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CONTENT

EDITORIAL

The end of another year; a year that has included some excellent forensic odontology contributions to various conferences and meetings around the world. In Funchal, Madeira this September, IOFOS participated in the 19th World Meeting of the IAFS, (including the World Police Medical Officers and the Mediterranean Academy of Forensic Sciences). I attended the Inaugural Symposium of the Australian Society of Forensic Odontology in October, held in Darwin, the capital city of Northern Territory, Australia. This is a city familiar with disasters having been rebuilt twice following the Japanese air raids of the Second World War and Cyclone Tracy in 1974. The New Zealand Society of Forensic Odontology is wrestling with accreditation, so there is much activity in the Antipodes too!

It is hoped that manuscripts from some of the presentations of these meetings will be submitted to the JFOS in due course. It is encouraging to note the variety and quality of the forensic odontology (and related subject) presentations and learn from the developing and continuing research. A global approach with sharing of information and ideas is very welcome to the ongoing success of our discipline.

Official figures released after the earthquake in February in Christchurch, New Zealand, show that odontology contributed to more than 30% of the identifications, our fingerprint colleagues were successful in over 40% of cases. With teamwork and the relevant quality assurances in place, the painstaking DVI process moves forward, returning mass fatality incident victims to families and friends. Non-accidental injury to children continues to be a global problem despite various interventions and bite mark evidence is still causing occasional problems.

Following the General Assembly of IOFOS at the Madeira conference there are several changes, most notably that the Presidency of IOFOS is now in the hands of Professor Pinchi in Italy. Hrvoje Brkic (Croatia) is taking over the Newsletter. I too am standing down as editor and am happy to hand over to Patrick Thevissen in Belgium. I have enjoyed the last few years as editor but now is the time to pass on the responsibilities and I am sure that Patrick with the support of a department and administrative staff will move the Journal and its reputation forward. I must thank my assistant editor (Charles) for his time and patience helping me format each issue. On behalf of us all I wish the new team every success in steering IOFOS forward and congratulate the departing colleagues for all their hard work and dedication.

This issue is a truly international effort, with authors from America to Australia and includes case histories, a pilot study and various research articles – I hope that there is something to interest all readers whatever their experience levels. I thank you for the invitation to become the editor and I will take away a valuable experience, along with international networks and new friendships. Also, I would like to thank all the reviewers for their efforts and willingness to make time to encourage and support our authors.

Warmest festive greetings to you all. Wishing you a happy and healthy 2012. Perhaps your New Year's resolution will be to provide the new editor with a manuscript for summer 2012?

Judy Hinchliffe (BDS, Dip F Od, Hon FFFLM)
Editor

OPERATION EARTHQUAKE 2011:
CHRISTCHURCH EARTHQUAKE DISASTER VICTIM IDENTIFICATION.

H. Trengrove.

New Zealand Society of Forensic Odontology

ABSTRACT
At 12.51pm on Tuesday 22 February 2011, an earthquake of magnitude 6.3 struck the Christchurch region of New Zealand causing massive destruction with hundreds of people injured and killed. The New Zealand Society of Forensic Odontology response commenced two hours after the earthquake with the implementation of the national Disaster Victim Identification (DVI) forensic odontology plan. The importance of good planning, the integration of odontology as part of the immediate response and the deployment of odontology personnel to the scene were features of this operation. Stringent quality assurance processes were integrated into the planning which assisted in the robust outcomes. Smile photograph comparisons played a role in a number of difficult identifications. In the four months following the earthquake teams of odontology personnel worked tirelessly in an effort to identify the remains of those killed during the disaster. At the conclusion of the operation 97% of the deceased have been identified and returned to their families.

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Keywords: Christchurch earthquake, DVI, forensic odontology, identification

Running title: Christchurch Earthquake - Disaster Victim Identification

INTRODUCTION
Earthquakes and New Zealand are synonymous. New Zealand is located on the boundary of the Australian and the Pacific tectonic plates. As these plates grind into each other buckling and fragmentation occurs causing gradual changes in surface and subsurface topography. When the forces build up sufficiently rupture at the boundary occurs manifesting as an earthquake. New Zealand has a long history of devastating earthquakes causing significant destruction and loss of life.[1] Authorities have attempted to reduce the potential impacts of earthquakes through community preparedness including stringent emergency and support services training. Unfortunately, no amount of training and preparation could have prepared the county for the devastation caused by the series of major earthquakes affecting the Canterbury region of the south island, New Zealand. At 12.51pm on Tuesday 22 February 2011, an earthquake (an aftershock following a large earthquake in September 2010) of Richter scale magnitude 6.3 (energy magnitude 6.7) struck the Christchurch region (depth 5km with its epicentre Lyttleton). The forces involved were massive and catastrophic. High ground accelerations (some in excess of two times the acceleration due to gravity) lead to the rare occurrence of the 'slapdown effect' where the surface soils lost cohesion resulting in violent ground shaking and extensive liquefaction.[2,3] The major earthquake at 12.51pm, and the hundreds of aftershocks (many shallow and measuring over 5 on the Richter scale in strength) over the next twenty four hours, caused massive destruction in the Christchurch central business district, to Lyttleton, and to the surrounding suburbs (Fig. 1).

The severe shaking, combined with the widespread and significant liquefaction, severely compromised the city's roads, water, electrical and sewerage infrastructure and complicated the rescue and recovery operations. Many buildings either collapsed or suffered partial collapse with walls, facades and debris falling into the streets. Fire broke out in the collapsed six-story Canterbury Television Building (Fig. 2). In total 164 people were critically injured and 181 people from 22 nations died as a direct result of the earthquake and aftershocks.[4]

FORENSIC ODONTOLOGY - NEW ZEALAND
The use of forensic odontology in the identification of the deceased and victims of mass disasters has had a role in New Zealand for over seventy years. However, it wasn't until the misidentifications of casualties of the Tangiwai rail crash in 1953, that the value of forensic odontology was more formally

recognised.[5] This was further advanced following the 1979 Air New Zealand crash on Mt Erebus in Antarctica and the formation of the New Zealand Society of Forensic Dentistry (subsequently the Society name changed to New Zealand Society of Forensic Odontology - NZSFO). Since its formation all national and international Disaster Victim Identification (DVI) responses have been coordinated at a Society level. Recently this 'central coordination' has been further facilitated by the inclusion of a Society representative as part of the National Police DVI team and as a member of the National DVI committee.

The NZSFO has a detailed DVI odontology readiness plan that is based on the guidelines of the International Organisation for Forensic Odonto-Stomatology, Interpol (DVI) and the Australian Society of Forensic Odontology and the many lessons learned by the members of the NZSFO.[6,7,8,9] The forensic odontology response to the Christchurch earthquake commenced two hours after the earthquake with the implementation of the national DVI forensic odontology plan.

INITIAL RESPONSE

A key component of the earthquake response was the moral, legal and ethical requirement to accurately identify the deceased. Significant resources were made available to ensure optimal identification outcomes were achieved. The NZ National DVI team were activated and key personnel were in Christchurch coordinating the immediate DVI response within hours of the earthquake. The National DVI team is a squad of police with specialist DVI training and includes non-sworn scientific (pathology, odontology and fingerprint) personnel. This ready response team is well trained, is well resourced, follows international best-practice guidelines and protocols and has worked nationally and internationally. The value of such a team is well recognised as is the role of odontology in mass disaster situations.[10,11,12] The early deployment to the disaster area ensured an organised and orderly DVI response which was a key element to the relative success of this operation.[13] The DVI plan for Christchurch called for the use of the Christchurch hospital mortuary in the event of a mass casualty incident.

Unfortunately, the mortuary is located within the city hospital which was damaged by the earthquake and given the risks associated with the continuous aftershocks and the hospital activity treating the injured, alternative mortuary arrangements were required. The practicality of moving the deceased to mortuaries in other cities was considered but discounted because no single mortuary had the capacity to manage the numbers involved and because of the logistic challenges of getting the deceased out of the disaster area. A field mortuary was subsequently developed in a vehicle hangar at Burnham Military Camp, some 30km to the southwest of the city. The mortuary was configured to allow the unidirectional movement of remains from the storage containers across the mortuary floor (3 lines) and back to the containers. Whilst simple in appearance, the development of this facility was a complex process taking into account the need for efficiency, privacy, shelter, security, hazard management, body storage and staff facilities.[14] Co-located with the mortuary were body storage containers with the capacity of around 300 and the ability to supplement this (Fig. 3). It took the National DVI team, assisted by New Zealand Defence Force (NZDF) personnel and private contractors, two days to establish the mortuary with the first casualties entering the post-mortem (PM) examination process in the evening of 25 February 2011, three days after the earthquake.

RECOVERY

Locating and recovering the deceased victims of a disaster such as this is dangerous, time consuming and requires sound planning and organisation. It necessitates people searching badly damaged or collapsed buildings with the threat of aftershocks and further collapse. A careful and ordered approach is required to ensure the safety of those undertaking the recovery whilst balancing the community and political imperatives for speed. The difficulty and challenges of body recovery increases with the complexity of the disaster environment, especially in situations where there has been significant and sustained fire. Body recovery techniques are detailed to ensure the location and preservation of material useful in establishing identification. This is of great importance in situations where there has been fragmentation or burning of remains. The recovery phase was a coordinated response between Urban Search and Rescue teams, Police specialist search and rescue and DVI teams. Following lessons learned during other disasters, a forensic odontologist was deployed as part of the police DVI scene teams to assist with locating, securing and preserving dental and facial material at the collapsed and burning Canterbury Television Building (Fig. 4).[11,15,16]

POST-MORTEM PHASE

The mortuary was configured for the linear flow of casualties commencing from body storage (body registration), through property, pathology and biology, odontology, fingerprints, post-mortem quality review, body registration and then back to storage (Fig 5). In this DVI a partial medical post-mortem was completed with a focus on obtaining identification information and determining the likely cause(s) of death. The cause of death information was important as during the subsequent inquests families frequently wanted to know how their relative died. Biologists/scientists worked with the pathology and odontology teams in obtaining tissue samples for DNA testing. DNA testing was only performed if other methods of identification were unsatisfactory. Three PM lines were equipped and staffed which, to reduce bottlenecking of the process at odontology, required four odontology teams.

The forensic odontology aspects of the PM followed international 'best-practice' guidelines with two examiners trained in forensic odontology being involved with each examination. The two examiner process is an essential quality control measure which facilitates the cross-checking of findings and encourages critical thinking. There were many cases of incineration and in addition to extreme burning, significant fragmentation and comingling of remains had occurred. This necessitated careful and detailed re-evaluation of body bag contents to ensure that no dental and orofacial elements were overlooked. Once located, the dental remains required careful handling during the examination, radiography and photography process.[17,18] The use of a mortuary 'panel of odontologists', in addition to the primary examiners, to provide assistance with identifying and characterising fragmented teeth was very useful and assisted in creating an accurate and complete post-mortem record. Examination findings were recorded on the Interpol PM forms and comprehensive digital radiography and photography were completed for each case. Recognising the importance of teeth as a source of DNA, in many cases teeth were taken for DNA analysis.[19] The choice of specimen was decided following the pre-agreed DNA protocol for the operation and in collaboration with an on-site biologist.

A separate odontology 'quality assurance section' was developed to complement the quality assurance measures of the paired examining odontologists. The odontology quality assurance section reviewed the examination information and radiographs for accuracy, legibility and completeness. If deficiencies or errors were identified these were addressed prior to the casualty being returned to the storage area. As a result of these robust quality assurance measures there was only one post-mortem odontology revisit for a minor matter.

Most of the specialist post-mortem equipment was provided by the NZDF (Dental Services) from the DVI reserve. At the peak of activity five odontology teams and a quality review dentist were working in the mortuary.

INFORMATION CENTRE

Also located in the military camp was an Information Centre which accommodated (in distinct areas) the ante-mortem (AM) section, post-mortem data entry, reconciliation, coroner's office and administrative support.

Ante-mortem data collection formally commenced two days after the main earthquake. Significant police effort was placed on locating latent fingerprints along with objects and samples potentially containing material suitable for obtaining reference DNA. The success in acquiring latent fingerprints was a key factor in the high number of identifications made using fingerprints as the primary identifier. Dental records were obtained nationally through the local network of dentists and internationally through Interpol and the network of dental associations. Many of the casualties of the earthquake attended dentists in the cordoned off central city, this along with the constantly changing missing persons list, necessitated dentists entering the dangerous disaster area, sometimes on multiple occasions to retrieve records.

The use of 'smile photograph analysis' or photographic comparison techniques has been used to assist in the identification of unknown human remains.[20,21] In several cases during this DVI important information directly supporting the formal identification of victims arose through the comparison of odontologic features in ante-mortem and post-mortem photographs. The key to success with the 'smile analysis' was ensuring facial photographs were collected during the ante-mortem data collection process and that, in addition to conventional post-mortem occlusal and lateral dental views, post-mortem photography simulated the angles and approaches that typically occur during social photographic sessions.

Plassdata (version 3) was utilized on networked computers and was the main repository for ante-mortem and post mortem information. Plassdata was also used to data-mine and establish preliminary reconciliation matches.

Reconciliation was progressive in that the Chief Coroner elected to complete reconciliations as soon as there was sufficient information to do this. Reconciliation was based on the primary identifiers (odontology, fingerprints and DNA) with secondary identifiers taking an important but subordinate role. Initially odontologists attended Reconciliation Board meetings but subsequently submissions to the Board were by way of a report with an odontologist being available to answer questions or clarify issues. Major efforts were made to ensure the progress through the DVI process was accurate and efficient in an effort to ensure the speedy return of the deceased to their families as soon as practical after the Reconciliation Board confirmed their identification. The last identification was made on 27 July 2011 with over 85% being completed within four weeks of the disaster.

RESULTS

At the conclusion of the DVI process of the 181 deceased, 177 (including 70 foreign visitors) had been formally identified and released back to their families. Ninety-four percent of identifications were based on single or multiple primary identifiers. Four individuals remain unaccounted for. Six percent of the identifications were based on a combination of secondary identifiers including, property, physical/visual and circumstantial evidence. When all identifications were considered 43% of identifications were attributed to fingerprints, 33% to odontology, 4% to DNA and 14% a combination of fingerprints, odontology and DNA (Fig. 6). The relatively high identification rate by fingerprinting reflects the localised nature of the incident and the well organised and thorough approach taken by fingerprint personnel in collecting latent and post-mortem fingerprints.

If the methods of identification are further broken down into identifications on deceased with multiple DVI numbers (fragmented remains), then as expected, a greater use was made of multiple primary identifiers with 85% of identifications involving a combination of odontology and DNA with minimal contribution from fingerprints (Fig. 7). Twenty and five percent of cases respectively involved odontology and DNA alone.

Thirty-four odontologists, including five overseas dentists were involved with the DVI operation and in excess of 400 working days dedicated to the task. In addition to the forensic odontologists, considerable assistance was provided by other oral health providers (dental technicians, dental hygienists and dental therapists) and by dental auxiliaries (assistants/nurses).[22,23,24]

CONCLUSION

This disaster reconfirms the importance of forensic odontology in the DVI process and in particular in situations where there has been significant trauma and fire. To optimise the identification outcomes it is essential that detailed forensic odontology support plans are developed and initiated early in the DVI response. The forensic odontology plan must be integrated into the overall DVI plan and key to this is the representation of forensic odontology within the organisations tasked with mounting the response. To ensure the best outcomes it is essential that a forensic odontologist works 'on-site' with the recovery teams. Unfortunately disasters do occur and they do occur close to home – is your DVI team ready?

ACKNOWLEDGEMENTS

It is important to acknowledge the tireless application of all those involved with this disaster victim identification operation. Their steadfast dedication and devotion to the task at hand is a testament to their sense of duty and compassion. It was a privilege to work with

them. Support and resources provided by the New Zealand Defence Force and the New Zealand Police were critical to the success of this operation.
To those who lost family members and friends I offer my heartfelt commiseration.

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FIGURES

Fig.1. *Damaged buildings and buses, Christchurch Central Business District*

Fig.2. *Canterbury Television Building*

Fig.3. *Field mortuary, Burnham Military Camp (body storage containers on right)*

Fig.4. *Recovery operations at the collapsed Canterbury Television Building*

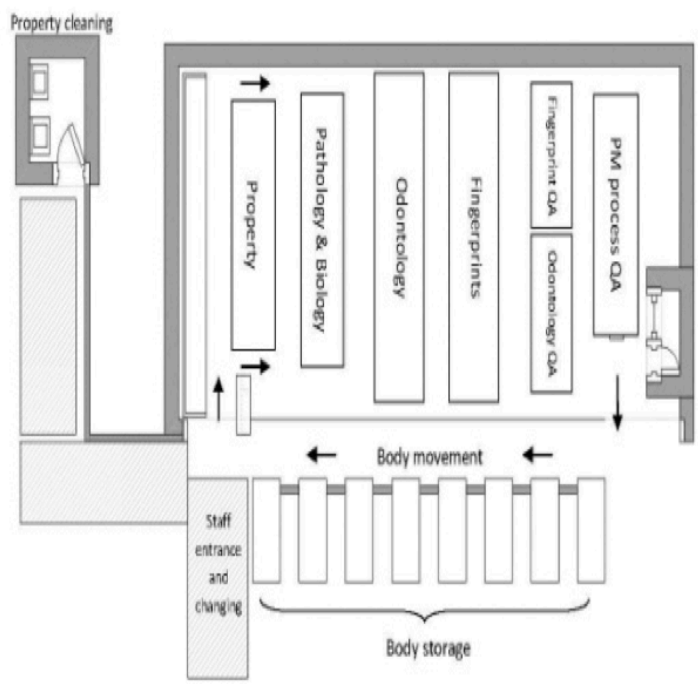

Fig.5. *Schematic of the field mortuary at Burnham Military Camp*

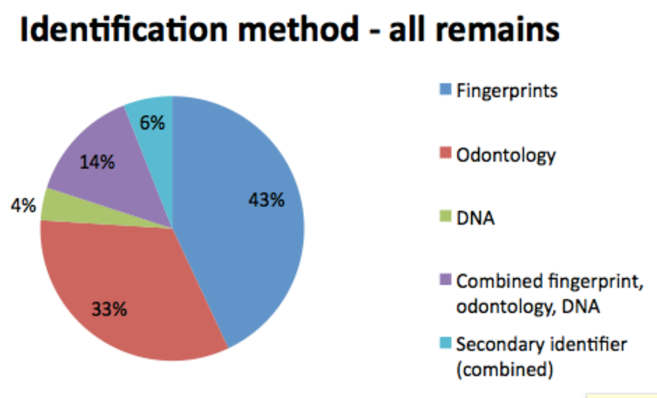

Fig.6. *Identification method – All remains, showing the success of fingerprint and odontology methods*

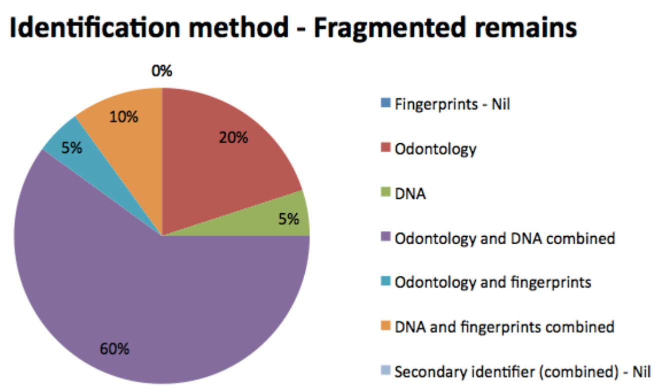

Fig.7. *Identification method – Fragmented remain by method*

FORENSIC ODONTOLOGICAL EXAMINATION OF A 1500 YEAR-OLD HUMAN REMAIN IN ANCIENT KOREA (GAYA).

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ABSTRACT
Forensic odontological examination was performed on one of the 1500-year old human remains of ancient Korea (Gaya) excavated from a burial site at Songhyeon-dong, Changnyeong, South Korea in April, 2008. The main purpose of the examination was to age estimate the remains and record any dental characteristics to aid full-body reconstruction and life history data collection. Oral and radiographic examinations and metric data collection were conducted. During the oral examination, the following observations were made: dental caries, semi-circular abrasion on the maxillary right lateral incisor and enamel hypoplasia on the left and right canines and first premolars in the mandible. The metric data was similar to that of average metric data of modern Koreans. Age estimation was initially conducted using the degree of dental attrition with methods of Takei and Yun, and was estimated to be approximately 40 years. However, it was observed in the radiographic examination, that the maxillary right second molar, together with the mandibular left and right second and third molars had incompletely developed root apices. The age estimation was then performed using the developmental status of the lower second and third molars. The age was estimated to be approximately 16 years using Lee's method which was consistent with the estimation using forensic anthropology. This case study highlights that the degree of attrition should not be used as a sole indicator for age estimation.

(J Forensic Odontostomatol 2011;29:2:8-13)

Keywords: Dental age estimation, attrition, enamel hypoplasia, Korea, ancient remains.

Running Title: Forensic odontological examination of a 1500-year old Korean human remain.

INTRODUCTION
Human skeletons of four individuals: two males and two females, were recovered from a burial site at Songhyeon-dong, Changnyeong, South Korea in April, 2008. Archaeological evidence and analysis of the remains suggested that the burial site is of the early 6th century A.D. At that time, the region in which the burial site is located was under the rule of Gaya, an ancient kingdom of Korea. The remains seem to be the subject of one of the burial customs of Gaya; burying servants along with their master (owner of the tomb) in order to serve them in their afterlife. Under the supervision of Gaya National Research Institute of Cultural Heritage (GNRICH), comprehensive research was conducted by a multidisciplinary team in the fields of archaeology, paleopathology, anthropology, forensic odontology, human anatomy, genetics, chemistry, physics and fine arts. This research was conducted from July 2008 for a year in order to gather the life history of the remains. Full-body reconstruction was a part of the research and one of the female remains was selected since the skeletal elements were relatively well preserved. Essential information for the reconstruction such as age, sex, stature was estimated by the team. Age estimation was conducted using forensic odontology since teeth can produce more accurate estimations than other age indicators of the body.[1] A thorough forensic odontological examination was conducted to record dental characteristics which could reveal important aspects of her life history.

MATERIALS AND METHODS
Macroscopic examination (using naked eye and a magnifying glass) as well as radiographic examination was performed on the maxillary and mandibular dentition. The examinations were performed by a well-trained forensic odontologist. Age estimation methods, using the degree of attrition by Takei[2] and Yun[3] which were developed on modern samples of Japanese and Koreans respectively, were utilized during the macroscopic examination. Developmental and pathological characteristics observable were also recorded.

Crown height, bucco-lingual diameter, mesio-distal diameter, and root length of teeth were measured with a vernier caliper (Mitutoyo Co., Tokyo, Japan). It was impossible to collect data on teeth that suffered postmortem loss of crown and/or root. Visual root examination was not observed in teeth that could not be extracted with passive finger pressure in order to avoid destruction of the archaeological remains.

Radiological examination was conducted on all the existing teeth using CT scans and periapical radiographs. It was impossible to take a panoramic radiograph because of technical difficulties due to a loss and/or destruction of skull bones that support the maxilla. Some incompletely developed second and third molars were observed in the radiographs. Age estimation was conducted using Lee's method[4] which uses the second and third molar developmental status of Koreans. In this case, the right side was chosen because it showed clearer images for evaluation - Lee et al[4] found that there was no statistically significant difference between the left and right side in the developmental status of second and third molars. Also any pathologic lesions of bones and teeth observed in the radiographs were recorded and analysed.

RESULTS

Macroscopic Examination

The maxillary left lateral incisor, second premolar and second molar could not be examined due to postmortem loss. Advanced dental caries was observed in the maxillary left first premolar (Fig. 1). Moderate and insipient dental caries were observed in some mandibular molars (Fig. 2). Partial enamel loss due to fracture was observed in the maxillary right second premolar.

From the age estimation conducted using methods utilizing the degree of attrition; age was estimated to be about 39.05±5.00 years using Takei's method,[2] and about 42.38±4.97 years using Yun's method[3] (Table 1).

Semi-circular abrasion was observed on the incisal edge of the maxillary right lateral incisor (Fig. 3) and enamel hypoplasia was found on the labial side of the left and right mandibular canines and the first premolars (Fig. 4). Asymmetry was not observed between the left and right side and the metric data were similar with the average of modern Korean dentitions published by Oh et al.[5] (Table 2).

Radiological Examination

Any morphological variation or pathologic findings were not observed in the radiographs (Fig. 5). The maxillary right second molar and the left and right mandibular second and third molars were found to be incompletely developed, and the third molars were impacted (Figs. 6 and 7).

Age estimation was conducted using Lee's method[4] utilising the developmental state of the second and third molars of the mandible. Lee's method[4] has a gender-specific regression equation and the sex of the individual was confirmed by DNA analysis to be female. Therefore the regression formula for females was used in estimating the age of the remains. The age was estimated to be 16.39±1.41 years using a second molar, 16.94±1.68 using a third molar, and 16.44±1.27 using a combination of second and third molars.

DISCUSSION

Age estimation was emphasized during this forensic odontological examination for the reconstruction of the selected female human remains. During examination using methods based on the degree of attrition, dentine exposure was found in several teeth of the remains and the age was estimated to be approximately 40 years using the two methods, of Takei[2] and Yun.[3] However, it was found that her dental development was incomplete upon radiographic examination suggesting a much younger age. A possible reason for such contradiction is because the methods used here were developed on samples of the modern population of Korea and Japan and it is highly probable that there are many differences in many aspects which can affect the degree of attrition between modern and archaeological populations.

Age estimation using dental development is relatively more accurate and reliable because there is a low variability among individuals.[1] However, it can only be applied to individuals with incomplete dental development, which means age estimation of sub-adults is relatively more accurate compared to that of adults. The remain's age estimation was conducted again using dental developmental status, since her dental development was incomplete, and the age was estimated to be approximately just over 16 years, which was consistent with the estimation using anthropological age indicators. Most of the long bones were recovered except the right femur and left tibia, and it was observed that epiphyseal plate closure was not yet complete. Based on this information, the age was estimated to be about 15 to 17 years.

Age estimation methods using the degree of attrition are greatly affected by different factors of a population such as ancestry, socio-economic status, diet as well as temporal variation. These factors should be carefully considered before extrapolating the results on a different population. For instance, Brothwell's method[6] was developed on an English population, thus applying it to Koreans should be avoided, but if deemed necessary it should be used with caution. For the remains examined in this research, a standard developed with an archaeological Korean population would have offered the best estimation. Research into the development of appropriate standards cannot be stressed enough. Despite the disadvantage that there are just too many factors to be taken into consideration, methods using the degree of attrition are still frequently utilized since they are non-invasive, easy to use, and have a relatively high inter-observer reliability. Nevertheless, it should be kept in mind that the degree of attrition should not be used as a sole indicator for age estimation. In this research, the inaccuracy of the age estimation using the degree of attrition would not have been realised if the radiographs were not examined for dental development status. In addition, quality assurance of dental age estimation of the International Organisation for Forensic Odonto-Stomatology (IOFOS) recommends using at least two independent statistical methods.[7]

Uniquely shaped abrasion was observed in the maxillary right lateral incisor. This abrasion was categorized as B/2 according to Romero,[8] who published a standard of classification regarding artificial dental modification. Such modification could be due to a number of different reasons such as sorcery, aesthetics, or other social reasons. It could be caused by repetitive actions using a particular part of the dentition. Fox[9] claimed that a uniform pattern of striation found in maxillary incisors of Paleolithic men was caused from their repetitive actions of using teeth for securely holding foodstuff in order to cut them using lithic tools. The remain's wear in this project may be a result of repetitive action during sewing, based on the knowledge that many Korean women often cut a thread with their teeth while sewing (instead of using scissors).

Loss of enamel due to enamel hypoplasia was observed on the labial side of left and right mandibular canines and first premolars. There are various causes of enamel hypoplasia, generally caused by systemic insults which can affect the formation of enamel. Factors causing such systemic insults include: infection, metabolic disorder and malnutrition which share similar clinical findings and therefore it is often impossible to confirm exactly which of these cause enamel hypoplasia.[10] Nevertheless, it was clear that she had suffered several systemic insults and detailed analysis should be conducted with pathological characteristics observed from the bones in order to find out the specific disease.

CONCLUSION

Much can be learned from studying ancient remains. In this case, age estimation initially conducted using the degree of attrition was found to be inaccurate following radiographic examination of the dentition. The age of the human remains utilising Lee's method[3] on the developmental state of the second and third molars of the mandible was estimated to be approximately 16 years old from the forensic odontological examination. This case study highlights that the degree of attrition should not be used as a sole indicator for age estimation. It was suggested that the remains had suffered from a number of systemic insults causing enamel hypoplasia. Metric data analysis showed that there is no significant difference in the morphology of teeth between a 1500-year old human remain and modern population.

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FIGURES

Fig.1. *Advanced dental caries observed on maxillary left first premolar.*

Fig.2. *Moderate dental caries observed on mandibular left second molar.*

Fig.3. *Semi-circular abrasion found on incisal edge of maxillary right lateral incisor.*

Fig.6. *Periapical radiograph of mandibular right third molar.*

Fig.4. *Enamel hypoplasia observed on labial surfaces of mandibular right canine and first premolar.*

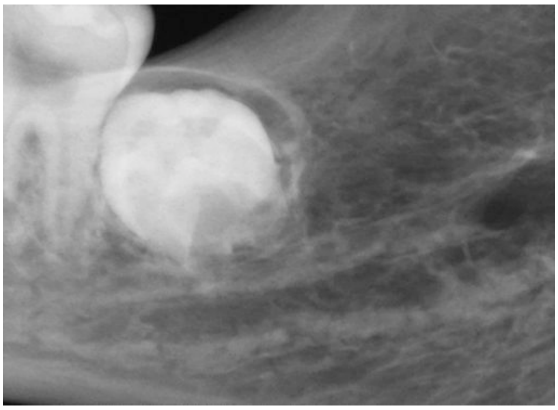

Fig.7. *Periapical radiograph of mandibular left third molar.*

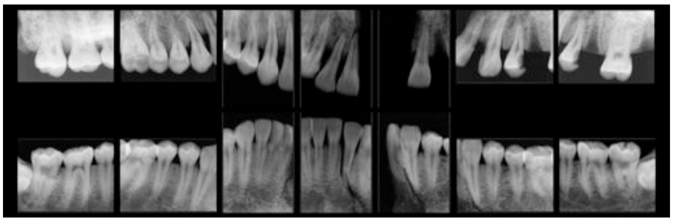

Fig.5. *Periapical radiographs of maxillary and mandibular dentition excluding third molars.*

TABLES

Table 1. *Attrition degree of the examined ancient human remain*

Maxillary teeth FDI notation	*17*	*16*	*15*	*14*	*13*	*12*	*11*	*21*	*22*	*23*	*24*	*25*	*26*	*27*
Takei[a]	B	C	B	B	C	B	C	C	—	C	B	—	C	—
Yun[b]	2/3	1Sc	2S	2S	Sc	Lc	Lc	Lc	—	Sc	1S	—	1Sc	—
Mandiblular teeth FDI notation	*47*	*46*	*45*	*44*	*43*	*42*	*41*	*31*	*32*	*33*	*34*	*35*	*36*	*37*
Takei[a]	B	C	A	A	C	B	B	B	B	C	B	B	C	B
Yun[b]	2B	5Pc	1S	1S	Sc	Lc	Lc	Lc	Lc	Sc	1B	2/3	3Pc	2/3

[a]Method presented by Takei[2] for scoring a degree of attrition
[b]Method presented by Yun[3] for scoring a degree of attrition

Table 2. *Metric data of the examined ancient human remain*

Maxillary teeth	*17*	*16*	*15*	*14*	*13*	*12*	*11*	*21*	*22*	*23*	*24*	*25*	*26*	*27*
CH[a] (mm)	7.89	7.26	7.77	8.40	10.18	10.40	11.40	11.04	—	10.91	8.72	—	7.84	—
MDD[b] (mm)	10.45	10.43	6.74	7.36	7.89	7.90	8.19	8.27	—	8.01	—	—	10.69	—
BLD[c] (mm)	11.75	11.52	9.27	9.65	8.78	6.58	11.27	—	—	8.98	9.80	—	11.76	—
RL[d] (mm)	—	—	—	—	—	11.80	10.79	11.36	—	13.58	—	—	—	—
Mandibular teeth	*47*	*46*	*45*	*44*	*43*	*42*	*41*	*31*	*32*	*33*	*34*	*35*	*36*	*37*
CH[a] (mm)	6.36	6.29	7.62	8.73	11.35	10.10	8.96	8.99	10.00	11.24	8.57	7.03	6.46	7.77
MDD[b] (mm)	11.18	11.01	6.82	6.75	6.83	6.24	5.09	5.20	6.38	7.19	7.15	6.64	10.83	11.39
BLD[c] (mm)	10.32	10.74	8.21	8.01	8.17	6.52	5.66	5.82	6.46	8.32	8.14	8.13	10.62	10.42
RL[d] (mm)	—	—	—	—	—	—	—	—	—	—	—	—	—	11.08

[a]Crown height
[b]Mesio-distal diameter
[c]Bucco-lingual diameter
[d]Root length

AGE ESTIMATION IN ARCHAEOLOGICAL SKELETAL REMAINS: EVALUATION OF FOUR NON-DESTRUCTIVE AGE CALCULATION METHODS.

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ABSTRACT

Estimation of age at death is an essential part of reconstructing information from skeletal material. The aim of the investigation was to reconstruct the chronological age of an archaeological sample from Croatia using cranial skeletal remains as well as to make an evaluation of the methods used for age estimation. For this purpose, four age calculation methods were used: palatal suture closure, occlusal tooth wear, tooth root translucency and pulp/tooth area ratio. Cramer's V test was used to test the association between the age calculation methods. Cramer's V test showed high association (0.677) between age determination results using palatal suture closure and occlusal tooth wear, and low association (0.177) between age determination results using palatal suture closure and pulp/tooth area ratio. Simple methods like palatal suture closure can provide data about age at death for large number of individuals, but with less accuracy. More complex methods which require qualified and trained personnel can provide data about age for a smaller number of individuals, but with more accuracy. Using different (both simple and complex) age calculation methods in archaeological samples can raise the level of confidence and percentage of success in determining age.

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Keywords: Archaeology; paleodontology; palatal suture closure; occlusal tooth wear; tooth root translucency; pulp/tooth area ratio; age estimation; Croatia.

Running title: Age estimation in archaeological skeletal remains.

INTRODUCTION

There are three main elements in the procedure of anthropological investigation and the identification of exhumed human remains: race determination, sex determination and age determination at the time of death. The most difficult one to determine is the age. Age estimation is a sub-discipline of the forensic sciences and should be an important part of every identification process, especially when information relating to the deceased is unavailable.[1] There are forensic[2, 3] and archaeological reasons for age determination of human skeletal remains.[4] Age estimation is of broader importance in forensic medicine, not only for identification purposes of the deceased, but also in connection with crimes and accidents.[1] According to the growing interest in vital statistics of past populations and palaeodemography (for example: age-group composition, sex ratios and the reasons for mortality in a community), procedures of sexing and ageing of skeletal remains are considered as a very important part of bioarchaeological investigations.[5]

Dental and bone material from each exhumed body or parts of the body are helpful in the age estimation process. There is more or less interdependence between time and many natural changes of the human body which can be used for determination of age at death. Patterns of aging are detected on both macroscopic (direct observation and radiological examination) and microscopic levels.[6, 7] The ageing of human remains is based upon a detailed knowledge of biological changes that occur during development, growth and maturation.[8] The exact chronology of these changes is dependent upon physiological variations in any one individual.[9] Skulls and teeth can provide a lot of information about age at death and that is the reason why there are many age determination methods based on cranial and dental features. Techniques for chronological age estimation in children based on dental maturity may be divided into those using the atlas approach[10-12] and those using scoring systems.[13,14] Once the development of crowns and roots is completed and the teeth are in functional occlusion, age determination using dental findings becomes more difficult. After the age of about 24 years dental estimates depend upon subtle changes in the teeth which are dependent not only upon increasing age but also upon the effects of wear.[9] Age determination methods applicable in adults could be divided into morphological[15-17] and radiological techniques.[14,18-20] Although there are many methods available, only methods based on non-destructive examination of the sample are recommended to use in bioarchaeological investigations. Therefore the methods for age estimation most often used by anthropologists and bioarchaeologists are macroscopic.

Given that skeletal remains coming from archaeological series are very often poorly preserved and fragmentary and demand careful handling to prevent further damage, age determination can be particularly complex. Assessments of age based on skeletal remains are most likely to be fairly accurate with immature or young adult individuals. Remains of older persons present more of a problem, and when dealing with earlier populations, it is difficult to be sure that significant age-changes took place at the same time, and that they showed the same group variability, as in modern populations.[7] For this reason it is best to combine several methods in order to raise the level of confidence and the percentage of success in determining age.

The aim of this investigation was to reconstruct the chronological age of the archaeological sample from Croatia using cranial skeletal remains as well as to make an evaluation of four non-destructive age estimation methods applicable in bioarchaeological investigations.

MATERIALS AND METHODS

The research was carried out on a total of 192 skulls from excavations of the crypt at St. Theresa's Cathedral in Požega in Croatia. The exhumation of the remains was done in 2004. The skeletal remains were dated from 18th and 19th centuries. The age and sex of the skulls at the time of death was unknown. During the investigation the skulls were stored in the Department of Dental Anthropology, School of Dental Medicine University of Zagreb.

For the purpose of this investigation, four age calculation methods were used: palatal suture closure, occlusal tooth wear, tooth root translucency and pulp/tooth area ratio. Suture closure and tooth wear were chosen because they are simple methods with a long tradition of usage for age estimation purposes. Tooth root translucency and pulp/tooth area ratio are more complex and more time consuming methods but probably giving more reliable results. All of these methods are non-invasive methods and this is very important in the examination of ancient bones and teeth.

The median palatine suture was examined on each skull in order to determine the amount of obliteration. Obliteration was defined as any portion of a suture no longer visible. If the obliteration of the suture was completed (Fig. 1), it was considered that the person at the time of death was older than 35 years. If the suture was open or partially open (Fig. 2), it was considered that the person was younger than 35 years at the time of death.

Age estimation by occlusal tooth wear was done according to Lovejoy`s method.[21] All teeth present in both jaws were used for this examination.

Single-rooted teeth with minimal or no caries, mostly upper canines, were used for age determination using tooth root translucency. A sliding calliper was used to measure the length of translucent dentine. The age was calculated according to Bang and Ramm.[17]

Radiographic images of upper canines were used for age determination using pulp/tooth area ratio according to Cameriere et al.[22] Twenty points from each tooth outline and ten points for each pulp

outline were identified and used to evaluate tooth and pulp areas (Figure 3).
Examinations of palatal suture closure, occlusal tooth wear and tooth root translucency were carried out by one observer (MV) and age determination using pulp/tooth area ratio was performed by another observer (RC).

Cramer's V test was used to test the strength of association between the age calculation methods in a contingency table. The closer V is to 0, the smaller the association between the variables. On the other hand, V being close to 1 is an indication of a strong association between variables. Statistical analysis was performed with Statistica 5.0 statistical program.

RESULTS

Out of the total of 192 skulls, males presented 50.5% (97 skulls), females 41.7% (80 skulls) and children presented 7.8% (15 skulls with mixed or deciduous dentition). Skulls with mixed or deciduous dentitions were excluded from further investigation.

Age estimation using palatal suture closure was possible on 148 individuals (83.6%). More than a half (51.4%) of the population was younger than 35 years at the time of death.

Using occlusal tooth wear age could be determined on 113 individuals (63.8%), Table 1. An average age at death was 31.4 years. The majority of the sample (46.0%) was between 31 and 40 years at the time of death.

Age estimation using root dentine translucency was performed on 77 individuals (43.5%), Table 2. An average, age at death was 51.0 years. Almost all the individuals in the sample (94.8%) were older than 40 years.

Age estimation using pulp/tooth area ratio was performed on 88 individuals (49.7%), Table 3. An average age at death was 48.0 years. The majority of the sample (72.8%) was older than 40 years.

Cramer's V test showed high association (V = 0.677) between age determination results using palatal suture closure and occlusal tooth wear. This suggests that from the biological point of view these two processes are closely linked; palatal suture closure takes place simultaneously and almost in the same correlation to the chronological age as occlusal tooth wear. Association between age determination results using occlusal tooth wear and pulp/tooth area ratio was V = 0.241. There was low association (V = 0.177) between age determination results using palatal suture closure and pulp/tooth area ratio. According to the results of Cramer's V test the biological relationship between occlusal tooth wear and pulp/tooth area ratio and between palatal suture closure and pulp/tooth area ratio is not obvious. Although all of these processes are correlated to the chronological age, there are no reciprocal links between them as was found between palatal suture closure and occlusal tooth wear. Calculation of the association between age determination results using root dentine translucency and other age estimation methods could not be calculated because there was no root dentine translucency found on individuals younger than 35 years.

On a repeated random sample, performed after three weeks, identical findings were observed, so kappa value was 1, confirming intra- and inter-examiner reliability.

DISCUSSION

This research used four non-destructive age calculation methods based on four different tissues: bone, dental enamel, dentine and pulp. This provides a wide spectrum of information about age changes in a human body. Such approach is common in recent populations, but quite rare in archaeological investigations because it is time-consuming and expensive, additionally highly trained personnel are necessary.

Degree of obliteration of cranial sutures can be used to estimate the actual age of a person at death.[23] At birth, the secondary palate is composed of right and left maxilla and the right and left palatine, joined by broad sutures. With increasing age, the gaps visible between suture edges decrease, fuse and ultimately obliterate. Mann et al.[24] showed that obliteration of these sutures could be used as an estimator of biological age. They found that suture closure and age are correlated, but they concluded that this method can be used to sort commingled skeletons and corroborate age estimates based on other ageing techniques.[24] A problem with this method can appear if the cranial remains are fragmented and poorly preserved. This was the reason why 16.4% of skeletal remains examined in this investigation could not be involved in this age calculation method. Sutures may also be of help in determining the number of individuals represented by a series of skull fragments. For example, if we compare a fragment showing a part of the suture nearly completely obliterated, with another displaying the suture completely open, it may usually be concluded that more than one person is represented.[7]

Tooth wear may be defined as the wearing away of tooth substance during mastication by the rubbing of one tooth surface against another, together with the abrasive effect of any hard material present in the food. Most normal teeth show some degree of tooth wear, but this is less marked in recent civilized groups than in ancient and modern primitive populations.[7] Tooth wear has been frequently used as a tool of age estimation.[25] Lovejoy`s method[21] used in this study is a simple, not time-consuming method based on comparison of a degree of a tooth wear. This method is not population specific and this must be taken into consideration during the age estimation of different populations particularly in archaeological investigations. Dental attrition can provide a population-specific means of age estimation; but archaeologically relevant reference samples, that is, samples of skeletons of known age and sex coming from a population with the same way of living as any given archaeological sample of skeletons, are virtually nonexistent. Therefore, age estimation of ancient individuals from dental attrition is difficult.[26]

The increase in size of the apical zone of sclerotic dentine in human teeth has been used in forensic science as a method of age assessment, either as one of several regressive changes related to age, or as the sole variable since the finding that the increase in apical translucency was the factor most closely linked to age.[27] Measuring the length of translucency in millimetres provides accuracy and a high degree of objectivity.[17] The most reliable way to measure the dentine translucency is to measure on sections of the teeth. This is impossible if a unique archaeological sample is examined where the preparation of sections of the teeth is not allowed. When a section of a tooth is made, the tooth is permanently destroyed and cannot be used for other investigations - in this case the only way to study the dentinal translucency is the use of strong light and intact teeth. Sengupta et al.[28] studied difficulties in estimating age using root dentine translucency in human teeth of varying antiquity and found that the majority of the archaeological sample was affected by a morphological change creating a “chalky'” appearance to the dentine. Removal of the obviously affected teeth did not improve the correlation coefficients to any useful degree.[28] “Chalky” dentine appeared under the light microscope to be composed of large fenestrations, islands of mineralized tissue and masses of filiform structures that appeared to be following the path of the dentinal tubules in their invasion of the peripheral dentine. Whittaker and Bakri[29] studied racial variations in the extent of tooth root translucency and concluded that factors other than age may be important in the formation of sclerotic apical dentine in teeth of different racial origin. The effect of racial origin should be considered when using sclerosis as a means of age determination in forensic cases.[29]

Pulp/tooth area ratio as an indicator of age is quite a new age estimation method presented by Cameriere.[22] This method requires a radiographic image of an examined tooth, computer-aided drafting software and trained personnel. In extensive archaeological investigations where age estimation is only one of many parameters which must be determined, there is often no time, money and knowledge to perform such age assessments. This method, which is for a beginner time-consuming, is recommended in individual cases where a reliable and accurate age assessment is necessary both for living and deceased persons.[22] We used this method in our investigation in order to test the reliability and accuracy of the other three methods which are easier to perform and less time-consuming. Cameriere at al[30] tested the reliability in age determination by pulp/tooth ratio in upper canines in historical samples of known age and found that the pulp/tooth ratio method is not only a useful technique to assess the chronological age of living persons, but it is also a reliable tool in the determination of age at death in skeletal remains.[30]

It should be noted that in the age estimation the term "accuracy of an age estimation method" is the degree of closeness of the estimated age to the true (chronological) age. The term "precision of an age estimation method" is the degree to which repeated age estimations under unchanged conditions show the same results. Our specimens were of unknown age, therefore, there is no 'gold standard' against which the 'accuracy' of the methods can be gauged.

CONCLUSION

Using four adult age calculation methods in our investigation, age determination was possible in 100% of individuals, but with different levels of accuracy. The more methods used promised a higher level of accuracy. Number of used age estimation methods was dependent of the state of preservation of the skeletal remains.

Simple methods like palatal suture closure can provide data about age at death for large number of individuals, but with less accuracy. More complex methods which require qualified and trained personnel can provide data about age for a smaller number of individuals, but with more accuracy. Using different (both simple and complex) age calculation methods for archaeological samples can raise the level of confidence and percentage of success in determining age.

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TABLES and FIGURES

Table 1. *Age groups distribution according to occlusal tooth wear*

Age group (years)	N	%
<24	30	26.5
24 – 30	16	14.2
31 – 35	26	23.0
36 – 40	26	23.0
>40	15	13.3
Total	113	100.0

N = number of individuals

Table 2. *Age groups distribution according to root dentine translucency*

Age group (years)	N	%
<24	0	0.0
24 – 30	0	0.0
31 – 35	0	0.0
36 – 40	4	5.2
>40	73	94.8
Total	77	100.0

N = number of individuals

Table 3. *Age groups distribution according to pulp/tooth area ratio*

Age group (years)	N	%
<24	2	2.3
24 – 30	4	4.5
31 – 35	9	10.2
36 – 40	9	10.2
>40	64	72.8
Total	88	100.0

N = number of individuals

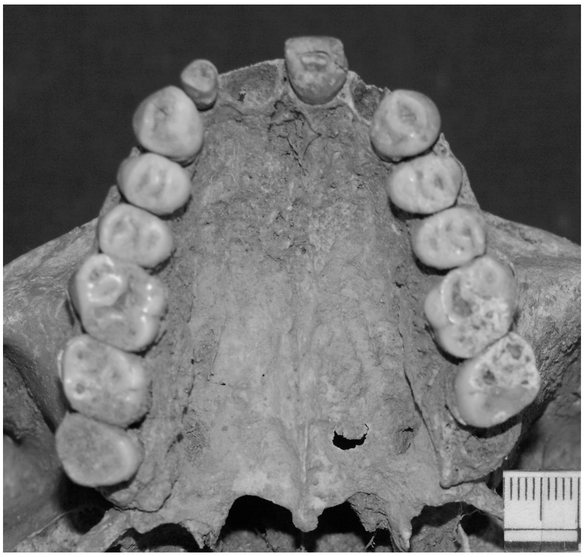

Fig.1. *Obliterated median palatine suture*

Fig. 2. *Open median palatine suture*

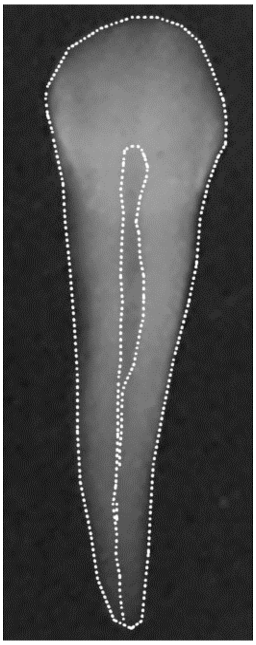

Fig. 3. *Age estimation using pulp/tooth area ratio (dotted lines on the radiograph indicate the outlines of upper canine and its pulp)*

DENTAL AGE ASSESSMENT: ARE DEMIRJIAN'S STANDARDS APPROPRIATE FOR SOUTHERN CHINESE CHILDREN?

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ABSTRACT

Estimation of age is an important requisite in forensic, judicial and criminal proceedings. Dental age can be estimated from a dataset that has been prepared from a similar or a different population group. Demirjian and his co-workers proposed dental maturity scores from a French-Canadian population and this has served as a reference dataset for evaluation of age for various population groups. Considering the high number of illegal immigrants who have entered Hong Kong from neighboring countries, age estimation studies on southern Chinese is warranted. This study aimed to validate the applicability of Demirjian's dataset on a southern Chinese population. A total of 182 dental panoramic tomographs comprising an equal number of boys and girls with an age range from 3 to 16 years were scored. Dental maturity scores were obtained from the Demirjian's dataset and dental age was calculated. The difference in chronological and estimated dental ages was calculated using the paired t-test. There was a mean overestimation of dental age of 0.62 years for boys (p<0.01) and 0.36 years for girls (p<0.01). Demirjian's dataset is not suitable for estimating the age of 3-16 years old southern Chinese children.

(J Forensic Odontostomatol 2011;29:2:22-28)

INTRODUCTION

Age estimation is an important requisite in some judicial proceedings. Circumstances where age assessment is required are; asylum seekers of unknown age, young people accused of criminal activities, and convicted criminals whose age is claimed to be less than 18 years prior to sentencing.[1] Universal law enforces that any asylum seeker under the age of 18 years should be considered as a child and has the right of abode in the country where asylum is claimed. Age assessment is, on occasions, required to assist in the identification process, especially of subjects from mass disasters.[2]

Age of an unknown person can be assessed by correlating the physical, skeletal and dental maturity of an individual. Many radiological methods involving dental maturity as an indicator have been widely studied.[3,4] This includes age estimations based on measurement of open apices of teeth, pulp-tooth ratio and the staging of tooth development.[5-7] The Tooth Development Stages (TDS) described by Demirjian and his co-workers is considered the most simple and reliable method as it hasl the highest values for both intra- and inter- observer agreement. [8]

The development of clinically useful radiographic images, especially the Dental Panoramic Tomograph (DPT), which shows the whole of the dentition on a single image, has provided clinical investigators with a uniquely effective way of assessing dental maturation.[9] Dental maturity scores based on the development of teeth from a French-Canadian population have been widely used as a standard reference.[8] Many investigators have evaluated its applicability for other populations. The results showed wide variations from the known chronological age of the subjects in the study.[10-12]

The number of illegal immigrants intercepted in Hong Kong from mainland China has increased from 1890 in the year 2009 to 2340 in 2010 representing a total increase of 23.8%. Considering this high increase, age estimation studies in southern Chinese are warranted.[13] The only study which utilized the Demirjian dataset for age assessment on southern Chinese was reported by Davis and Hagg who confined it to 5 and 7 year old children.[14] Consequently, there is a necessity to test the applicability of the Demirjian's dataset on a wide age group of southern Chinese population. Hence, the aim of this study was to evaluate the applicability of the Demirjian dataset on 3 to 16 years old southern Chinese children.

MATERIALS AND METHODS

Sample distribution

The study sample comprised 182 dental panoramic tomographs (DPT) obtained from the archives of Prince Philip Dental Hospital, Hong Kong. All of these films had been taken previously for routine diagnostic purpose so they were being reused. The sample numbers were divided into 13 groups with ages ranging from 3 to 16 years. Following this, 14 DPTs (7 for boys and 7 for girls) were randomly selected to represent each age group.

Inclusion and exclusion criteria

Good quality dental panoramic tomographs (DPTs) belonging to subjects who were of southern Chinese ethnicity were included. Subjects with one or more bilaterally missing mandibular teeth and with a medical history of developmental anomalies of the dentition were also excluded from the study.

Demirjian staging of tooth developmental stages (TDS)

Demirjian's classification of tooth development stages (TDS) was adopted in our study.[7] The staging system recognizes eight stages starting from initial calcification (Stage A) to root completion (Stage H).

Scoring method

The DPTs were scanned (Canon, Canon Inc, Japan) and transferred to a desktop computer (HP Pro 2000, HP Inc, US), so they could be viewed on a monitor under a magnification of 160 % for better visualization. A single calibrated examiner, who was well trained and experienced in assessing tooth development from radiographs analyzed all of the DPTs and scored the corresponding TDS for seven mandibular teeth on the left side. When a tooth was missing, the corresponding tooth on the right side was scored.

Intra-examiner reliability

Fifteen DPTs were scored for a second time after a period of 2 weeks to assess intra-examiner reproducibility. Cohen's kappa calculations were performed by comparing the TDS scores between the original and re-assessed DPTs.[15] The calculated Cohen kappa value (0.88) showed that the intra-examiner agreement was "almost perfect".

Calculation of chronological age (CA) and dental age (DA)

Chronological age (CA) was the age of the patient obtained by subtracting the date of birth (DOB) from the date at which the radiograph was taken (DOR) and the resultant values were expressed in decimal years. The Dental maturity score (DMS) for each TDS was obtained from the Demirjian dataset and the scores of all the teeth were added to provide an overall maturity score for each subject. This process was performed independently for boys and girls. The overall DMS was then converted to an approximate dental age using the comparison chart. The differences between the estimated dental age (DA) and the chronological age (CA) were calculated (DA-CA) separately for boys and girls and the overall differences were expressed in years.

Statistical tests

Data were analyzed using the statistical analysis computer software (SPSS 15.0.1 for Windows©, SPSS Inc. Chicago, US). As the normality (Kolmogorov-Smirnov test) assumption of the data appeared to be valid, paired t-test was used to analyze the differences between the estimated DA and CA. Statistical significance was set at $p<0.01$ to make the test more stringent and thereby to avoid the possibility of a difference in age estimation from occurring by chance. Pearson correlation analysis was also performed in order to derive the scatter plots of the mean difference in the dental age among various age groups.

RESULTS

The overall mean difference between the estimated dental age and chronological age for boys was 0.62 (±1.09) years ($p<0.01$) while for girls, it was 0.36 (± 0.95) years ($p<0.01$). Among the various age groups, the least difference in dental age was observed at approximately 7 years for boys and 9 years for girls (Table 1). Pearson correlation analysis further demonstrates variation between the estimated DA and CA among the boys and the girls ($p>0.01$). Minimal difference was observed in the younger children than the older ones (Figs. 1 and 2). The difference in the estimated dental age varied between +4.12 and -2.62 years for boys and +3.39 and -1.95 years for girls respectively.

DISCUSSION

Demirjian and his co-workers derived the initial dataset in 1973 and later updated the dataset with additional samples, both belonging to French-Canadian populations.[7,16] Our study evaluated the applicability of the original dataset by Demirjian et al (1973) on southern

Chinese children. This study has demonstrated the inapplicability of the Demirjian dataset in estimating the age of southern Chinese and the overall mean difference was 0.62 years for boys ($p<0.01$) and 0.36 years for girls ($p<0.01$). Genetic influences, socio-economic status, nutritional conditions and dietary habits have been reported as possible reasons for variations in skeletal and dental maturity among different populations and ethnic groups.[10,17]

In the current study, a total of 182 radiographs were chosen to estimate the applicability of the Demirjian dataset. A small number of radiographs (17 out of 182) were scored but the corresponding maturity scores were unavailable from the Demirjian's dataset, particularly at the upper and the lower extreme age groups. This could be attributed to variations in the dental maturity between the French-Canadian and the Chinese ethnicities. However, no effort was made to compensate for the missing numbers with additional radiographs in order to be consistent with the randomization procedure. Most studies that aimed to test the applicability of a dataset had variable numbers of subjects in each age group which, as a consequence, might affect the overall outcome of the study.[10-12] Hence, an effort was made in this study to standardize the procedure with an equal numbers of DPTs in each age group so that appropriate overall differences between the chronological age (CA) and the dental age (DA) could be determined.

Overestimation of age has been a consistent observation when the Demirjian dataset was applied for other populations and this has ranged from 0.20 years to 3.04 years in boys and from 0.23 years to 2.82 years in girls.[10,18,19] In contrast, underestimation of age was reported only in a Venezuelan population.[20] The finding that overestimation was more pronounced in the older children was also made by Nykanen and co-workers.[11] They indicated that the self-weighted scores of the Demirjian dataset were based on the midpoint between two successive stages and the appropriate score was assigned to that of the higher developmental stage. In addition, the time period between each individual stage increases with the age of the subject and so this phenomenon would result in an overestimation of the age expected for the older children. Furthermore, abnormal Gaussian distribution of dental age after a certain chronological age in the older individuals has also been suggested as a possibility for the overestimation of age.[21]

The number of stages included for calculation of the dental age determines the accuracy of age estimation. Hagg and Matsson compared the number of teeth and the various stages of development involved in dental age estimation between younger and older children.[21] They found that the stages occurring in younger age were of shorter duration and thus the higher degree of accuracy which occurred in young children may be attributable to the large number of stages with shorter duration. In our study, the estimated difference in dental age declined towards negative in older children and consistent underestimation of age was observed after 13 years in both the boys and girls. This was consistent with the studies conducted in Malaysian, western Chinese and Iranian populations which also demonstrated underestimation of age for older children.[22-24] In contrast, overestimation of age of older children was observed in northeastern Brazilian and south Indian populations.[10,25]

The Demirjian method of staging was utilized in our study because it has been claimed to be the simple and reliable method.[9] The DPT's were digitized so that the images could be magnified to make analysis much easier. However, difficulty was encountered when staging the teeth which were approaching root completion. The duration of time required for attaining the next consecutive stage is longer for stages F and G and this may have resulted in poor accuracy and reliability.[11] Moreover, certain stages of dental development were found to be easier to score and therefore more reliable. This was supported by Dhanjal and co-workers who reported that Stage E was the most reliable stage among Demirjian's classification of tooth developmental stages.[26] Considering the complexity of scoring and for better accuracy of the results, it has also been suggested that it would be beneficial to further split the stages proposed by Demirjian and his co-workers, especially, stages F and G.[17] The stages were split into F1 and GI and the resulting ten stage method has been successfully used.[27] However, this method of splitting the stages was refuted by De Salvia and co-workers who reported inaccuracy in the scores and poor inter-rater correlation.[28]

It has been postulated that Demirjian's dataset is only applicable for individuals aged from 3 years to 16 years. Our findings supported the notion that the Demirjian dataset was applicable for southern Chinese with chronological ages starting from 3.26 years for boys and 3.05 years for girls. When Demirjian's dataset was used to estimate the age, inaccurate results have been observed between different populations and also different groups of the same population.[19,25,29] This observation was found to be true when comparing the estimation results derived for western Chinese subjects, for whom the difference in dental age observed was -0.08 years for boys and 0.15 years for girls while for southern Chinese subjects, it was 0.62 years for boys and 0.36 years for girls.[23]

Davis and Hagg evaluated the applicability of Demirjian's dataset on southern Chinese children aged 5 to 7 years and found the dataset overestimated the age of boys by 10.8 months and girls by 7.2 months.[14] A similar age group (5 to 7 years) in our study was evaluated and the outcome was consistent with the previous study as the dataset overestimated the age of boys by 15 months (1.25 years) and girls by 6 months. Different statistical methodologies have been employed to adapt the existing data with Demirjian's dental maturity scores. The adapted scores represent statistical adjustments of the data and are not truly representative of the population. Furthermore, this statistical transfer of the data would not be able to take into account age estimations beyond 16 years of age.

CONCLUSION

Statistically significant difference and no correlation between the estimated dental age and the chronological age clearly indicates the inapplicability of the Demirjian's dataset to precisely estimate the age of southern Chinese children aged 3 to 16 years. Thus, it can be concluded that the Demirjian's dataset is inappropriate for estimating the age of southern Chinese children.

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Table 1. *Difference between the estimated dental age (DA) and chronological age (CA) among various age groups.*

Age group	Mean CA	Mean DA	(DA-CA)	P-value
Female				
3-3.9	3.68	3.55	-0.13	0.459
4-4.9	4.60	4.96	0.36	0.346
5-5.9	5.56	5.70	0.14	0.575
6-6.9	6.66	7.24	0.58	0.008*
7-7.9	7.52	7.69	0.16	0.297
8-8.9	8.30	9.09	0.79	0.068
9-9.9	9.54	10.00	0.46	0.307
10-10.9	10.63	11.66	1.03	0.075
11-11.9	11.33	11.65	0.32	0.565
12-12.9	12.57	13.36	0.79	0.098
13-13.9	13.48	13.92	0.43	0.244
14-14.9	14.89	14.15	-0.74	0.392
15-15.9	15.51	14.10	-1.41	0.036
Average	**8.92**	**9.28**	**0.36**	**0.001***
Male				
3-3.9	3.57	4.36	0.79	0.001*
4-4.9	4.45	4.47	0.02	0.949
5-5.9	5.61	6.90	1.29	0.000*
6-6.9	6.41	7.49	1.07	0.006*
7-7.9	7.23	7.74	0.51	0.002*
8-8.9	8.50	9.00	0.50	0.160
9-9.9	9.58	9.30	-0.28	0.405
10-10.9	10.80	11.54	0.74	0.123
11-11.9	11.51	12.43	0.92	0.307
12-12.9	12.60	13.45	0.85	0.008*
13-13.9	13.40	14.92	1.52	0.013
14-14.9	14.54	14.50	-0.04	0.227
15-15.9	15.30	13.65	-1.65	0.340
Average	**8.93**	**9.55**	**0.62**	**0.000***

* P value < 0.01
CA, chronological age; DA, dental age

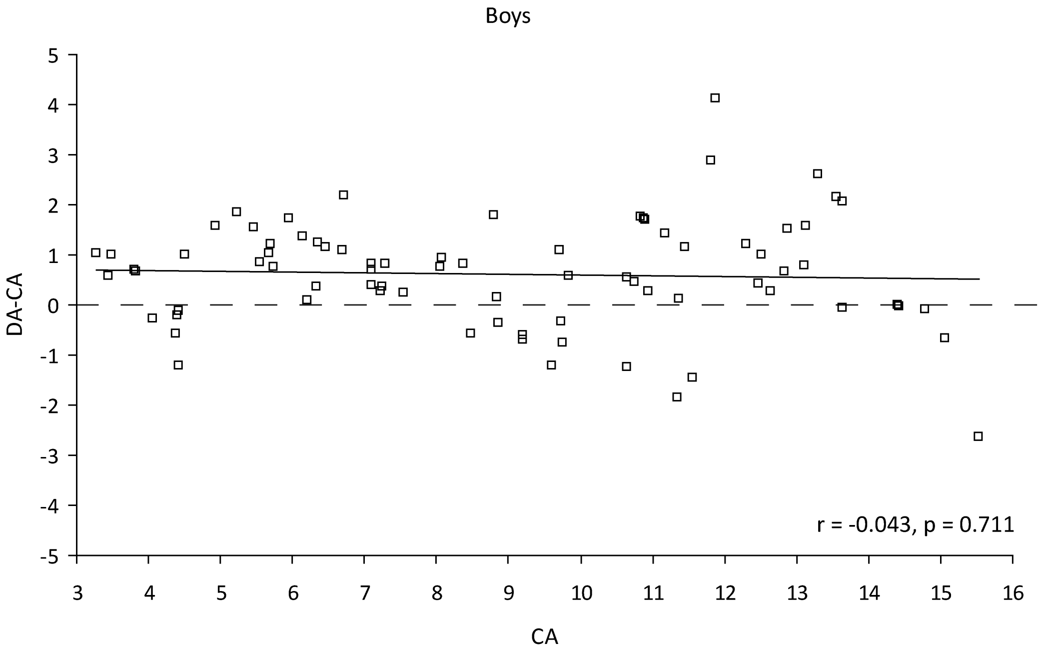

Fig. 1. *Regression line and Scatter plot showing differences in dental age and chronological age among southern Chinese boys.*

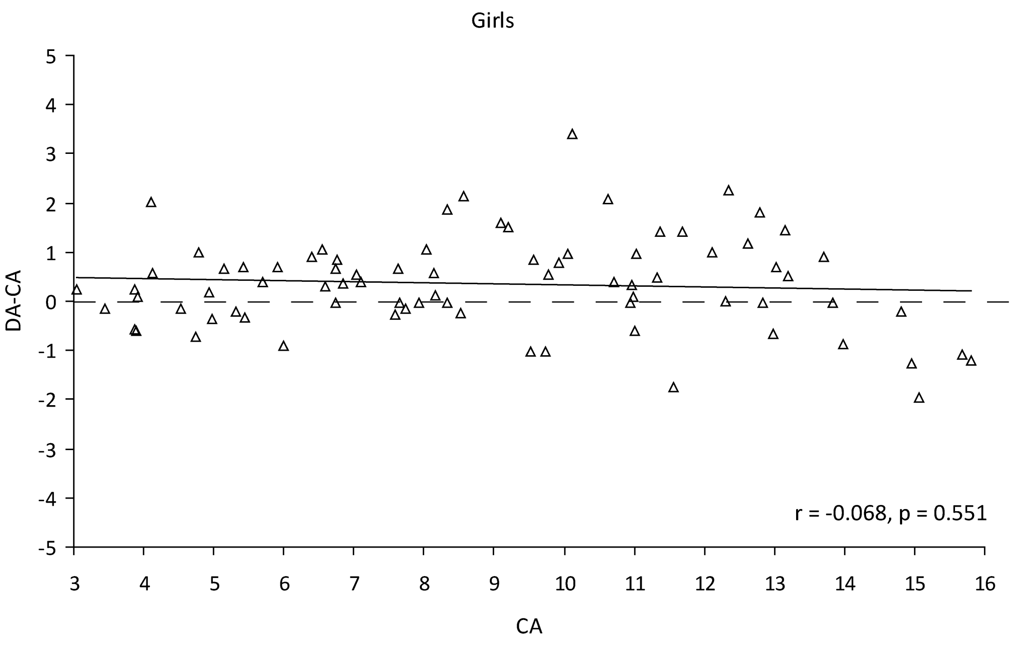

Fig. 2. *Regression line and Scatter plot showing differences in dental age and chronological age among southern Chinese girls.*

STANDARDS AND PRACTICES FOR BITE MARK PHOTOGRAPHY

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ABSTRACT

In most crimes where bite marks are discovered, photographic accuracy is crucial to the investigative process since in many instances the bite mark(s) may be the only evidence linking a particular suspect to the crime. Therefore, the rationale for employing superior photographic principles is mandatory for the investigation team. This paper will discuss current standards, best practice, and armamentaria for digital photography of bite mark injuries on skin. Full spectrum protocols will be described including Alternate Light Imaging, Reflective Ultra-violet, and Infrared techniques for photo-documentation of images of bite marks and other bruise patterns that have been inflicted on human skin.

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Keywords: forensic photography, bite marks, digital photography, Alternate Light Imaging, Reflective Ultra Violet photography, Infrared photography, Bite mark photography

Running title: Standards and practices – bite mark photography

INTRODUCTION

Accurate photographic documentation of a crime scene is a crucial component of any venture into evidence collection, especially when it applies to recording bite marks inflicted on humans during crimes of violence.[1] This exactitude of accurate images is particularly important since the comparative analysis of potential suspects to the bite is entirely dependent on how skillfully the photographic images of the injury are recorded. Historically bite mark photography gained relevance with film-based capture of images, where the film negative was used to enlarge the image to a life-sized printed photograph. An acetate or transparent hollow-volume overlay of the traced incisal edges of the anterior dentition of the suspected biter was then compared by hand to the bruise pattern on the victim.

The same fundamental principles exist today in bite mark analysis. However, since the arrival of digital cameras and computer imaging software, most qualified/knowledgeable odontologists today use digital imaging for both the collection of evidence from the victim, the analysis, and comparison to persons of interest. This paper will focus on the techniques used to properly record accurate images with digital camera systems in the visible and non-visible range of the electromagnetic spectrum of light.

STANDARD TECHNIQUE

Ensuring accuracy during the process of photographing bite mark injuries requires a thorough understanding of the basic principles of image capture, including a familiarization with the camera's features, limitations, and other equipment necessary for the task. Attempting to achieve success without first comprehending the fundamentals of photography is tantamount to playing golf in the dark. Familiarization with the essentials should occur long before the photographer ever finds him/herself employed in a real-time situation so that he/she knows exactly what camera settings, filters, and light sources are appropriate for each different protocol. A *Standard Technique* for crime scene photo-documentation includes proper orientation shots, close-up (macro) photography, correct angulation of the lens of the camera to the plane of injury, and inclusion of a scale with identifiers for each case.

ORIENTATION PHOTOS

Orientation shots are for the purpose of showing the location of the bite mark. These are usually captured from three to five feet from the subject and include enough information in the frame to see exactly where on the body the bite occurred (Fig. 1). Inclusion of a scale is not mandatory; however, it is a good idea to acquire a few images with a scale in place from this distance for data reference which can be included on a label attached to the scale. One recommended scale that is readily accepted by the forensic scientific community is the ABFO #2 scale available from Lightning Powder Corporation[2] (Fig. 2). This is an L- shaped scale with two arms perpendicular to each other. It includes millimeter indices, neutral grey color blocks, and perfect circles placed at the ends and intersection of each arm. The inclusion of the scale allows the user to determine photographic distortion if any, the ability to correct it later with imaging software such as Adobe Photoshop®, and facilitates enlargement of the injury to life-sized proportion. Johansen and Bowers described the protocol for image handling in "*Digital Analysis of Bite Mark Evidence"* published in 2000[3].

MACROPHOTOGRAPHY

Some basic prerequisites apply when taking close-up images of bite marks. Best practice includes first photographing the bite mark without a scale to demonstrate that there is no part of the injury that is obscured by subsequent images with the scale. The scale should then be placed adjacent to the injury without covering any portion of it. Positioning the scale in the same plane as the injury will provide better focal accuracy. Camera lens positioning in relation to the bite mark should be perpendicular to minimize angular distortion. Off-angle images introduce errors in size and shape of the injury, some of which cannot be corrected during enlargement. One simple technique for determining correct camera position is to place a small mirror over the area to be photographed, and oriented in the same plane as the injury. The photographer should look through the viewfinder of a tripod-mounted camera and be able to see his/her own eye looking back through the lens as it is reflected from the mirror. For bites on curved surfaces where it is difficult to achieve correct angulation of the camera for the entire bite mark, each arch of the bite should be photographed incrementally from the correct angle with the scale appropriately positioned for that arch. It is essential that proper labeling of the case being photographed be included in the images. Usually a sticky label can be attached to one arm of the scale, below the measuring ticks and away from the circular references at the ends of each arm of the scale. The data on the label may include either the case number or name of the victim, agency, date and the photographer's initials or name.

In some circumstances it is also appropriate to repeat the photographic documentation of the bite as it ages, particularly in decedents, since the bruise may become more defined as post-mortem changes occur in the tissue. Examination of the injury over a period of a week or two may prove to be valuable if time permits. Serial photographs should also be labeled in the same fashion for each session.

VISIBLE LIGHT IMAGING

Capturing images utilizing the visible part of the spectrum is the area where most photography is accomplished. In the past, there have been recommendations that bite marks should be photographed in both color and black and white film format due to the ability of the human eye to see differing details between these two modalities. With the advent of digital cameras and phasing out of film-based photography, both formats can be accomplished in one digital photo by opening the digital image in a software program such as Adobe Photoshop® and using the de-saturation feature to allow the viewer to see the differences between the color and monochrome details of the bite mark. Images can be acquired at almost any ISO rating using modern digital cameras that utilize improved chip technology and software. However, with film and some earlier digital cameras, higher ISO ratings (800 – 1600+) have been known to produce more grainy photographs due to the film emulsion qualities, or digital noise that may be generated by the camera's software. One advantage of shooting images at higher ISO ratings is improved depth of field from higher *f*-stops. If flash assisted, exposures from automatic digital settings on the camera will usually be adequate, however during macro photography, the user must frequently override those settings due to overexposure. One must familiarize oneself with the manual settings on the camera to correct for under and overexposed images.

If shooting forensic images, one convenient feature in many digital cameras is the advantage of recording in RAW mode. Although true RAW image files can be modified in software programs such as Adobe Photoshop® to correct for exposure and color balance, the modified image must be saved as a different file format such as J-PEG, TIFF, PDF etc., therefore preserving the original proprietary RAW image. Images shot in automatic mode usually produce J-PEG type files which are generally fine for showing the location (orientation) of the bite mark(s) in the visible part of the light spectrum but a programmable or manual mode features must be available for the Alternate Light, Ultraviolet and Infrared techniques. This will be discussed later.

A sturdy tripod is part of the required equipment necessary in order to achieve successful image documentation. Tripod mounting of the camera is usually applicable in shooting images out of the visible spectrum. In post-mortem photography a tripod is a useful tool for image composition and accurate focus, although sometimes it is difficult to position the camera directly over a bite mark when the gurney presents a hindrance. When the subject is a wriggling child, the use of a tripod is typically out of the question.

The resolution of images (size of digital file) should be large enough for the user to enlarge the image to life-size proportions at a minimum of 300 dots per inch (DPI) without loss of fine detail. The ability to transfer the image to either a hard drive or directly download it from the camera is also a must. The file size of the images should also be selectable through the camera setup mode, as well as the speed (ISO) during exposures.

Some digital cameras are equipped with a fixed zoom lens capable of macro photography, portrait, and telephoto ranges, while other camera bodies require multiple lenses for different camera-to-subject distances. Cost is always a consideration and recommendations for what type of equipment one should acquire is generally determined by the user's ability to purchase it. This author's recommendation is to find a mid-range "Pro-sumer" level SLR type 35mm format camera with a fixed zoom lens and the aforementioned capabilities.[4] A liquid crystal diode (LCD) viewing screen, particularly one that articulates, is a highly desirable feature so that one can immediately see whether or not the correct settings were used for each captured image. Some digital cameras also use the LCD as a preview screen for composing the field of view before actually acquiring the image.

ALTERNATE LIGHT IMAGING: (ALI)

Most digital cameras that are purchased with the intent of taking visible light images will also be capable of capturing images using a forensic light source as long as it has a "manual mode" wherein the user can adjust exposure settings either by changing the aperture of the lens and/or the time of the exposure. The exposure time is electronically determined by the software that drives the system and exposes the image to the electronic sensor inside the camera. That information is then written to the flash card as an electronic file, usually numbered according to the sequence of the images acquired. Another positive feature about many digital cameras is that metadata is also acquired simultaneously with the image. Metadata is a history of hidden information about each captured image that includes what settings were used to acquire the image, usually accessible from the "properties" pull-down menu when the image is right-clicked with a computer mouse. Each image, whether in RAW form, TIFF, or JPEG format has its own metadata. This metadata also typically includes the date the image was acquired or modified, type and size of the file, ISO, exposure duration, and *f*-stop.

There are specialized pieces of equipment one must obtain in order to take alternate light images. First, a forensic light source is necessary for illumination. There are numerous light source manufacturers that can be found on the internet. They range in features from a tunable multi-wavelength emitter, portable or hand-held equipment, or ring lights that emit a discreet frequency of light. For bite mark photography on skin, a 450 nanometer (blue) light is best since research has shown that skin has a peak fluorescence at that frequency[5]. Another requisite is a #15 yellow filter placed in front of the camera lens. The filter blocks the reflected blue light and transmits a lower frequency of light to the sensor, in effect, capturing a fluorescing image of the bruise. Without delving into the theoretical aspects about the bioluminescence of tissue, it can be summarized that the alternate light image shows details of the bruise pattern below the level of the epidermis by enhancing the differences between injured and uninjured tissue. Below the epidermis is where most of the blood and blood pigment components of the bite mark bruise are located. This author has found that slightly underexposing the image during ALI at least one or two stops will produce better results than capturing the image at normal or overexposed settings. In post-mortem situations the camera must be tripod-mounted for this protocol since exposure times can vary between ¼ second to 1 second intervals at mid-range *f* - stops. The photographer should first illuminate the bite mark with the forensic light source and set the correct exposure through the camera's metering system. Actual exposure time is dependent upon the ISO speed, strength of the forensic light source, the amount of pigmentation in the skin of the subject, and location of the bite mark. The last important item that must be mentioned when shooting ALI is that it should be done in total darkness, where the only light source illuminating the subject is from the forensic light. Focusing can be done through the yellow filter attached to the lens while overhead lights are on, but turn out all other lights for image acquisition. Figures 3 and 4 illustrate the differences between a bite mark image collected in visible and alternate lighting.

INFRARED PHOTOGRAPHY (IR)

Prior to the introduction of UVIR digital cameras, all images were film based. Special IR film is still available for purchase, however there are specific handling, developing, and focusing requirements that must be employed for successful image capture.

Unfortunately most digital cameras are designed for capturing images using visible light only. Their manufacturing process includes software designed for only the visible part of the light spectrum and a special filter in front of the electronic sensor that blocks the UV and IR ends of the spectrum. Therefore in order to acquire IR images with a digital camera, one must either have a camera that has been produced specifically for UV and IR capture, or modified to accomplish the task. Fujifilm of North America® was the first company to produce a digital camera with these capabilities. Sadly, these cameras are no longer being produced. However, there are a few companies that for a fee will modify some digital cameras for UV and IR shooting.[6] Many a fine art photographer has modified an older, retired digital camera and resurrected it for use specifically for IR imaging. The same modification allows the forensic photographer to shoot images in infra-red and ultraviolet.

Digital infrared photography can be tricky when it comes to recording bite marks in that one must adjust for a focal shift due to the longer wavelength of light reflecting back to the sensor. Focal shift changes can be eliminated with a quartz lens, a subject that will be discussed in the UV section of this paper. An IR filter must also be placed over the lens so that only the IR part of the spectrum is transmitted through the lens to the sensor. There are several types of IR filters to choose from, however a #87 glass or gelatin filter will suffice for this application. Lighting for IR is generally not an issue, as most ambient or room light will be adequate for exposures. In bite mark photography, the IR range of the spectrum shows the viewer the deepest part of the bruise pattern, well into the dermis and underlying vascular tissue. Results are often mixed, with IR photos showing less detail than ALI and visible techniques. However, one very useful area where IR application outperforms visible light techniques is in tattoo documentation when the original tattoo is either occluded or has faded considerably (Fig. 5, 6). IR also has the ability to “see” through blood (Fig 7, 8).

With practice, the forensic photographer should be able to repeatedly get good results using the IR technique.

REFLECTIVE ULTRAVIOLET PHOTOGRAPHY (UVA)

Purchasing the necessary UV forensic photography equipment can become quite expensive. In order to have the capability to acquire UV images of bite marks, one needs some very specialized components. The digital camera again must be either modified or designed with UV acquisition in mind. Fuji Corporation’s most recently produced version of this type of digital camera was designated the IS Pro (Fig. 9). The software was adapted for UV capability and the blocking filter removed. Currently, there are still a few of these cameras for sale if you can find them, however the glass lens that is sold with them is not ideal for UV transmission. In order to maximize the amount of UV light transmission to the sensor, a silicon-based (quartz) lens should be used. Quartz lenses are available for purchase from UKAoptics[7] and Coastal Optical Systems.[8] One other necessity for capturing ultraviolet images with a digital camera is the Baader UV filter.[9] Quartz lenses usually sell for about $4000 U.S, the filter costing about $275.00.

As for illumination during UV imaging, the more powerful the light source, the better the results. Adequate lighting requires a flash or strobe source with a high rating value, capable of creating an intense burst of light, usually through a UV filter placed in front of the flash window. Quantum Corporation®[10] makes such an item specifically for UV imaging. Some of the more expensive Vivitar® strobe units also provide adequate light for this technique. Whichever unit is purchased must be matched to the capabilities of the camera. This means the camera must have compatibility and enough power in the electronics to trigger the flash unit and synchronize its activation simultaneously with the exposure sequence. Ultraviolet images unlike IR and ALI depict the surface disruption of the skin when used for bite mark photography. Professional assistance is highly recommended when assembling the components for all of these three advanced photographic techniques.

PHOTOGRAPHIC EVIDENCE MANAGEMENT

Images collected during crime scene documentation, including bite marks, may become part of the legal system and as such, are subject to chain of evidence rules. The photographer becomes accountable for their possession and/or transfer to other involved participants of the investigation. It is very important to maintain the integrity of those images in their original form, and to document any modifications during their reproduction during analysis. Any steps taken during the collection, management, and file reproduction of images should follow the Imaging Guidelines developed by the Scientific Working Group on Imaging Technologies (SWIGIT) found at: http://www.fdiai.org/images/SWGIT%20guidelines.pdf

CONCLUSIONS

To summarize, biting injuries are complex and the evidence collection, analysis and interpretation should be handled with caution. Acquiring accurate, reproducible images is just one part of the process – albeit an important one. It should be stated that not all situations will require all of the previously discussed techniques. There will be instances where one advanced non-visible technique will outperform all others in terms of quality of images gained. Sometimes none of the advanced techniques provide any advantage over the tried and true visible light protocol. With practice, the seasoned forensic photographer will be able to predict which protocol will provide the best results before ever opening the camera case. It must also be said that even if none of the advanced techniques prove useful, it does not mean the entire session is a failure. Frequently the evidentiary value of the bite mark is of such low quality that neither advanced nor visible imaging protocol will be of use to the investigator. Sometimes the best option in those inferior cases is to disregard the bite mark evidence completely and rely on the DNA results instead.

Photography is an important tool of forensic dentistry and the demands on the photographer may be great, especially when the bite mark is the sole evidence tying a suspect to the crime. Patience and preparation in advance will ultimately lead to more successful results, albeit frustrating in many instances. The forensic photographer who develops the skills necessary to record these injuries will make a significant contribution to the case. Documenting bite marks in advanced photographic protocols will remain one of forensic dentistry's greatest challenges.

The author acknowledges that he has no financial interest, nor current affiliations with any of the manufacturers of products recommended or mentioned in this paper.

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FIGURE LEGEND

Fig. 1. *Orientation photo giving anatomical location of biting injury*

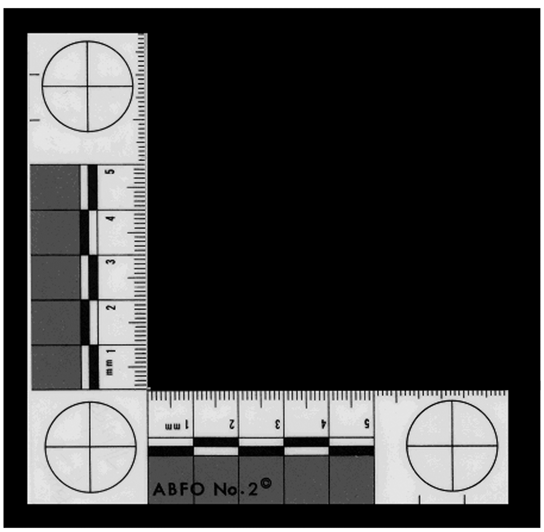

Fig. 2. *ABFO #2 scale*

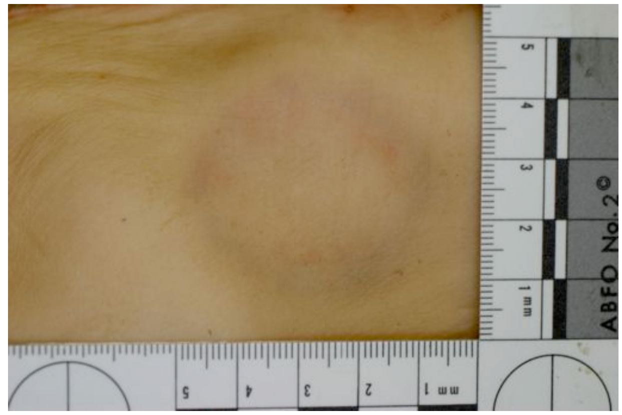

Fig. 3. *Visible light image of two-week old bite on arm*

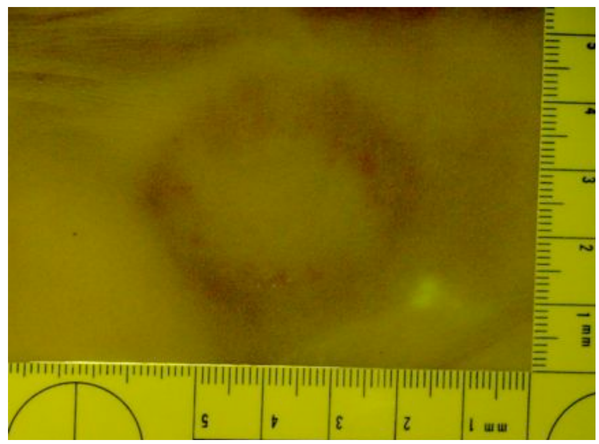

Fig. 4. *Alternate light image of same bite as seen in Fig. 5*

Fig. 5. *Tattoo occluded by hair in scalp of homicide victim*

Fig. 6. *Same tattoo as seen in Figure 9 using Infra-red protocol*

Fig. 7. *Facial wounds with blood*

Fig. 8. *Infra-red image of Fig. 11*

Fig. 9. *Fujifilm ISO Pro UVIR professional grade camera*

A PILOT STUDY IN THE RECOVERY AND RECOGNITION OF NON-OSSEOINTEGRATED DENTAL IMPLANTS FOLLOWING CREMATION.

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ABSTRACT

Minimal dimensional changes in free standing dental implants when incinerated in a kiln to a temperature of 1125°C have been reported previously. However, in the same study colour changes were observed between commercially pure titanium and titanium alloy type of implants, with speculation that this change may be a useful distinguishing tool in cases requiring forensic identification. The present study was instigated to determine what changes occur following cremation to bone-supported dental implants placed within mandibles of sheep. A selection of dental implants was photographed and radiographed. They were then surgically placed in sheep mandibles and the entire sheep heads cremated in a commercial cremator. There was detachment of the dental implants from the mandible, which could have implications for scene recovery. Following retrieval and re-irradiating of the implants, image subtraction evaluation of the radiographs was recorded using Adobe® Photoshop.® As with the previous study there was slight oxidation of the implant surfaces leading to minor alteration of the images. There was, however, no gold crust colour change in the commercially pure titanium. Photography within the retrieved implants revealed the batch number within the Straumann™ implant was still visible, which could significantly add weight to the identification of deceased persons.

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Keywords: Forensic odontology, dental implants, incineration, identification, sheep heads.

Running Title: Non-osseointegrated dental implants following cremation

INTRODUCTION

The identification of deceased victims is important for both moral and economic reasons. The family and friends of the victims are aided in closure with the certainty that identification brings. The legal and financial processes for the relatives and the relevant government authorities are also able to proceed.[1-3]

Current dental treatment practice has encompassed the use of implants as a viable method of replacing single or multiple missing teeth. This treatment option is occurring at a rapidly growing rate[4-6] increasing the likelihood that implants will be present in deceased victims and be detected in postmortem radiographic examination. As commercially pure titanium and titanium alloy dental implants have a melting point greater than 1650°C[7] the likelihood of implants surviving severe thermal insult is high.

If antemortem records are available, the matching of implants using postmortem radiographs or metric analysis is a straightforward process. If the deceased is unknown, the detection of dental implants could aid in the investigation of the victim by identifying the type, make and sizes of the implants.[8] Website search engines are available that can assist with the implant identification.[9] Regional manufacturers' sales records for the particular type and size of implants recovered in a postmortem examination could narrow the possibilities from a list of missing persons. The results of our recent research suggest that free standing dental implants heated in a temperature-controlled kiln are still recognizable following incineration and that there appeared to be a colour difference between commercially pure titanium and titanium alloy on their oxidized surfaces.[10]

Since 2010, the Straumann™ company has been laser etching batch numbers within the chamber of their implants. The number of implants with the same batch number varies between 24 and 2400 implants (*Per com.* Schuler M, Head Clinical and Scientific Affairs, Straumann™ Company). Although this number is still quite high it reduces the frequency from many thousands in some cases. A recent pilot study tested the ability of the etched batch numbers to be identified following intense heat exposure in a furnace at 1125°C.[11] In this previous study the removal of the abutment following incineration in the furnace revealed an intact identifiable batch number.

An issue identified in the previous study was that the implants were free-standing within a furnace, with no osseointegration with bone, nor were they contained within biological tissue.

This study was instigated to determine:

- What changes occur following cremation to dental implants surgically placed within mandibles of adult sheep, in an environment closer to reality where the implants are located within bone and exposed to fire in the presence of tissues and fluids?
- Whether the numbers within an implant were still visible following this incineration.

MATERIALS AND METHODS

Implants were requested from various dental companies. A Straumann™ Regular 3.3 x 10mm, a Nobel Biocare Replace Select™ 4.3 x 8mm, an Ankylos® plus 3.5 x 17mm, two Zimmer™ 3.7 x 13 mm, and a Neoss™ 3.5 x 9mm implants were kindly donated for this study. Each implant was photographed with a digital camera (Nikon Coolpix 5900, Tokyo, Japan) externally then internally with the aid of a WILD Heerburg™ microscope (Leica Microsystems, Wetzler, Germany). Each implant was irradiated for 0.18s at 65kVp, 8 mA using a Belmont Searcher model DX-068 (Takara Belmont, Osaka, Japan). The sensor was an MPSe Ethernet digital with Cygnus software (Cygnus Technologies, Scottsdale, USA). To allow standard methodology, purpose built apparatus made from a cold cure resin (VertexTM Trayplast, Zeist, The Netherlands) constructed for the previous study[10] was again utilized. To reproduce the rotation of the implant within the positioning aid, each implant was superficially marked on its leading head edge with a high speed diamond bur and this mark was aligned forward to the beam on a marked area on the positioning apparatus.

Two fresh adult sheep heads were sourced from a local abattoir. On the same day three mandibular incisor teeth were extracted from each head and spaced so that there was a tooth and supporting bone on each side of the extraction socket. The implant was then torque wrenched into each socket to bone level. An abutment or healing cap was then screwed on with tight finger pressure.

The heads were transported to a professional animal crematorium and placed in a gas fired Pathological Incinerator (Civil & Mechanical Services, Torrensville, Australia). Incineration continued for 2.5 hours, reaching a maximum temperature of 780 °C, before the heads were allowed to cool and the remains removed from the incinerator. The implants were retrieved from the carbonized material, re-photographed externally and internally, and re-irradiated.

As in the previous study[10] radiographic images of the implants taken before the firings were compared to the images taken after the firings utilizing the computer software Adobe® Photoshop® CS (Adobe Systems, San Jose, USA). An image subtraction function of the software was used to highlight differences between the images.[12] The retrieved incinerated implants were further examined using a Phillips XL20 Field Emission Scanning Electron Microscope (Amsterdam, Netherlands). The characteristic Xrays from the beam/specimen interaction, producing elemental spectra and maps of the surface, were analyzed with an EDAX® Unit (AMETEK, Inc, Mahwah, NJ USA).

RESULTS

During incineration teeth dislodged from their sockets in partially cremated sheep heads (Fig. 1) and following total incineration implants had fallen through the friable bone ash and had separated from the mandible (Fig. 2). All the implants appeared grey in colour (Fig. 3) and no distinctive gold-coloured crust was visible on the surfaces of the pure titanium implants.

The results of the comparative analysis in Adobe® Photoshop® CS revealed minimal image differences of all implants (Fig. 4). No detectable sagging was noted and the recognition features of threads and grooves were still identifiable.

The SEM images of the implants indicated little crust formation on the surface as seen in Fig. 5. There were at least three distinct surface shade differences (black, grey and light grey) on the implants (Fig. 6). The elemental analysis revealed that the majority of the surface (light grey) consisted of titanium oxide (Fig. 7). Small black areas of carbon (Fig. 8) were identified and other areas contained bone elements (calcium and phosphorus) and serum salts (sodium, potassium, chlorine) (Fig. 9).

Microscopic examination of the chambers revealed the batch number clearly visible within the Straumann™ implant before firing as shown in Fig. 10. Following the incineration the healing cap was removed easily. It can be seen in Fig. 11, the number was still visible, although not as clearly as in Fig. 10. Following the removal from the furnace of implants from the other companies and unscrewing of the fixtures, their internal chambers also showed little oxidation (Fig. 12). No batch numbers were observed in the other studied implants.

DISCUSSION

The observation that the some implants had fallen away reinforces the suggestion that odontologists should be involved in the scene phase of a fatality, especially where there has been severe incineration of the victims.[13,14] The retrieval of small dental implants and other dental restorative material, which could be pivotal in identification, might be overlooked by personnel not accustomed to identifying dental structures. Retrieval and radiographic screening of debris from the area around the head in incineration cases will readily locate implants that have detached from the body.

The lack of gold colour or thick crust could be attributed to the lower temperature of the incinerator or the formation of carbon on the implant first creating a barrier or a combination of both factors. The exact temperature that the implant reached would be difficult to predict, as the sheep heads ignite. There could be localized hot spots but as the incinerator did indicate 780 °C it is assumed that this was the minimum temperature. A further study incinerating the implants within sheep to temperatures closer to 1100 °C, similar to the early study,[10] would be required to see if a crust forms and that a gold appearance also eventuates on commercially pure titanium implants.

The elemental analysis significantly found bone elements of calcium and phosphorus indicating some bone contact with the implants. Osseointegration of implants takes approximately three to four months in live animals or humans.[15] If osseointegration was allowed to occur before the animals were sacrificed it is presumed that the amount of bone elements would be greater. If an implant was found at the scene with no bone elements present (upon analysis) it may suggest that the implant had not been placed in bone – this may help confirm or refute the suspicion that it had been deliberately placed at the scene with intent to complicate identification.

As the batch number was still visible and all the chambers had little oxidation it can be assumed that if numbers were laser etched in all implants that they would also be visible. If all dental implant companies placed a serial number within them and the local authorities legislated that a register be kept, dental implants would become extremely important in identification. Similar registers are maintained in Australia and the United states for knee and hip replacements.[16,17]

As well as having a high melting point, titanium is highly resistant to corrosion which could be useful in acidic or saline environments. Further studies would be required to prove this hypothesis.

CONCLUSION

Due to their physical properties, implants will resist thermal insult and will also retain the features such as shape and thread pattern necessary to identify the type of implant. The detachment of the implants from the mandible could have implications for scene recovery and debris collection from around and below the location of the head is recommended. The gold crust formation noted in the previous study was not visible under the present study conditions (possibly due to the lower temperature or to tissue contamination) but the ability to read the batch number within the Straumann™ implant following the incineration was replicated, adding weight to the previous study.

Ideally, for forensic identification purposes, each implant would be etched with an individual serial number. The survival of serial numbers would benefit forensic odontologists worldwide as data for identification. It would strongly support the need for an odontologist to visit the scene of a disaster where severe incineration of victim or victims has occurred to search for possible implants.

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FIGURES

Fig.1. *Partially incinerated sheep head showing dislodged tooth*

Fig.2. *Ashened sheephead mass following incineration and removal from incinerator*

Fig.4. *Image subtraction results for Nobel Biocare Replace Select ™ 4.3 x 8mm, Similar results were observed for each brand of implant: minimal image difference after incineration.*

Fig.3. *The Nobel Biocare Replace Select ™ 4.3 x 8mm after incineration.*

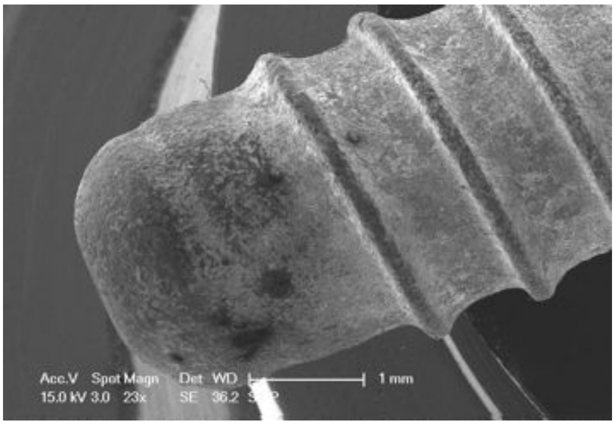

Fig.5. *Base of the Straumann ™ Regular 3.3 x 10mm showing little crust formation.*

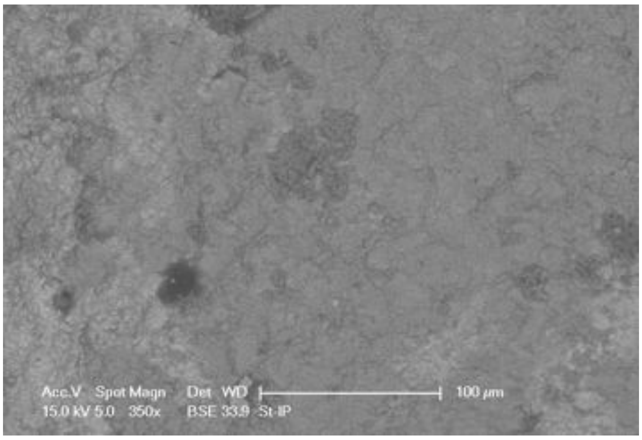

Fig.6. *The three distinct surface shade differences (black, grey and light grey) on the implants.*

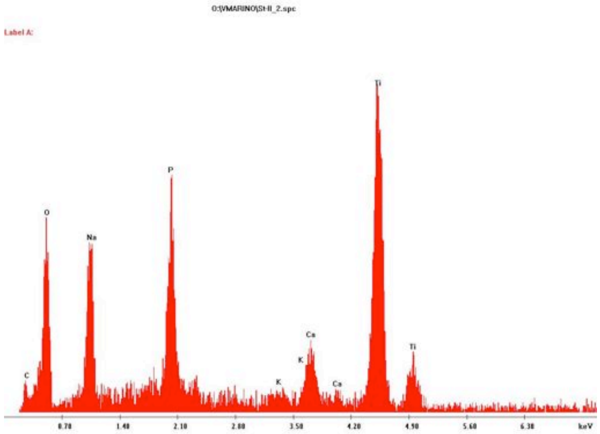

Fig.9. *Elemental analysis of the grey area depicting bone elements and serum salts together with titanium.*

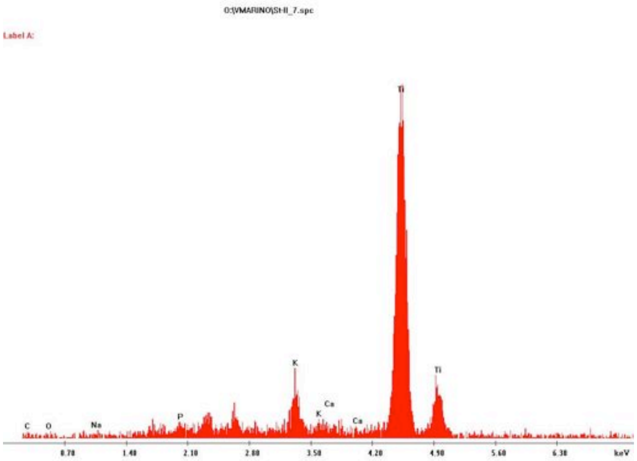

Fig.7. *Elemental analysis of the light grey area depicting a peak of titanium.*

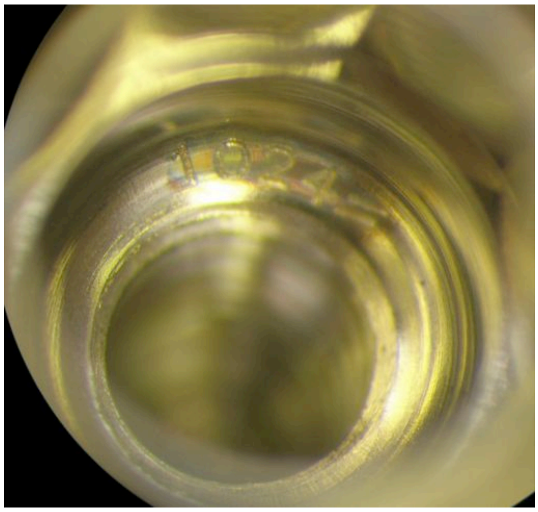

Fig.10. *The batch number clearly visible within the Straumann ™ implant before firing.*

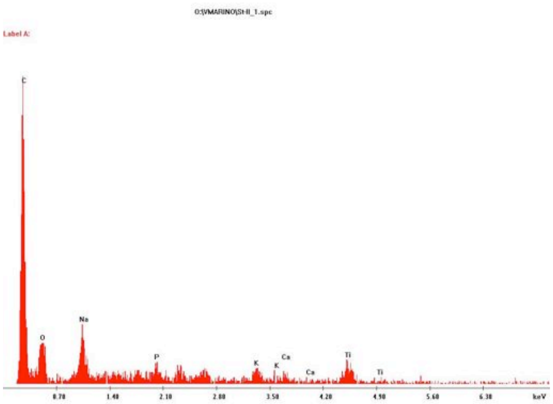

Fig.8. *Elemental analysis of the black area depicting a peak of carbon.*

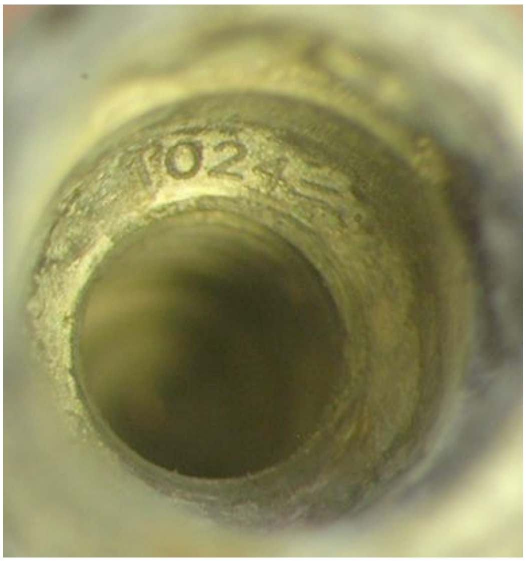

Fig.11. *The batch number within the Straumann ™ implant after firing.*

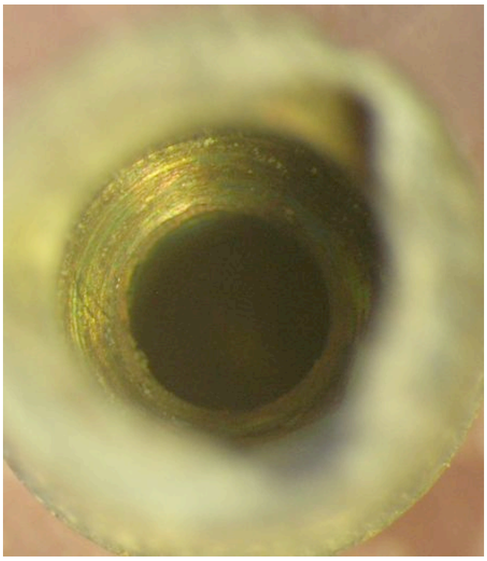

Fig.12. *The internal chamber of the Nobel Biocare Replace Select ™ 4.3 x 8mm after incineration.*

STUDY OF THE EFFECT OF AGE CHANGES ON LIP PRINT PATTERN AND ITS RELIABILITY IN SEX DETERMINATION.

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ABSTRACT
Cheiloscopy, a forensic investigation technique, deals with the study of elevations and depressions which form a characteristic pattern on the external surface of the lips. The objective of the study was to determine the most common lip patterns in North Indian population, to evaluate whether sex determination is possible on the basis of lip prints and to ascertain if there is any co-relation between advancing age and its effect on lip pattern. A total of 600 subjects, 289 males and 311 females were selected and divided into three age groups (group 1: 1-20 years, group 2: 21-40 years, group 3: 40 years and above). Statistical analysis (applying Chi square test) showed very highly significant difference for different lip patterns ($p < 0.0001$) in males and females in group 2 and no significant difference in group 1 and group 3. The most predominant pattern in the entire study population was Type I (32.33%). Age changes like immaturity of lips in younger age and diminished anatomic details and tonicity in older age can have a considerable effect on the lip pattern, thereby making the correct identification of sex in these age groups debatable.

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Key words: Cheiloscopy, lip prints, sex determination, forensic odontology.

Running title: Lip prints and its correlation with age and sex.

INTRODUCTION
The positive identification of living or deceased persons using the unique traits and characteristics of the teeth and jaws forms a cornerstone of forensic science.[1] Investigators often gain information and evidence through the use of odontology, anthropometry, fingerprints and other techniques that help determine, for example; gender, approximate age and height. Today, however, investigators may also rely on lip prints to identify possible suspects or to support evidence gained in specific investigations.[2]

The wrinkles and grooves on the labial mucosa (called sulci labiorum) form a characteristic pattern called “lip prints,” the study of which is referred to as cheiloscopy.[3,4] Fischer was the first to describe it in 1902.[5] Use of lip prints in personal identification and criminal investigation was first recommended in France by Locard.[6] In 1950, Synder also suggested the idea of using lip prints for identification.[7]

Lip prints are considered unique to an individual and analogous to fingerprints.[8] It has been verified that lip prints recover after undergoing alterations such as minor trauma, inflammation and herpes. However, major trauma to the lips may lead to scarring, pathosis and the surgical treatment rendered to correct the pathosis may affect the size and shape, thereby, altering the pattern and morphology of the grooves.[3]

A lip print found at the scene of a crime can be a basis for conclusions as to the character of the event, the number of people involved, sexes, cosmetics used, habits, occupational traits and the pathological changes of lips themselves.[2] Lip prints, as one of the dermatoglyphics, have been used as genetic markers in many congenital and clinical diseases.[9]

Very few studies have been conducted in the North Indian population with a large sample size. This study was designed with the prime objective of determining the most common lip pattern, differences in lip prints between males and females and to evaluate co-relation of lip prints with advancing age.

MATERIALS AND METHODS
The present study was undertaken amongst 600 subjects (289 males and 311 females). The subjects were divided into three age groups:
Group 1 (1-20 years) - 150 subjects; 72 females and 78 males
Group 2 (21-40 years) - 300 subjects; 159 females and 141 males
Group 3 (above 41 years) - 150 subjects; 80 females and 70 males.
All the participants were briefed about the purpose of the study and their lip prints were

obtained with their consent. Those with any inflammation, trauma, congenital deformity or any other disease of the lips were excluded from the study. Those with any known hypersensitivity to the lipstick that we would use were also excluded from the study. The materials comprised:

1. Lipstick of a dark, bright colour and non-glossy.
2. Transparent cellophane tape, glued on one side
3. Scissors
4. White bond paper
5. Magnifying lens.

The subject was asked to open the mouth and lipstick was applied in a single motion, evenly on the lips. The subject was asked to gently rub his/her lips together to spread the lipstick evenly. A strip of cellophane tape, ten cm long was cut with scissors. The subject was asked to relax the lips and to keep the mouth stationary and closed during the procedure. The glued portion of the cellophane tape was applied on the upper and lower lip together. It was held in place, applying gentle and even pressure for a few seconds. Then the tape was carefully lifted from the lips, from one end to the other, avoiding any smudging of the print. The strip of cellophane was attached to a piece of white bond paper. This served as a permanent record. The subjects' serial number was written on the back to serve as a record.

The print was subsequently visualized with the use of a magnifying lens. The number of lines and furrows present, their length, branching and combinations were noted. The lip prints obtained, were coded while noting the name and sex of the respective individuals. At the time of analysis the sex of the patient was not disclosed to the observer (two of the authors).

For classification, the middle part of the lower lip (ten mm wide) was taken as a study area because this fragment is almost always visible in any trace and as this is the part most frequently found at a crime scene.[4] In this study, we followed the classification of patterns of the lines on the lips proposed by Tsuchihashi, which is the most widely used classification in literature.[10] It was found to have a clear description of nearly all of the commonly encountered lip patterns and was easy to interpret as follow:-

Type I: Clear-cut vertical grooves that run across the entire lips
Type I′: Similar to type I, but do not cover the entire lip
Type II: Branched grooves
Type III: Intersected grooves
Type IV: Reticular grooves
Type V: Grooves do not fall into any of the type I - IV and cannot be differentiated morphologically (undetermined).

The sex of the individual was determined as per the descriptions given by Vahanwala et al.[6,7]

Type I, I′:	Patterns dominant - Female
Type II:	Pattern dominant - Female
Type III:	Pattern dominant - Male
Type IV:	Pattern dominant - Male
Type V:	(varied patterns) Pattern dominant - Male

Same patterns in all quadrants: Pattern dominant – Female.

The frequency of each type of lip print was tabulated and the percentage of each type was calculated. The data was compiled and analyzed with Chi – square test and a p – value less than 0.001 was considered as significant and less than 0.0001 as very highly significant.

RESULTS:

The examination of lip print patterns revealed that no two lip prints matched with each other, thus establishing the uniqueness of the lip prints. The most predominant pattern in the entire study population was Type I (32.33%). This was followed, in order, by Type III (26.1%), Type II (9.83%), Type IV (7%), Type I' (6.1%) and Type V (2.6%).

In females Type I (59.48%) lip pattern was most commonly found followed by Type II (12.54%) and Type III (11.89%). In males, Type III (41.52%) lip pattern was predominant, followed by Type I (37.71%) and Type IV (9.68 %). So the most common lip pattern for females is Type I and the most common lip pattern for males is Type III.

In group 1: (90.27 %) 65 out of 72 were correctly identified as female and 23 out of 78 (29.48 %) were correctly identified as male. In age group 1, Type I was the most common pattern in both males and females (Table1).

In group 2: (84.9 %) 135 out of 159 were correctly identified as female and 93 out of 141(65.9 %) were correctly identified as male. In age group 2, Type I was the most common pattern in females and Type III in males (Table 2).

In group 3: (65 %) 52 out of 80 were correctly identified as female and 40 out of 70 (57.14 %) were correctly identified as male. In age group 3, Type I was the most common pattern in females and Type III in males (Table 3).

The accuracy of cheiloscopy in sex determination was 58.67 %, 76% and 61.33 % in group 1, 2 and 3 respectively.

The Chi square test applied to test significant difference between males and females for different types of lip patterns in different age groups, showed a significant difference at 1% significance level for group 1, very highly significant difference for the patterns in group 2 and highly significant for group 3.

DISCUSSION

Human identification is one of the most challenging subjects that man has been confronted with. Identification of an individual is a pre-requisite for certification of death and for personal, social and legal reasons. Lip prints can be instrumental in identifying a person positively.[3,4]

A series of forensic odontological studies on the morphology of the lips and the pattern produced when they are impressed onto a variety of surfaces forms a worthy additional weapon for personal identification.[10] The vermilion border of the lips together with an individual structure of lines may constitute a source of circumstantial evidence. Cheiloscopy is applicable mostly in identifying the living, since lip prints are usually left at crime scenes and can provide a direct link to the suspect. Lip prints can be found on surfaces such as glass, clothing, cutlery or cigarette butts. Even the invisible lip prints can be used and can be lifted using aluminium and magnetic powder.[11,12] The edges of the lips have sebaceous glands with sweat glands in between, therefore, secretions of oil and moisture enable development of 'latent' or persistent lip prints, analogous to finger prints.[13]

In the present study, the lip prints were recorded in relaxed and closed position. Sivapathasundharam et al, stated that the uniqueness of patterns depended on the way the lip muscles are relaxed to produce a particular pattern.[4] Lip print pattern depends on whether the mouth is opened or closed. In closed mouth position the lip exhibits well defined grooves; where as in the open position the grooves are relatively ill defined and difficult to interpret.[14]

In our study, the middle portion of the lower lip was used for classifying the pattern. It was also found that the lower 1/3rd portion of the middle part of lower lip, almost always had a type III or IV patterns, irrespective of the sex (Fig.1). Therefore, to avoid misinterpretation of results, it was decided to study only the upper two thirds of the middle part of the lower lip. Lévêque and Goubanova[11] suggested that the furrows and grooves on the lips seemed to facilitate routes for saliva to spread over the lips and maintain good hydration. They also found the upper lip to be more hydrated than the lower one. The variations in pattern between the upper and lower lip may be attributed to these factors and might have a functional significance. Lévêque and Goubanova also noted that some continuity appeared to exist between the lips and adjacent skin lines and suggested a common origin.[11] The predominance of Type III and IV patterns, especially in the lower one third of the lower lip could be attributed to continuity of the lines on the skin adjacent to the lips intersecting with the grooves on the lips.

In the present study, the most predominant lip pattern in females was Type I followed by Type II and Type III whereas in males, Type III lip pattern was predominant, followed by Type I and Type IV.

In the present study the most predominant pattern in the entire study population was Type I, however other studies on Indian subjects have yielded varying results. Vahanwala and Parekh in their study in Mumbai also found that Type I was the most frequent.[15] Sivapathasundharam et al studied the lip prints of Indo-Dravidian population and noted that Type III was predominant.[4] Verghese et al studied lip prints in the population of Kerala and found that the most common pattern was type IV.[16]

The overall accuracy of cheiloscopy in sex determination was 58.67 %, 76% and 61.33 % in group 1, 2 and 3 respectively. In group 1: 90.27 % were correctly identified as female and only 29.48 % were correctly identified as male (Fig. 2). This may be attributed to the fact that the lips reach their maturity in late adolescence. Women arrive at maxillary lip maturity at 14 years of age and mandibular lip maturity at 16 years of age. Men reach

maxillary and mandibular lip maturity around 18 years of age.[17-19]
In group 2: 84.9 % were correctly identified as female and 65.9 % were correctly identified as male. Beginning in the mid to late thirties, age changes occur in the upper face first. The lips still have significant tonicity to them and do not show effects of ageing.[20]

In group 3: 65 % were correctly identified as female and 57.14 % were correctly identified as male (Figs. 3 and 4). This can be attributed to the occurrence of wrinkles on the adjacent skin and thinning of lips in old age which affects the lip pattern. Volume is lost in lips and the perioral area as age advances and definition of lip anatomy diminishes. The intercommissural distance increases with age, whereas lip height decreases.[21]

In our study it was observed that in age group 1, Type I was most predominant pattern followed by Type II and Type III. In age group 2 Type I was most common followed by III and IV. Type I was most common in group 3 followed by III and II (see Figs. 5, 6 and 7 for varying types and location). This is in accordance with previous studies which also indicate the diversity in pattern of lip prints among individuals of different age groups. Thus, age groups have no relevance for any similarity of lip prints.[22]

We observed that no lip prints matched with each other and that lip print pattern was unique to every individual. This is in accordance with the results of previous studies.[23] In addition, every quadrant in each individual did not have only one pattern, but appeared to have a mixture of different patterns. It was also observed that Type III and Type IV were the most commonly superimposed patterns, and were difficult to differentiate at times. These findings were consistent with previous studies.[22, 24]

Cheiloscopy is a relatively new field among the large number of identification tools available to the forensic expert. Work on this subject has already elicited useful information, however; limitations still exist in the use of lip prints (Figs. 8, 9, 10). A method of standardization has to be developed to assess and accurately measure the lip patterns. The effect of age and seasonal influences on the groove pattern remains a problem which needs further study. Further studies are also required to confirm that they remain stable over time.

CONCLUSIONS

In conclusion, it can be said that the lip print pattern may have some use as an additional means for sex determination but there are limitations. In this study, analysis of lip print patterns revealed that no particular pattern was specific to any quadrant or any age group. The most common lip pattern in the entire study population was Type I, Type I being most common in females and Type III in males.

Although, the lip print patterns showed better reliability for sex determination in the 21-40 years age group, differentiation of gender was uncertain in young and late age. This showed that age changes related to the size, shape of the lips and skin surrounding the lips can influence the lip print patterns.

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FIGURES

Fig. 1: *Type I lip pattern in a female patient*

Fig. 2: *Type I' lip pattern in a female patient*

Fig. 3: *lip pattern Type II in female patient.*

Fig. 4: *lip pattern Type III in a female patient*

Fig. 5: *lip pattern Type IV in a male patient*

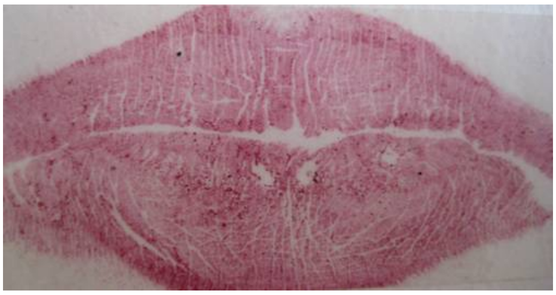

Fig. 6: *lip pattern Type V in male patient.*

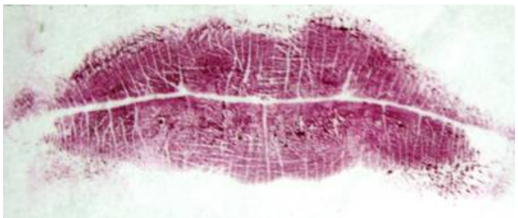

Fig. 7: *Lip print pattern of a 9 year old female with a reticular pattern in the lower 1/3rd of the middle portion of the lower lip.*

Fig. 8: *Type I pattern in a 6 year old male incorrectly recognised as a female*

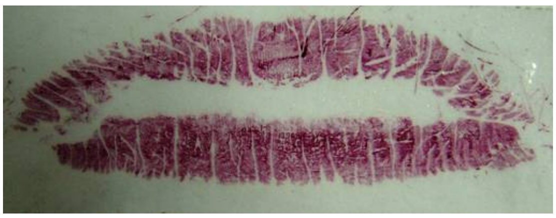

Fig. 9: *Type I pattern in a 60 year old male incorrectly recognised as a female.*

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Fig. 10: *Lip print of a 50 year old female patient with Type III pattern incorrectly recognised as a male. Note the increased intercommissural distance and thinning of lips*

TABLES

Table 1. *Group 1 (Age 1-20 Yrs)*

Type	Female	Male	Total
I	48	40	88
I’	6	4	10
II	11	11	22
III	3	16	19
IV	0	7	7
V	4	0	4
Total	72	78	150

p = 0.001; Significant at 1% significance level

Table 2. *Group 2 (Age 21-40 Yrs)*

Type	Female	Male	Total
I	102	39	141
I’	19	5	24
II	14	4	18
III	14	71	85
IV	7	18	25
V	3	4	7
Total	159	141	300

p < 0.0001; Very Highly Significant

Table 3. *Group 3 (Age 41Yrs & above)*

Type	Female	Male	Total
I	35	30	65
I'	3	0	3
II	14	0	14
III	20	33	53
IV	7	3	10
V	1	4	5
Total	80	70	150

p < 0.001; Highly Significant

Table 4. *Intra and Inter- observer kappa value*

		Kappa value
Intra-observer	Observer 1	0.82
	Observer 2	0.91
Inter- observer		0.95

BOOK REVIEW

Disaster Victim Identification.

Experience and Practice.

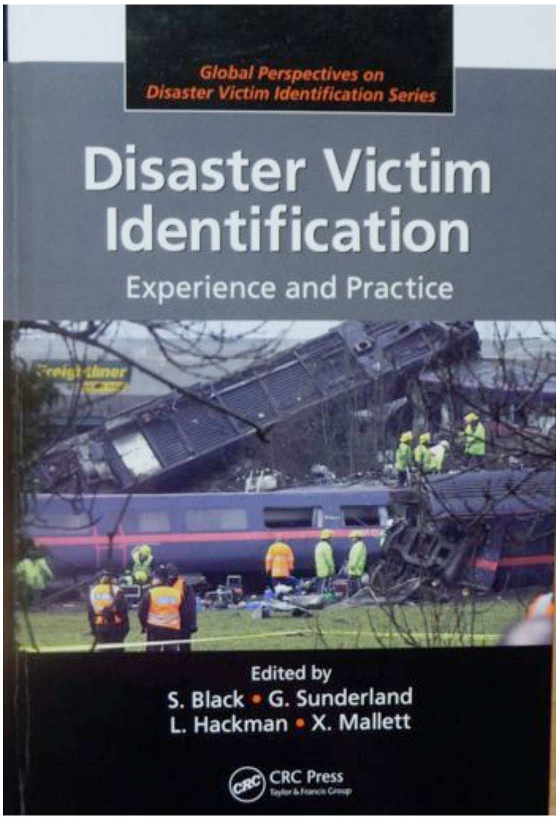
Edited by Professor Sue Black, Graham Sutherland, Lucinda Hackman and Xanthe Mallett
CRC Press 2011
ISBN 978-1-4200-9412-1
Price £82.00, [Amazon price £77.90]
Royalties from the sale go to the charity: Care of Police Survivors.

Edited by the team responsible for the former Dundee university DVI course for UK police officers, this book is the result of required 2500 word essays reviewing a mass fatality incident in the UK or overseas, giving an overview and discussing the management problems involved following the incident, lessons learned and reviewing solutions for future investigative teams.

This hardback book comprises 16 chapters and a total of 248 pages. Fifteen major incidents occurring between 1966 (the Aberfan disaster) and 2005 (London bus and underground bombings) are covered, including those with the largest loss of life (Lockerbie and Piper Alpha), football disasters (Bradford City and Hillsborough), railway incidents and some less remembered incidents such as the Morecambe Bay cockling disaster. Overall, a good cover of various types of disaster over the past few years. Although the Marchioness riverboat incident is reported, the Zeebrugge ferry disaster involving police forces both sides of the channel does not appear. This is unfortunate as the problems faced by UK DVI teams working abroad, in this and subsequent disasters, are very different from those within the UK.

This text will primarily appeal to police officers concerned with major incident management but will be of interest to those in the emergency services, to forensic pathology and odontology specialists and, to a limited extent, those in the coronial service, finger print and forensic science staff.

The book is printed in the USA and, although aimed at the British market, suffers from US spellings such as center. The quality of the photographs (all monochrome) is poor, with some rather out of focus (Figures 5.3 and 7.2 for example) and it must be assumed that it



was originally intended to incorporate some colour photographs as this is referred to in several of the illustrations (see Fig 10.3, 12.3, 16.2).

Each chapter follows a useful general pattern of introduction, background, response/body recovery, identification, post incident, conclusion and comprehensive references. The importance of the four primary identification methods, namely DNA, Fingerprints, Odontology and Unique Medical Condition, are emphasised.

It would have been of great value to have a chart in each chapter outlining the manpower involved, broken down into the various specialities with period on site, also a table showing the methods of identification with numbers and percentages. In some cases this appears buried in the text or is missing altogether (4 rail incidents & the London Bus and Underground bombings).

There are a number of factual errors, possibly because the original essay writer was unable to obtain all the facts or was not present at the disaster. For example, in the Manchester airport disaster, Kenyon's are stated to have dealt only with the personal effects whereas they also undertook the preparation and processing of the human remains and supplied forensic odontologists. The Chinese Lorry Deaths (Dover) chapter states that identification methods, at this time (2000), were almost unknown in Kent - the Kent police were well aware of identification methods having handled the Zeebrugge disaster (1987). These and other of factual errors in other disaster reports are unfortunate.

The Kings Cross Underground fire contains an excellent report on the identification of the last body 15 years later and demonstrates the value of thorough police and forensic investigation. The Marchioness disaster chapter contains details concerning the 'removal of hands' incident and subsequent public enquiry.

Having worked in several of the disasters covered I found the book an interesting read.

Dr Derek Clark
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