the anatomical location of teeth. [8-10] This loss of postmortem evidence leads to examination problems with regards to comparison of antemortem and postmortem data with subsequent delays to the reconciliation (formal identification) phase of the investigation. [11] These delays create frustration and anger for relatives and friends of the victims as sometimes months may pass before the authorities have sufficient information to release the remains.[12] Therefore it is vital to maximize the postmortem information by creating an appropriate pre-disaster protocol and quality control, with the enforcement of that protocol through training and maintaining Standard Operating Procedures. [13] Much of the success of any identification operation can be attributed to pre-planning, a sound response plan and training. [14-16] Areas of training specifically related to incinerated remains include the use of stabilization sprays of remains before movement, wrapping and protection of the heads before transportation, handling, documentation and radiography.

The aim of this exercise was to simulate a disaster victim identification scenario to allow training in documentation of postmortem incinerated remains and reconciliation of dental data. For this purpose pig (*Sus Scrofa*) heads were considered for a training exercise involving incinerated tissues. They are readily available, inexpensive and similar in size to human heads. As they are an omnivore rather than herbivore, the enamel and dentine from swine and human teeth share structural similarities, [17] although there is a greater stiffness and high fracture resistance of human cusps. [18] Figure 1 displays the anterior teeth of a juvenile *Sus Scrofa*.

A previous study has shown that the oral maxillofacial region of miniature pigs is similar to that of humans in anatomy, development, physiology, and disease occurrence. [19] As the heads were to be incinerated, previous research has noted that the burning of lean pig's tissue is comparable to burning of human remains. [20]

MATERIALS AND METHODS

Animal ethical approval was granted by the University of Adelaide for the study to take place, using pig heads sourced from a local abattoir.

Ten heads were transported from the abattoir to a non-clinical laboratory. Utilizing disposable hand pieces and burs, varying numbers of restorations were placed in each head. The teeth and restorations were charted, with the restorations radiographed and documented, creating an antemortem data set.

The following day the heads were placed in an animal crematorium furnace. Within the furnace, each head was placed on a separate ceramic tile and cremated for 4 hours. Following cooling, the tiles were taken carefully out of the furnace. Each tile (with the head upon them) was carefully placed in a separate clear plastic bag and then into a body bag with bubble wrap. The body bag was transported for a trip of approximately 50 miles for a postmortem examination by trained specialist odontologists who were not involved in the initial antemortem phase. Recordings included the charting of teeth, restorations, lost teeth, and radiographs to simulate postmortem examination. Anatomical bone structure damage and the subjective ease of examination and radiograph taking were noted. Results were tabulated to correspond with the antemortem information for comparison and a reconciliation of postmortem to antemortem information was attempted.

Fig. 1: Image of anterior teeth of juvenile *Sus Scrofa* demonstrating the anatomical circular form of the lower incisors.

RESULTS

The results of the postmortem condition of the teeth are shown in Table 1 with damage sustained due to the incineration and travelling processes.

Table 1. The results of the postmortem condition of the teeth

Pig head no.	Lost in transport	Fractured crowns	Fractured roots	Tooth displaced
1	0	0	3	1
2	0	2	4	0
3	0	3	4	1
4	2	2	3	0
5	0	1	3	1
6	0	5	3	1
7	0	3	2	0
8	0	0	7	0
9	0	3	1	1
10	0	3	6	0

All the restorations remained in place. However, despite care having been taken over the transportation process, two teeth (both from case 4) were lost between incineration and examination. Eight of the heads displayed at least one fractured crown; all had fractured roots and loosening resulting in displacement from their sockets of teeth in 5 of the 10 heads. This proved to be a problem with regards to the anterior teeth as their circular morphology meant they could not be correctly orientated when placed back in the jaw. Table 2 tabulates the postmortem examination findings that could affect the reconciliation processes.

Table 2. Tabulation of postmortem examination findings

Pig head no.	Incorrect nomenclature	Missed restorations
1	0	4
2	2	1
3	0	0
4	1	2
5	3	1
6	2	0
7	1	1
8	0	0
9	3	1
10	2	1

DISCUSSION

Several difficulties were noted during this study. During the placement of the restorations in the antemortem phase rigor mortis occurred quickly. The size of the masseter and temporalis muscles of *Sus Scrofa* mean maxilla and mandible are soon difficult to separate. To overcome this it is suggested that soon after the slaughter of the animal the jaws are wedged apart to maintain easy access for the placement of restorations and the wedge subsequently removed to allow closure of the jaws before incineration. There were also difficulties in radiographing the teeth, due to a mismatch between the width of the pigs' jaws and the width of the digital sensor, resulting in elongation of the digital images.

In retrospect it was noted that the incineration had not been ideal. There had been uneven incineration of the heads due to their positioning relative to the to the heat inlet portals and the ceramic tiles on which the heads had been placed for easy extraction fractured due to heat. These issues could be resolved by better placement of the heads and use of metal trays.

Of note was a considerable number of root fractures occurring beneath the crestal bone with an example seen in Fig. 2.

Fig. 2: Postmortem radiograph demonstrating root fractures beneath the crestal bone.

This observation does not mimic the position of fractures observed in human incinerated teeth where the crowns tend to fracture off the roots at the dentin-enamel junction, an example of which is shown in Fig. 3.

There was a significant error rate in the postmortem examination of the heads. The errors related mainly to dislodged teeth and subsequent incorrect opinion of which charted surfaces the restorations were placed upon. This can be explained by the fact that the pig's lower anterior teeth have a circular morphology and it is difficult to orientate the displaced teeth correctly for charting, irradiating or replacing them into their sockets correctly. An example can be seen in Fig. 4 to Fig. 6.

Fig. 4 is the antemortem radiograph of the lower anterior teeth and of note is that the lower *left* lateral has two restorations with one of them clearly positioned on the distal surface. Fig. 5 has the postmortem radiograph of the 42 to 31 teeth showing correct orientation, however Fig. 6 (the radiographic image of tooth 32 incorrectly orientated) displays a mesially placed restoration but no distal restoration.

This lack of restoration on the distal surface would exclude a match. Due to the fractured crowns and teeth displaced, seven out of the total ten heads had at least one nomenclature discrepancy. These errors would be unacceptable in a real-life situation, and would adversely affect the

Fig. 3: An example of incineration induced fractures at or above the crestal bone height in a human.

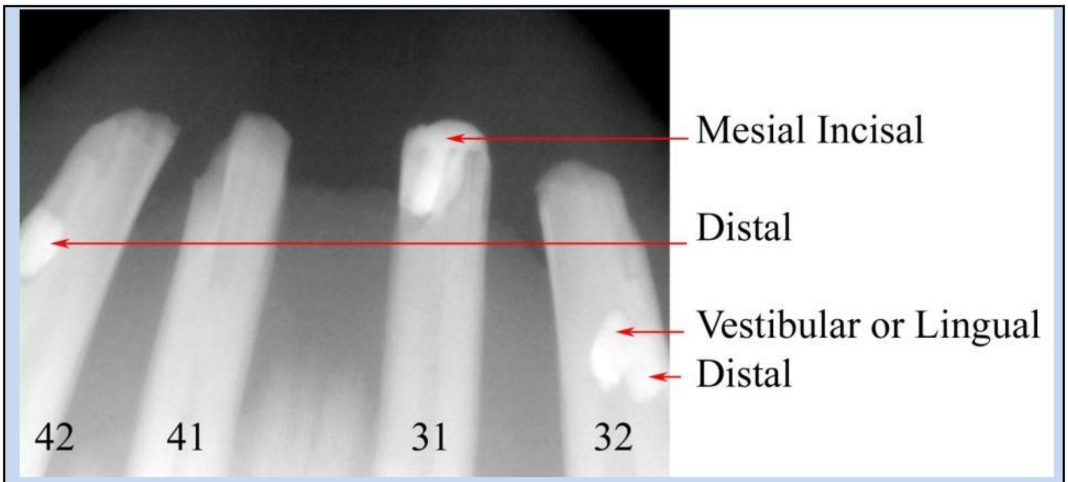

Fig. 4: Antemortem radiograph of 31, 32, 41 and 42 teeth showing four restorations including a distal restoration on the 42 tooth.

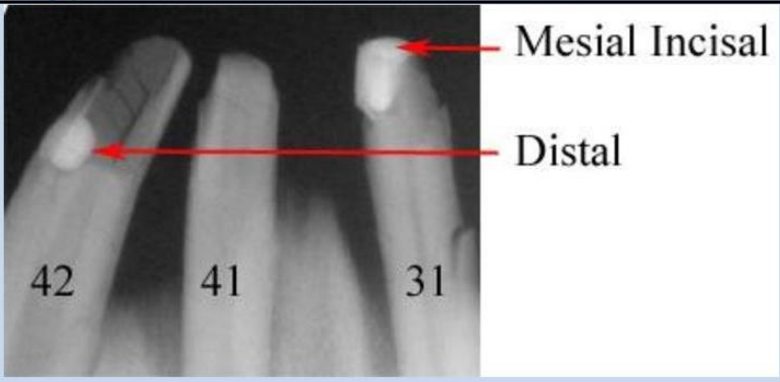

Fig. 5: Postmortem radiographs of the same area as Fig. 5 with the 31, 41 and 42 teeth correctly orientated.

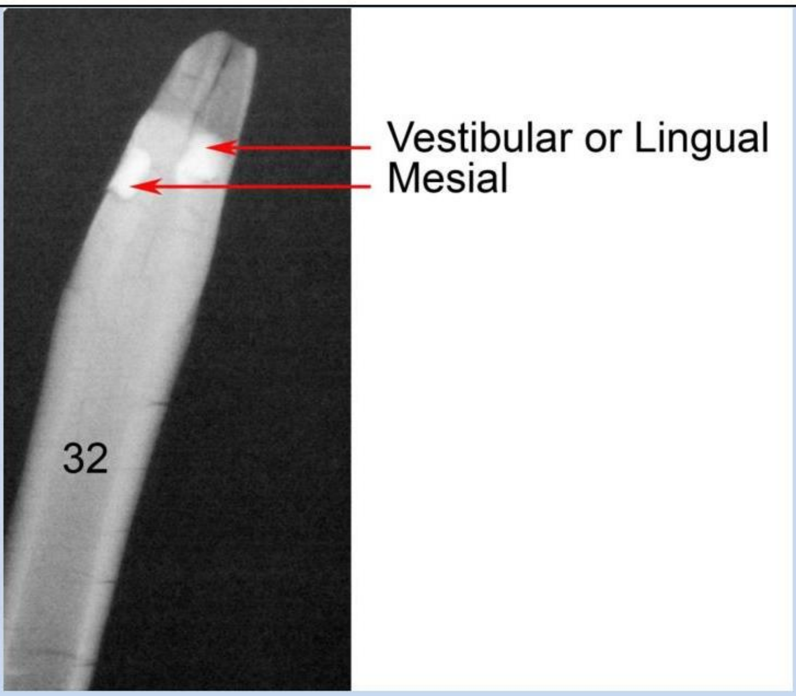

Fig. 6: Postmortem radiograph of the 32 tooth incorrectly orientated suggesting a mesially placed restoration.

reconciliation process. As a consequence of these observations it was decide not to continue to utilize incinerated pig heads as a model for the forensic odontological training.

CONCLUSION

Incinerated pig (*Sus Scrofa*) heads is not an ideal model for forensic odontology training in disaster victim identification. Differences in both anatomy and behavior following exposure to heat were shown to hamper documentation and subsequent comparison to antemortem data.

ACKNOWLEDGEMENTS

Members of the Forensic Odontology Unit, University of Adelaide are acknowledged for their assistance in this project.

REFERENCES

1. Cordner SM, Woodford N, Bassed R. Forensic aspects of the 2009 Victorian Bushfires Disaster. *Forensic Sci Int.* 2011;205:2-7.
2. Holden JL, Clement JG, Phakey PP. Age and temperature related changes to the ultrastructure and composition of human bone mineral. *J Bone Miner Res.* 1995;10:1400-9.
3. Imaizumi K, Taniguchi K, Ogawa y. DNA survival and physical and histological properties of heat-induced alterations in burnt bones. *Int J Legal Med.* 2014;128:439-46.
4. Woisetschläger M, Lussi A, Persson A, Jackowski C. Fire victim identification by post-mortem dental CT: radiologic evaluation of restorative materials after exposure to high temperatures. *Eur J Radiol.* 2011;80:432-40.
5. White TD. Human Osteology. San Diego: Academic press; 1991.
6. Thompson TJ. Recent advances in the study of burned bone and their implications for forensic anthropology. *Forensic Sci Int*. 2004;146 Suppl:S203-5.
7. Reichs KJ. Forensic osteology : advances in the identification of human remains 2nd ed. Springfield: Charles C. Thomas; 1998.
8. Griffiths CJ, Bellamy GD. Protection and radiography of heat affected teeth. *Forensic Sci Int.* 1993;60:57-60.
9. Cardoza AR. Dental forensic identification in the 2003 Cedar Fire. *J Calif Dent Assoc.* 2004;32:689-93.
10. Park DK, Park KH, Ko JS, Kim YS, Chung NE, Ahn YW, et al. The role of forensic anthropology in the examination of the Daegu subway disaster (2003, Korea). *J Forensic Sci.* 2009;54:513-8.
11. Hill AJ, Lain R, Hewson I. Preservation of dental evidence following exposure to high temperatures. *Forensic Sci Int.* 2011 Feb 25;205:40-3.
12. Coroner eases process to id fire victims. The Australian; 2009. Available from: http://www.theage.com.au/national/coroner-eases-process-to-id-fire-victims-20090305-8q2v.html#ixzz1qqaXd0Ju [cited 12 May 2012].
13. Lake AW, James H, Berketa JW. Disaster victim identification: quality management from an odontology perspective. *Forensic Sci Med Pathol.* 2012;8:157-63.
14. De Winne J. Preparing for major incidents. *Forensic Sci Int.* 2006; 159S:S9-S11.
15. Lain R, Taylor J, Croker S, Craig P, Graham J. Comparative dental anatomy in Disaster Victim Identification: Lessons from the 2009 Victorian Bushfires. *Forensic Sci Int.* 2011;205:36-9.
16. Pretty IA, Webb DA, Sweet D. The design and assessment of mock mass disasters for dental personnel. *J Forensic Sci.* 2001:46, 74-9.
17. Lopes FM, Markarian RA, Sendyk CL, Duarte CP, Arana-Chavez VE. Swine teeth as potential substitutes for in vitro studies in tooth adhesion: a SEM observation. *Arch Oral Biol.* 2006;51:548-51.
18. Popowics TE, Rensberger JM, Herring SW. Enamel microstructure and microstrain in the fracture of human and pig molar cusps. *Archives Oral Biology.* 2004;49:595-605.
19. Owsley DW. Identification of the fragmentary, burnt remains of two U.S. journalists seven years after their disappearance in Guatemala. *J Forensic Sci.* 1993;38:1372-82.
20. DeHaan JD, Campbell SJ, Nurbakhsh S. Combustion of animal fat and its implications for the consumption of human bodies in fires. *Sci Justice.* 1999;39:27-38.

*****

Chapter 9

Conclusion

9.1. Introduction

The causes of severe incineration of individuals in fire events such as motor vehicle accidents, plane and high speed train crashes, native vegetation fires, residential and commercial fires and terrorism are unlikely to diminish. Identification of these victims not only aids in the healing process for surviving relatives and friends by bringing about closure but also is required for legal reasons [1-3]. The destructive nature of fire limits what postmortem information is available for comparison methods of identification. The literature review revealed specific topics which could be further investigated to improve the amount and quality of postmortem information. This study looked at:

- what information does remain,
- how can this information be maximised,
- testing products that would preserve the material yet not interfere with criminal investigations,
- identifying surviving medical devices and materials from which information could be retrieved,
- investigating a training method to examine severely incinerated heads and
- implementation of these research findings through publications together with national and international presentations.

This thesis comprises an introduction, a chapter reviewing the literature, followed by a series of chapters presented as either published papers, or as a draft manuscript, containing discussions all on the topic of maximising post-mortem information. This concluding chapter discusses further findings since the initial study, the current implementation of the findings, the significance of the outcomes of this research project together with limitations and suggestions for possible directions for future investigations in this area.

9.2. Further findings

Since the publication of the review chapter, there has been further literature published regarding identification of severely incinerated victims. In 2012, Tümer et al. mention the importance of testing for accelerants following homicide as there could be deliberate burning of the corpses to destroy evidence (4). This article reinforces the importance of my study in utilising a volatile free stabilising agent on ashen remains. Reesu et al. in 2015 published a review on dealing with incinerated human dental remains (5). Unfortunately in their article they attribute Mincer et al. as saying "Runny mix of acrylic spray using a horsehair brush is the material of choice for dental stabilization of incinerated remains" (5). What Mincer et al. did state was "In our opinion, the most advantageous impregnation material for stabilizing incinerated teeth is clear acrylic spray paint, and the second best is probably cyanoacrylate cement" (6) without any mentioning of a horsehair brush. The term 'runny mix of acrylic spray" is also confusing and the physical touching of the ashened remains with any tool should be avoided before stabilisation has been achieved.

In 2014, De Angelis and Cattaneo also published a case where the recovery of a burnt oral implant connected to a bone fragment as evidence (amongst 2780 charred bone fragments suspected to have belonged to a victim of homicide) was presented in an Italian court. The uniqueness of the traits convinced the jury of the identification of the remains [(7)]. Having only one dental implant with no numbering but attached to an anatomical marker, highlights how significant the careful and methodical retrieval of postmortem data is to obtaining a positive result. It also substantiates the validity of my study in utilising dental implants for identification.

9.3. Implementation

Following the discovery and testing of a non-volatile Clag™ solution stabilising agent it is important to further test, monitor and implement the findings. Information from my study was provided to the South Australian Coroner and to all forensic pathologists in this state. All pathologists gave approval to utilise the Clag™ solution stabilising agent and the Coroner encouraged the South Australian police to implement a protocol of stabilising incinerated remains. This has allowed appraisal of how the material works in real life scenarios and with real cases.

In one incident three victims were all severely incinerated following a motor vehicle crash. The victims were one father and two twin adult sons, which would have presented difficulties for DNA comparison. Clag™ solution was utilised to stabilise the remains. To emphasise the importance of the spray, in one victim (Figure 1.), all that remained of the dental tissues at the scene were the mandibular roots and two partial crowns of the victim yet all incinerated dental remains survived a trip of some three hundred kilometres. All three victim’s identities were subsequently established by odontological methods.

Figure 1. Mandible of incinerated victim with two crowns still attached, at the mortuary.

In another case, similarly following a motor vehicle accident a victim was severely incinerated and suspended by the metal framework of the car seat upside down. The position of her head can be just seen in Figure 2. with her head facing towards the centre of the car.

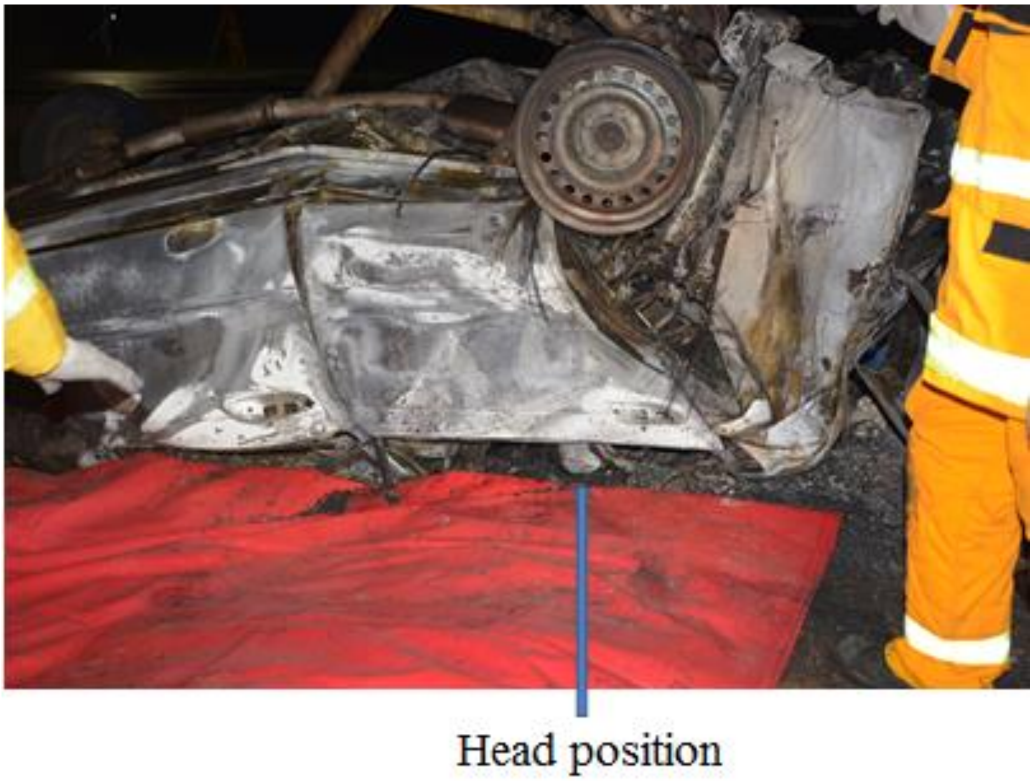

Figure 2. Victims head position in crushed incinerated car.

As there was partial roof collapse there was no direct visual analysis of the dentition and placement of materials such as cyanoacrylate would not have been possible. I was however able to place my arm into the vehicle and direct a spray of Clag™ mixture in the vicinity of her face. There was a delay of approximately one hour till the fire officers arrived with the appropriate machinery to remove door structures which allowed some setting of the material before the rigour of door removal began. Following door removal, the body was extricated and the dentition can be seen in Figure 3. Of note was that the Clag™ mixture had not fully set as some parts of the dentition appeared a milky blue rather than clear.

Figure 3. The milky blue Clag™ mixture unset material can be seen on the victims right side.

Although the material had not totally set, there was sufficient bonding to preserve the remains of the dentition upon extrication. The temperature was low (approximately 4°C) with occasional drizzle outside the vehicle. In such conditions of low temperature and high moisture environment the evaporation of water within the mixture was not going to eventuate. Investigations on methods to set the Clag™ mixture were instigated. So as not to contaminate the area with chemicals, the use of warmers such as torches and lights was contemplated. Police investigators attending major crashes, usually also have portable flood lights. The heat from non-LED lights is quite substantial and sufficient to set the Clag™ mixture.

In a recent case a victim who was totally incinerated was presented at the mortuary for odontological examination. Her dentition had not been stabilised with any agent and although survived the transportation process, concerns were raised that her dentition may be disrupted during the odontological and pathological examinations. Her fragile dentition can be seen in

Figure 4. We stabilised the dentition by spraying the Clag™ mixture (Figure 5) and then applied a portable flood light to that area for 30 minutes (Figure 6).

Figure 4. Fragility of lower dentition with loss of 43 buccal restoration and buccal bone can be observed.

Figure 5. Post spraying of Clag™ mixture.

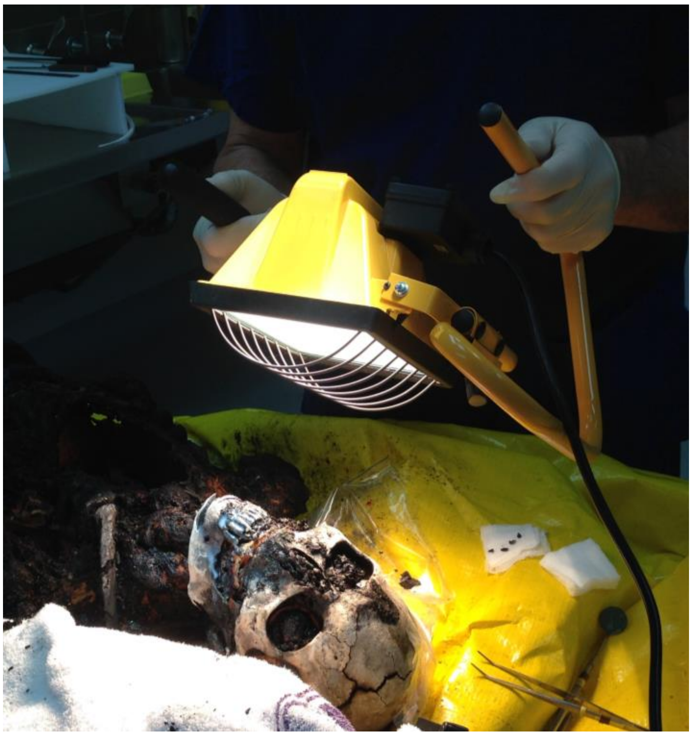

Figure 6. Gentle heating of the Clag™ mixture with portable floodlight.

Once set, the mixture no longer appeared milky blue but clear, and we were able to remove the tongue (Figure 7.) without disrupting the lower dentition and radiographic sensors were easily placed submentally.

Figure 7. Following setting the remains appeared clear and the removal of the tongue did not disrupt the dentition.

One of the advantages of the mixture is that it is absorbed by the ashened tissues. The 43 tooth appeared to have lost a restoration (Figure 4. and Figure 8a.). Exploration revealed an amalgam restoration at the back of the mouth which could fit the cavity. We were able to place the restoration into the cavity of the 43 and confirm the fit with another radiograph. (Figure 8b.)

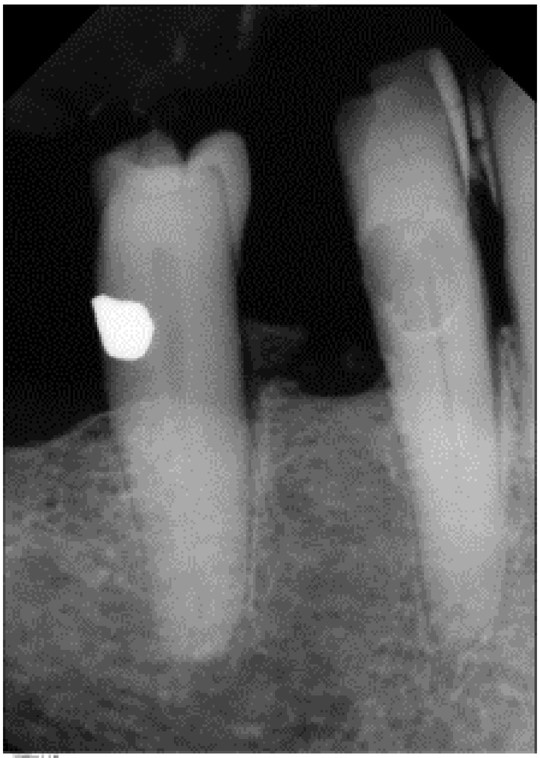

Figure 8a. Loss of 43 restoration.

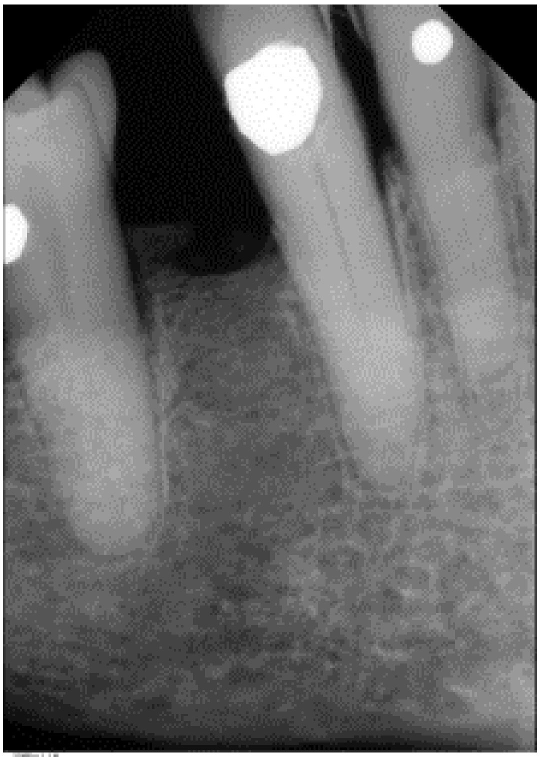

Figure 8b. Restoration in 43 reset in position.

In another recent case, the incinerated victim was slumped down across the front seats with her face down. It was impossible to gain direct vision of her dentition but fortunately I was able to place my arm underneath the seat and spray the Clag™ solution upwards in the general direction of her dentition and wait for 30 minutes for setting to occur. This action was sufficient to stabilise her dentition so that when her body and head was rotated upwards no further loss of dental structures occurred. Her body was then removed from the car, her head sprayed again, dried with the assistance of a portable light, wrapped in bubble wrap and enclosed in a large paper bag which was sealed at the neck level before placement in a body bag. The victim was later identified by forensic odontology methods.

Table 1. summarises the use of the Clag™ solution this year. All victims were so severely burnt

that there was no facial soft tissue remaining, there was cracking and loss of at least some alveolar bone as well as tooth material loss at the scene. In all cases, the paste prevented further fracture and loss of dental information.

Table 1. Cases in 2015 utilising the Clag™ paste solution.

Case	Incineration type	Dental identification
1	Car fire	Established
2	Car fire	Established
3	Car fire	Established
4	Car fire	No antemortem records
5	Caravan fire	Established
6	Bushfire/wildfire	Established
7	Self immolation in car	Established
8	Car fire	Probable

Although actual cases have highlighted the applicability of the knowledge gained from this research study with successful outcomes, due to the size of South Australia it is impractical for forensic odontologists to attend all incineration scenes. It was decided to train police scene officers in the application of the spray and handling of dental postmortem information. As there are over one hundred and twenty crime scene officers spread across the state it was decided to create a joint video with South Australian police (SAPOL) on recovery of incinerated remains emphasising the correct mixing and application of the spray. This has been successfully created and it is hoped that this will also be presented nationally and internationally to scene officers and forensic odontologists to aid the implementation of the Clag™ solution stabilising agent.

Since the publication of the cochlear article presented in Chapter 5 a Cochlear™ implant was noted during postmortem examination. The local forensic pathologist was aware of the article and the victim was readily identified following recovery of the implant, recording of the data upon it and cross checking with the company records.

In a separate case, a victim was severely incinerated and a burnt tibia healing rod was retrieved from the victim's ashened remains. As the fine steel wool technique described in the article in Chapter 6 could be extrapolated to all metal medical appliances within a body, utilising the technique, the numbers were retrieved and were matched to antemortem hospital records.

9.4. Significance, limitations, and further research recommendations

This study has significant practical implications for the future in the identification of severely incinerated victims. With regard to the use of stabilising spray, a major reason why scene police officers were not utilising a stabilising agent, is the possibility of contamination with petroleum based volatiles at the scene of an incineration event. There was a notable lack of appreciation of the importance of maintenance of postmortem information for dental examination by scene officers.

Also the burden of another task inflicted on scene officers in what would be a physical and mental demanding situation could be a further reason for stabilisation procedures not being applied routinely. It is hoped the publication and publicity of this study will stimulate the routine use of stabilisation of severely incinerated remains at the scene. Following the production of the video, I have presented my findings to forensic pathologists and allied professions attending the Royal College of Pathologists of Australasia meeting this year in Queenstown, New Zealand. Forensic odontologists were also updated as I presented at the Australian Society of Forensic Odontology symposium in Darwin this year and I did plan to present the findings to the American Academy of Forensic Sciences meeting in Las Vegas early next year, however a restriction placed on the intellectual property by the university at the time of abstract submission did not allow me to submit. I have been invited to speak at the New

Zealand Forensic Odontology Society meeting in May of 2016 and hope to update further findings on my research.

One of the limitations of the use of Clag™ paste is there is no measure of the placebo effect of having a forensic odontologist at the scene. Being present and treating the ashes of the victim would have a psychological effect on the other scene team members to be more aware of dental issues and take more care of the fragile material during processing of the body and transport to the mortuary. Another limitation of the spray solution is that Clag™ paste is currently not available internationally. Although plain flour could be substituted, it does leave an opaque residue and is therefore not ideal. As it would be advantageous to have a ready-made spray commercially available, recently the corporate arm of the University of Adelaide (ARI) was in discussion with the Bostik Company (Bostik, Melbourne, Australia) the makers of Clag™ paste, to see if this could be commercially feasible. The company have since deemed that the numbers of spray kits sold is insufficient to be commercially viable.

This minor setback has spurred me on to investigate what is available in relation to wheat based pastes. Further literature review has shown that starch is one of the few highly polymer substances with a high initial adhesive strength which is relatively simple to produce aqueous colloidal solutions(8). Starch also provides high affinity to many porous substrates(9). Starch granules in wheat (*Triticum aestiyum*) kernels consists of mainly two types of carbohydrate polymers, the linear amylose (approximately 30%) and the highly branched amylopectin (approximately 70%), with other minor components, including lipids and proteins(10, 11). If water is added and the mixture is heated above 64°C gelatinisation of the starch occurs. At this temperature, hydrogen bonds on both polymers continue to be disrupted and water molecules attach to the hydroxyl groups and the starch granules swell increasing the starch solubility, paste consistency and (most relevant to this study) its paste clarity[11]. Adhesives made from wheat starch (referred to as wheat paste) is used in paper making [12], wallpaper hanging [13], attaching fine glass particles to kite string[14] and poster billboard plastering [15]. There are many videos on YouTube on the internet[16] describing the simple manufacture of wheat paste. Importantly plain flour is obtainable universally and could be a source of commercially available adhesive where Clag™ paste is unavailable. A further research recommendation would involve testing different solutions of wheat starch/water ratios followed by further vibration studies on incinerated tissues to create a balance of applicability and strength before suggesting the materials for use.

The significance of cochlear implants having a unique serial number emphasises the importance of having a national registry similarly to the AOANJRR to assist in the identification. Although it is quite simple to have the company pass on this information, some companies may not be so helpful and the reliance of the company to retain this information for many years (as a patient most likely to have a cochlear implant early in their life) is not ideal. Many companies commercially fail or are taken over and the need to retain this information may not be apparent to board directors of the takeover companies.

The perceptions that a burnt hip or knee implant has unreadable data numbers are no longer a valid presumption and have been proven to be recoverable in this study. The significance is that there should a greater successful identification rates from victims with incinerated hips and/or knees in future incidents. Also, in cold cases from the past these could be reinvestigated to see if identification is possible. An example is the 2011 Japanese tsunami that followed the huge earthquake, where remains that have been cremated (with subsequent loss of DNA) are being stored in local temples and municipal mortuaries. Due to the popularity of hips and knee procedures in Japan, there is a high likelihood that there could be victims with either a hip or knee implant. Another example where this research could benefit the authorities is in a closed case where the names of the victims are known, a search of the national hip or knee registry would identify if any of the victims have a hip or knee implant. In an incident where there has been either severe fragmentation or fire such as the MH17 plane disaster, the authorities could pass on the morphological information to the scene recovery officers to particularly be aware that they might come across such objects.

The limitations of the hip and knee implant study are due to limited resources as not many numbers of implants were tested. Also there could be different materials that could be more beneficial in data recovery and the separation of the balls from the stems of the hip implants is quite crude. Further research is required in these areas by testing on implants with new products that come available. Also the further development of a better tool to separate the ball from the stem that is currently available and monitoring of casework where these methods were utilised to see if further refinement is required is envisaged.

Similarly, dental implants are extremely popular and it seems logical that a registry for dental implants should be set up not only in Australia but also worldwide. The Straumann company laser etches a batch number within the chamber of their implants, which resist incineration if a fixture is placed upon it (which is the usual situation) [17]. The Therapeutic Goods Administration (TGA) should encourage all implant companies to follow suit. As well as providing assistance in the identification of victims, a dental registry could highlight design faults in certain types of implants, which would have a benefit of maximising the prognosis of dental implant treatment. An example of this has occurred with DePuy's company's Articular Surface Replacement hip replacements. I have contacted the TGA (personal communication) and have written to the Australian federal health minister twice regarding the introduction of a registry without success, but I recommend further lobbying to establish a dental implant register.

As arthroplasty registries become more prevalent around the globe together with dental implant registries, it would be ideal to have international cooperation so that computer searches could quickly identify a victim with a numbered implanted device. The major problem of this is the ethical considerations of privacy as well as having all countries agreeing and having such registries in existence.

Although incinerated pig (*Sus Scrofa*) heads is not an ideal model for forensic odontology training in disaster victim identification it is important for forensic odontologists to prepare and train for events. Due to ethical restraints, I suggest that sheep heads be utilised as they are readily available, cheap and have realistic lower mandibular teeth. However, I suggest that the temperature when incinerating the sheep heads is kept below 490° C as the tooth crowns tendered to fracture beyond 500° C during my studies.

9.5. Concluding remarks

The maximisation of postmortem information for identification of severely incinerated victims was the driving force behind this research. Improvements have been achieved by the discovery and testing of a non-volatile stabilising agent spray that has brought about important practical implications for the treatment of fragile remains, together with the contribution to knowledge regarding retrieval of data from cochlear, dental, hip and knee implants in tracing back the identity of an unknown recipient. The perception that a burnt or cremated implant has unreadable data numbers is no longer a valid presumption through the testing of techniques not previously published.

The knowledge in this thesis has already been successfully applied in forensic identification casework of human incinerated remains. Plans are to spread this knowledge through all levels of the identification process both nationally then globally not only through publications but through attendances at international conferences.

This information can now be used to maximise chances of identification so that the term "burned beyond recognition" may be minimised and allow families to have closure and legal processes to occur.

9.5a References

1. Fixott RH. The dental clinics of North America. Philadelphia: W.B.Saunders; 2001.

2. Stimson PG, Mertz AC. Forensic dentistry. Baton Rouge: CRC; 1997.

3. Cordner SM, Woodford N, Bassed R. Forensic aspects of the 2009 Victorian Bushfires Disaster. Forensic science international. 2011;205(1-3):2-7. DOI: 10.1016/j.forsciint.2010.08.008.

4. Tümer AR, Akçan R, Karacaoğlu E, Balseven-Odabaşı A, Keten A, Kanburoğlu Ç, et al. Postmortem burning of the corpses following homicide. Journal of forensic and legal medicine. 2012;19(4):223-8.

5. Reesu GV, Augustine J, Urs AB. Forensic considerations when dealing with incinerated human dental remains. Journal of forensic and legal medicine. 2015;29:13-7.

6. Mincer HH, Berryman HE, Murray GA, Dickens RL. Methods for physical stabilization of ashed teeth in incinerated remains. Journal of forensic sciences. 1990;35(4):971-4.

7. De Angelis D, Cattaneo C. Implant Bone Integration Importance in Forensic Identification. Journal of forensic sciences. 2015;60(2):505-8
.

8. Onusseit H. Starch in industrial adhesives: new developments. Industrial crops and products. 1992;1(2):141-6.

9. D'Amico S, Hrabalova M, Müller U, Berghofer E. Bonding of spruce wood with wheat flour glue—Effect of press temperature on the adhesive bond strength. Industrial crops and products. 2010;31(2):255-60.

10. Yasui T, Matsuki J, Sasaki T, Yamamori M. Amylose and lipid contents, amylopectin structure, and gelatinisation properties of waxy wheat (Triticum aestivum) starch. Journal of cereal science. 1996;24(2):131-7.

11. Olkku J, Rha C. Gelatinisation of starch and wheat flour starch—a review. Food chemistry. 1978;3(4):293-317.

12. Belard R, Higuchi H, Perry J. Furunori (aged wheat starch paste): challenges of production in non-traditional settings. Journal of the Institute of Conservation. 2009;32(1):31-51.

13. Shelley M. The Conservation of the Van Rensselaer wallpaper. Journal of the American Institute for Conservation. 1981;20(2):126-38.

14. Wankhede AG, Sariya DR. "Manja" – A dangerous thread. Journal of forensic and legal medicine. 2008;15(3):189-92.

15. Briggle L, Curtis B. Wheat worldwide. Wheat and wheat improvement. 1987(wheatandwheatim):1-32.

16. YouTube. 2015 [cited 2015 21/11/2015]. Available from: https://www.youtube.com/

17. Berketa JW, James H, Marino V. A pilot study in the recovery and recognition of non-osseointegrated implants following cremation. Journal of forensic odonto-stomatology. 2011;29(2):38-44.

Appendix A

Achievements

Further published publications and drafts during my candidature:

- **Berketa JW**, James H, Lake AW. "*Forensic odontology involvement in disaster victim identification.*" Forensic Sci Med Path. 2012;8(2):148-56.
- Lake AW, James H, **Berketa JW**. *"Disaster victim identification: quality management from an odontology perspective."* Forensic Sci Med Path. 2012;8(2):157-63.
- James H, **Berketa JW**, Higgins D, Lake AW, Cirillo G. *"Disaster Victim Management – Role of Forensic Odontology"* chapter in Encyclopedia of Forensic and Legal Medicine, 2nd edition. Published on line 2015.
- Byard R, James H, **Berketa JW**, Heath K. "*Locard's Principle of Exchange, Dental Examination and Fragments of Skin"* J Forensic Sci. Published on line 2015. DOI: 10.1111/1556-4029.12964
- **Berketa, J**. "*Dentures in dementia: the oral health management of patients in institutional care"* Forensic Sci Med Path. Published on line 2015. DOI 10.1007/s12024-015-9689-1

Awards:

- 2012 ANZFSS travel scholarship
- 2012 ADRF Federal Grant
- 2014 ANZFSS International Congress poster presentation - finalist
- 2014 Florey International Research Conference 2014 - Northern Communities Health Foundation Prize
- 2015 JL Eustace international travel award

- 2015 Gerry Dallitz award for best oral presentation
- 2015 NIFS (Australia) Highly Commended in the Best Paper in a Referred Journal

Collaborations established:

- Forensic Science South Australia (FSSA). FSSA has supported my research by provision of their laboratories, materials and technical assistance throughout my PhD candidature.
- South Australian police (SAPOL). SAPOL have also provided me with technical assistance and access to scenes.

Presentations:

- 2012 *"Stabilisation of incinerated remains"* ANZFSS S.A branch meeting. Adelaide, Australia. Oral presentation.
- 2012 *"Stabilisation of incinerated remains"* ANZFSS International Congress Hobart, Australia. Oral presentation.
- 2013 *"Maximising the postmortem information of severely incinerated victims"* Sri Lanka Dental School, Kandy, Sri Lanka. Oral presentation.
- 2013 *"Maximising the postmortem information of severely incinerated victims- a medical perspective"* National Sri Lanka Forensic Pathologist meeting, Colombo, Sri Lanka. Oral presentation.
- 2014 *"Maximising postmortem information on severely incinerated victims"* Adelaide University Dental Faculty postgraduate research day. Adelaide, Australia. Oral presentation.
- 2014 *"Identification by implants"* RCPA Forensic Interim Meeting. Adelaide, Australia. Oral presentation.

- 2014 *"Stabilisation of severely incinerated human remains at the scene"* ANZFSS International Congress. Adelaide, Australia. Poster presentation.
- 2014 *"Sifting through the ashes: Odontology and Anthroplogy aspects of identifying incinerated individuals"* ANZFSS International Congress. Adelaide, Australia. Oral presentation
- 2014 *"Stabilisation of severely incinerated human remains at the scene"* Florey International Research Conference 2014. Adelaide, Australia.
- 2015 *"The retrieval of hip, knee and dental implant postmortem data from severely burnt bodies"* 23rd Congress of the International Academy of Legal Medicine, Dubai, U.A.E. Oral presentation.
- 2015 *"Stabilisation of severely incinerated remains for identification purposes"* RCPA Forensic Interim Meeting. Queenstown, New Zealand.
- 2015 *"Stabilisation of severely incinerated remains for identification purposes"* Forensic Science South Australia monthly meeting
- 2015 *"Implementation of non-volatile stabilisation agent to severely incinerated remains"* Australian Society of Forensic Odontology Symposium, Darwin, Australia.

Future presentations planned:

- 2016 *"Maximization of postmortem information for identification purposes"*
  Invited speaker at the New Zealand Forensic Odontology Society meeting, Wellington.