ISSN 2219-6749

I-O-F-O-S

The Journal of Forensic Odonto-Stomatology

Volume 24, n. 2 - Dec 2006

OFFICIAL PUBLICATION OF THE
INTERNATIONAL ORGANIZATION FOR
FORENSIC ODONTO-STOMATOLOGY

CONTENTS

CLASSIFICATIONS USED BY AUSTRALIAN FORENSIC ODONTOLOGISTS IN IDENTIFICATION REPORTS

D. Higgins, H. James

Forensic Odontology Unit, University of Adelaide, South Australia

ABSTRACT

Forensic odontologists are repeatedly called upon to assist in the identification of deceased persons. A great deal of information is available in the literature as to how and why comparative dental investigation of identification is performed but there is little information on the descriptive terms used in reporting these identifications. A forensic odontology report sets out the findings of a comparison between antemortem and postmortem evidence and indicates the odontologist's opinion on the identification. This opinion needs to be defendable in a court of law. This paper investigates the classifications utilised in the six states and two territories of Australia and reflects on the differences.

Three states of Australia use American Board of Forensic Odontology classifications, whilst the remaining regions use a modified format. Since there are no significant legal, cultural or religious differences, and similar practitioners and clients, variation between regions within Australia would seem hard to justify. National standard terminology should be encouraged.
(J Forensic Odontostomatol 2006;24:32-5)

Key words: forensic odontology, identification categories, classification

INTRODUCTION

A common role for the forensic odontologist is identification of deceased individuals at the request of the Coroner, for whom a report must be prepared.[1] The most important component of this report is the conclusion, which is the odontologist's opinion of the likelihood of identity. Identification is established by comparison of antemortem and postmortem evidence. Based on the quality and quantity of comparable features available, different categories of identification can be assigned to cases with regard to their proximity to positive confirmation. It has been suggested that there is no requisite number of points needed to establish an identity.[2,3] When sufficient characterisation exists without unexplainable differences identity can be confirmed. The onus is on the odontologist as to how the identification opinion is classified, bearing in mind that the report is a legal document that may be called upon in court proceedings.[4]

A number of authors have published individual classification criteria for identification.[5-9] More recently, the American Board of Forensic Odontology (ABFO)[10] and the International Organization for Forensic Odonto-Stomatology (IOFOS)[11] have produced recommended standard definitions, described in Table 1 and Table 2.

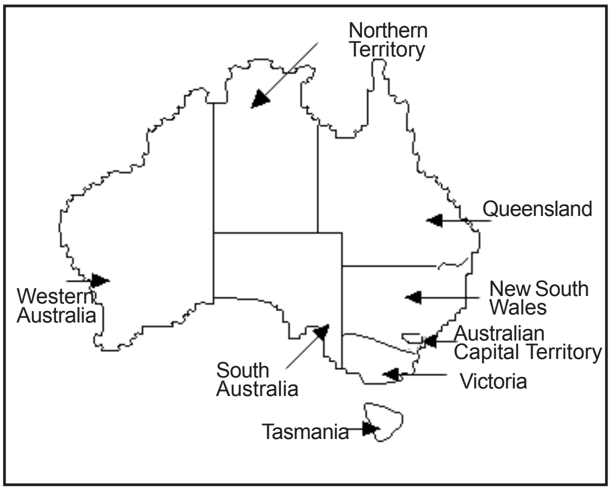


Fig.1: *Map showing states and territories of Australia*

MATERIALS AND METHODS

Australia is divided into six states and two territories (Fig.1) and identification casework tends to be limited to centralised groups in each region. It was assumed that each region adopted common reporting practices and a forensic odontologist from each region, active in regular coronial casework, was surveyed to determine how the state/territory categorises identification when reporting to the Coroner. Each odontologist was asked to document the classifications used in his/her identification reports. The results were then compared

Table 1: *ABFO Classifications*[10]

Positive Identification – The antemortem and postmortem data match in sufficient detail to establish that they are from the same individual. In addition, there are no irreconcilable discrepancies
Possible Identification – The antemortem and postmortem data have consistent features, but, due to the quality of either the post-mortem remains or the antemortem evidence, it is not possible to positively establish dental identification
Insufficient Evidence – The available information is insufficient to form the basis for a conclusion
Exclusion – The antemortem and postmortem data are clearly inconsistent

Table 2: *IOFOS Classifications*[11]

Identity established - less than 1:10,000 other persons may fit the details; this conclusion may stand alone as evidence of identity
Identity probable - the conclusion needs to be supported by other evidence
Identity Possible - more than 1:100 persons may fit the details; the conclusion needs to be supported by other strong evidence

Table 3: *Classifications used in Australia*

State	ABFO	IOFOS	Other
Australian Capital Territory		No	Confirm - need 10 points of concordance, no discordance Possible - 10 points of concordance, explainable discordance or less than 10 points concordance Not possible - insufficient information Exclude
New South Wales		No	Confirmed - must have antemortem radiographs Consistent with - radiographs not mandatory More information required Exclusion
Northern Territory		No	Positive Insufficient information Exclusion
Queensland		No	Conclusive Consistent Lack of information Exclusion
South Australia		No	Confirm Strongly support Support Insufficient information Exclusion
Tasmania	Yes	No	
Victoria	Yes	No	
Western Australia	Yes	No	

to each other and with the ABFO and IOFOS categories.

RESULTS

The results obtained are presented in Table 3. None of the odontologists surveyed report using the IOFOS classifications. Western Australia and Victoria adhere to the ABFO classifications and Tasmania generally follows these classifications, although not strictly. Of the remaining states the ABFO terms are used in modified format.

Positive identification is used in those states conforming to ABFO definitions and also the Northern Territory. The Australian Capital Territory, New South Wales and South Australia use *Confirm* and Queensland uses *Conclusive.*

Those regions using ABFO terminology, as well as the Australian Capital Territory, use *Possible.* New South Wales and Queensland use *Consistent.* South Australia exchanges this category for two terms:

Table 4: Dictionary definitions

Word	Definition
Positive	Explicit, definite, unquestionable[13] Impossible to deny or disprove[14] Admitting of no doubt, irrefutable[16]
Confirm	Provide support for the truth or correctness of, formally make definite[13] Make valid by necessary formal approval, indisputable fact[17]
Possible	Capable of being[13] Having potential[14] Is that which is capable of happening (not feasible)[15] Of uncertain liklihood[16]
Consistent	Not contradictory, compatable[13] Logical argument[14] In agreement, compatible, reliable[16]
Support	Give corroboration to, strengthen[13] To uphold or defend as valid, substantiate or corroborate[17]

Support and *Strongly Support.* The Northern Territory eliminates *Possible* altogether and has just three categories.

Insufficient Information is used in the Northern Territory and South Australia, as well as ABFO-adherents Tasmania, Victoria and Western Australia. The Australian Capital Territory uses *Not Possible,* New South Wales *More Information Required* and Queensland *Lack of Information.* All states and territories use *Exclude.*

DISCUSSION

Australian odontologists unanimously prefer not to use IOFOS classifications. This may be due to perceived difficulties in evaluation of cases statistically, given the lack of available relevant population data. The relative occurrence of individual features and combinations, and the resulting discrimination potential, is often unknown. The statistical component is designated as a "recommended step, which may be omitted or changed without further explanation,"[11] but inclusion in the classifications may be sufficient to act as a deterrent.

Only two states are satisfied that ABFO classifications are suitably worded to accurately reflect the intent of the odontologist. Given that an identification report is a legal document and its content may have to be justified in a court of law the terminology used must be accurate and the author of the report needs to be confident in qualifying it. If we examine the words disputed, their definitions can be explored and appropriateness ascertained. Definitions from various sources are shown in Table 4.

The main category of ABFO that was altered or omitted was *Possible Identification.* This may be a reflection of the perceived legal weight of the word *Possible.* It is not recognised as being within the legal standard of proof.[12] Common and legal definitions[13-16] indicate uncertainty. After all, it is possible that the moon is blue, but highly unlikely. *Consistent with*[13,14,16] (New South Wales) and *Supports*[13,17] (South Australia) imply limited corroboration of existing evidence.

Keiser-Nielsen[18] and others[19,20] have proposed a minimum number of concordant characteristics are required to establish identity, whilst other researchers have suggested that one or more highly individual characteristics may surfice.[2,3,21-23] The Australian Capital Territory is the only region to specify a quantity requirement in their classifications; all the other states avoid a prerequisite level of concordance for each category.

Clearly individual odontologists will have his or her own opinion on which wording is most appropriate in a given situation and will thus report accordingly. It is important, however, that Coroners and Police investigators understand what is implied by the various categories. Legally, it is the Coroner who must determine identity.[24] Since there are no significant legal, cultural or religious differences, and similar practitioners and clients, variation in standard terminology between regions within Australia would seem hard to justify. Perhaps in the future group discussion will result in a national conformity between odontologists in Australia. A global approach also may be considered appropriate.

CONCLUSION

Between the various regions of Australia the categories of classification in identification vary marginally in the precise wording used and in some instances in the number of possible categories. Given that these classifications are presented to others who are not experts in the field and that these definitions on occasions need to be justified and qualified as being accurate it maybe that consistency in classifications would make life easier for odontologists in both reporting and defending their opinions.

ACKNOWLEDGEMENTS

The authors acknowledge the support of both the Minister for Police in South Australia and the South Australia Police.

REFERENCES

1. Ranson DL. Guides and checklists for medico-legal reports. in Clement JG, Ranson DL Eds. Craniofacial Identification in Forensic Medicine. London, Sydney, Auckland:Arnold,1998:291.

2. Acharya AB, Taylor JA. Are a minimum number of concordant matches needed to establish identity in forensic odontology? J Forensic Odontostomatol 2003;21:6-13.

3. Pretty A, Sweet D. A look at forensic dentistry- Part1: The role of teeth in the determination of human identity. Br Dent J 2001;190(7):359-66.

4. Fixott R. The Dental Identification Report. in Bowers CM, Bell GL Eds. Manual of Forensic Odontology. 3rd edn. Grimsby: Manticore, 1997:45-6.

5. Sopher IM. Forensic Dentistry. Springfield: Charles C Thomas, 1976:109-12.

6. Keiser-Nielsen S. Personal Identification by means of the teeth. Bristol: John Wright & Sons Ltd, 1980:69.

7. Clark DH. Practical Forensic Odontology. Oxford: Butterworth-Heinemann Ltd, 1992:73.

8. Solheim T, Lorentsen M, Sundnes PK, Bang G, Bremnes L. The “Scandinavian Star” disaster 1990 – a challenge to forensic odontology. Int J Leg Med 1992;104:339-45.

9. Morlang WM. Mass Disaster Management. in Stimson PG, Mertz CA eds Forensic Dentistry. Boca Raton: CRC Press, 1997:235.

10. American Board of Forensic Odontology. Body Identification Guidelines. JADA 1994;125:1244-54.

11. International Organization for Forensic Odonto-Stomatology. Identification in single cases. http://www.odont.uio.no/foreninger/iofos/quality/Identification-IOFOS.htm 2005.

12. Findlay M, Odgers S, Yeo S. Australian Criminal Justice. Melbourne: Oxford University Press, 1994:160.

13. Oxford Australian Dictionary. Melbourne: Oxford University Press, 1996.

14. Wordnet 2.0 Princeton University.2003. http://www.dictionary.com

15. Bailey JA II. The Concise Dictionary of Medical Legal Terms. London, New York: Parthenon Publishing Group, 1998:24.

16. American Heritage Dictionary of the English Language 4th ed. Boston: Houghton Mifflin Co. 2000.

17. Merriam Webster Dictionary of Law. Springfield: Merriam-Webster Inc, 1996.

18. Keiser-Nielsen S. Dental Identification: Certainty v Probability. Forensic Science 1977;9:87-97.

19. Phillips VM, Scheepers CF. A comparison between fingerprint and dental concordant characteristics. J Forensic Odontostomatol 1990;8:17-9.

20. Borrman H, Grondahl HG. Accuracy in establishing identity by means of intraoral radiographs. J Forensic Odontostomatol 1990;8:31-6.

21. Hill IR. Forensic Odontology – are points of correspondence viable? J Forensic Odontostomatol 1989;7:17-8.

22. Dailey JC. The identification of fragmented Vietnam War remains utilising a healing extraction site. J Forensic Sci 1991;36:166-78.

23. Slabbert H, Ackerman GL, Altini M. Amalgam tattoo as a means for person identification. J Forensic Odontostomatol 1991;9:17-23.

24. Freckelton I, Ranson D. Death Investigation and the Coroner’s inquest. Melbourne: Oxford University Press, 2006:387.

Address for correspondence:
Dr Helen James
Forensic Odontology Unit
The University of Adelaide, SA 5005
AUSTRALIA
Tel: +61 (08) 8303 5431
Fax: +61 (08) 8303 4385
Email: helen.james@adelaide.edu.au

COMPONENT ANALYSIS OF DENTAL PORCELAIN FOR ASSISTING DENTAL IDENTIFICATION

H. Aboshi, T. Takahashi, T. Komuro

Department of Legal Medicine, Nihon University School of Dentistry, Japan

ABSTRACT

The fluorescence of porcelain crowns recovered from the mouth of an unknown murder victim, and several control porcelain samples, were examined by fluorescent examination lamps. The fluorescence from two of the control samples was quite similar to that from the porcelain crowns recovered from the victim. To increase the objectivity of the results by quantitative analysis, the composition of each porcelain crown and control sample was also evaluated by wave dispersion X-ray microanalyser. The elements detected from the porcelain crowns of the victim matched those of two of the porcelain samples. Later, the antemortem dental records and radiographs of the victim were obtained through a dentist, who had recognized the name of the porcelain manufacturer in a postmortem dental information request placed on the Japanese Dental Association web page. Although component analysis of dental porcelain may be an effective means of assisting dental identification, a more rapid and non-destructive analysis for detecting the elements is required. The energy dispersive X-ray fluorescence (EDXRF) spectrometer was used for a pilot study of identification of porcelain composition.

(J Forensic Odontostomatol 2006;24:36-41)

Keywords: EDXRF, component analysis, dental porcelain, dental identification

INTRODUCTION

The detection of tooth coloured restorations can be difficult under certain conditions in both controlled mortuary environments and mass fatality incidents managed outside of regular facilities.[1-3] White or composite filled teeth look similar to natural teeth under natural light, but under UV light they exhibit different features to those of natural teeth.[4] By using these characteristics, some fluorescent examination methods for identifying composite restorations have been discussed in the forensic dental field.[5-7] These characteristics are also available to identify various dental porcelain products. Both the detection of white dental materials and porcelain products in an unknown body by fluorescent examination may lead to a successful identification,[8,9] but unfortunately the evaluation of fluorescence must be carried out subjectively by the naked eye and is extremely difficult in a small sample. This may limit its application in some situations.

A previous case at our institution involved aesthetic dental porcelain veneer jacket crowns and porcelain fused to metal crowns found in the mouth of a skeletonised, unknown, murder victim.[10] Initially no antemortem dental information could be located. It was suggested to police that information about the victim might be obtained through dental technicians and porcelain manufacturers. As a screening, fluorescence examination was performed, comparing the recovered dental porcelains against several collected porcelain samples. Fluorescence from two brands of porcelain samples was quite similar to that from the porcelain veneer jacket crowns found in the victim.

To establish objective results by which to identify the products, the composition elements of each of the porcelain crowns were also evaluated by wave dispersive X-ray microanalyser (WDX). The elements comprising the samples from the victim matched those of two of the reference porcelain samples. We believe, as a result of this experience, component analysis of dental porcelain may be an effective means of assisting dental identification.

Using a wave dispersive X-ray microanalyser (WDX) for detection of elements involves much time-consuming sample preparation, requiring the sample porcelain to be cross-sectioned, polished to a smooth surface, and then covered with a thin film of carbon to avoid charging of the insulating targets.[11] This means that the dental evidence is destroyed and this technique is, therefore, not necessarily the best method to identify dental products. In addition, no database of constituent elements of dental porcelain products has been developed for forensic use. As an alternate investigative technique an energy dispersive fluorescent X-ray (EDX) spectrometer was used for fluorescent X-ray analysis. This instrument can perform quick and precise non-destructive qualitative and quantitative analyses of elements.

The aims of this study were to establish preliminary composition data of dental porcelains suitable for applying in dental identification, and to develop a convenient and non-destructive method of fluorescent X-ray analysis.

MATERIALS AND METHODS

Sample collection and preparation

Porcelain fused to metal restorations are the most frequently used restoration in Japan for the complex restoration of anterior teeth. From over 10 manufacturers of dental porcelain for the production of porcelain-fused-to-metal restorations in Japan, one was selected to provide samples for this study.

In building up the crown form to satisfy esthetic requirements, several kinds of porcelain powders must be used according to manufacturer's recommended procedures.[12] By accumulating thin layers of adequate enamel and dentin porcelains, appropriate transparency and opaqueness can be achieved. For the test analysis, the dental porcelains collected were the powders used around the crown surface (i.e. enamel and translucent porcelain powders). For the component analysis 14 kinds of porcelain powders (3 for enamel, 11 for translucency) were collected, as shown in Table 1. A total of 5 discs of each kind of porcelain powder were heat treated in a porcelain furnace (Sella-Fusion; Sekisui Co. Ltd.) using the manufacturer's recommended firing cycles. A total of 70 disc specimens were produced for this analysis.

Energy dispersive X-ray fluorescence

The energy dispersive fluorescent X-ray spectrometer [Rany EDX-900, (hereafter abbreviated as EDX900); Shimadzu Co., Japan] was used for the component analysis of the dental porcelains (Fig.1). The desktop type fluorescence X-ray spectrometer EDX900 consists of an analyzer, workstation, and printer. The analyzer irradiates X-rays onto a sample and detects generated fluorescence X-rays. The workstation processes the data by operating the analyzer. Quick and precise non-destructive qualitative and quantitative analyses of elements of a wide range from sodium ($_{11}Na$) to uranium ($_{92}U$) can be performed.

Component analysis of porcelain samples

Qualitative and quantitative analyses were performed at the centre of each of the 70 disc samples after confirming the setting position via a built-in CCD camera. The sampling depth of the method is approximately 1.0mm.

In the qualitative analysis, the specified elements were detected on the profile and their names displayed on the monitor automatically. Depending on measuring conditions, two or more fluorescent X-ray pulses may enter the sample at the same time. These cannot be separated to individual pulses and are signal-processed as a single pulse. As a result, a peak appears at a position higher than the actual energy position. To check for overlap of summed peaks and the peaks of other elements included in the sample, the energy table of individual elements was referenced against a final register of element composition.

***Table 1:** Porcelain powders used for component analysis*

Porcelain Powder (type)	Batch Number
E_1 (Enamel)	OCX 19
E_2 (Enamel)	OCY 14
E_3 (Enamel)	OD 120
T_0 (Translucent)	OC 604
T_1 (Translucent)	OCY 30
T_2 (Translucent)	604 17
Tx (Translucent)	OB 706
LT_0 (Translucent	OCY 08
LT_1 (Translucent)	OCY 22
T•B (Translucent)	OCZ 04
S•B (Translucent)	OC 130
C•E (Translucent)	OC 314
C•W (Translucent)	806 17
I•A (Translucent)	806 17

***Fig.1:** The energy dispersive fluorescent X-ray spectrometer (Rany EDX-900; Shimadzu Co., Japan)*

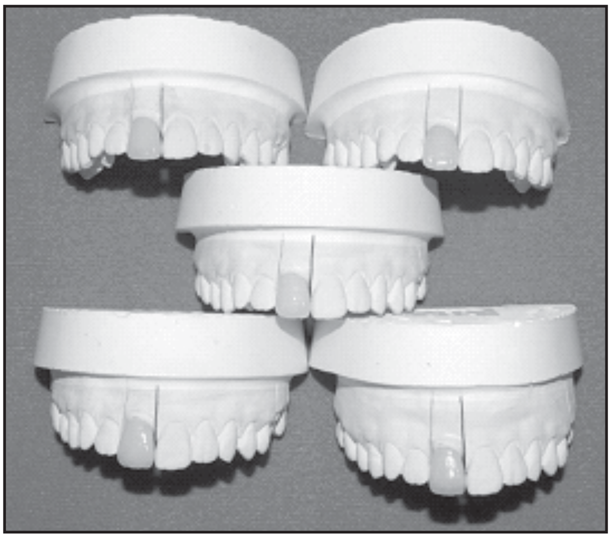


***Fig.2:** Porcelain fused to metal crowns by 5 dental technicians*

In the Qualitative-Quantitative Analysis mode, quantitative calculation of an element detected by the qualitative analysis was carried out by the Fundamental Parameter method without using standard samples.

The main component of porcelain is feldspar and its chemical compositions were assumed to be some metallic elements combined with oxygen to form stable oxides. We, therefore, set the compound form as an Oxide with the following analytical conditions:

- Collimator size/ 1.0 mm
- Atmosphere/vacuum
- Voltage/ 15 ~ 50kV
- Current/ 100 µ A
- Integration Time/ 300 sec

The lower limit of detection by EDX900 in the qualitative-quantitative analysis mode was different in each element detected, as follows; Si: 500ppm, Ca:50ppm, Fe-U:10ppm.

The qualitative-quantitative analysis was carried out three times per disc sample on separate days of the week, and the mean value of measured wt% in each kinds of porcelain was calculated to determine element composition.

To study the reliability of this analysis, 5 dental technicians were asked to produce a porcelain-fused-to-metal crown on working casts using the same products in shade Vita-A3 (Fig.2). The

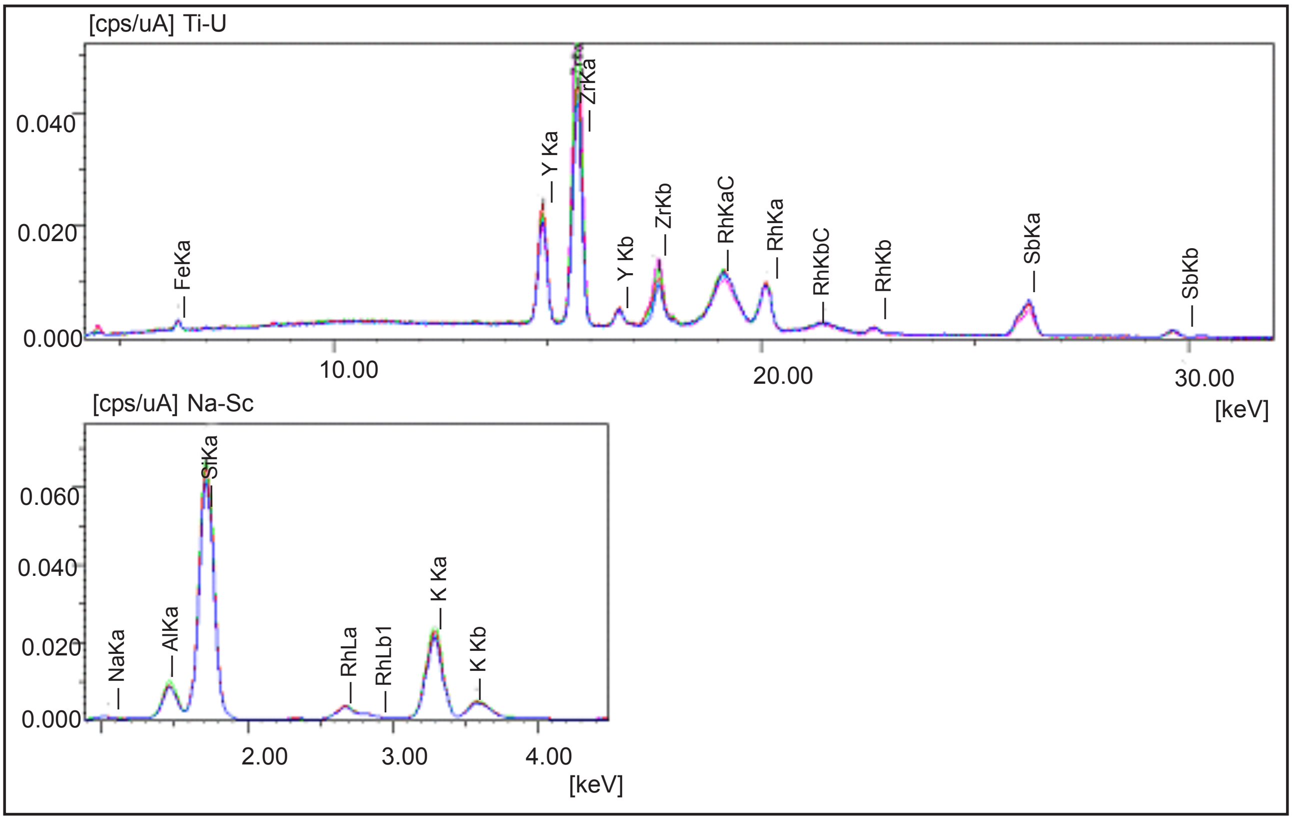


***Fig.3:** Overlapped profiles of five porcelain crowns*

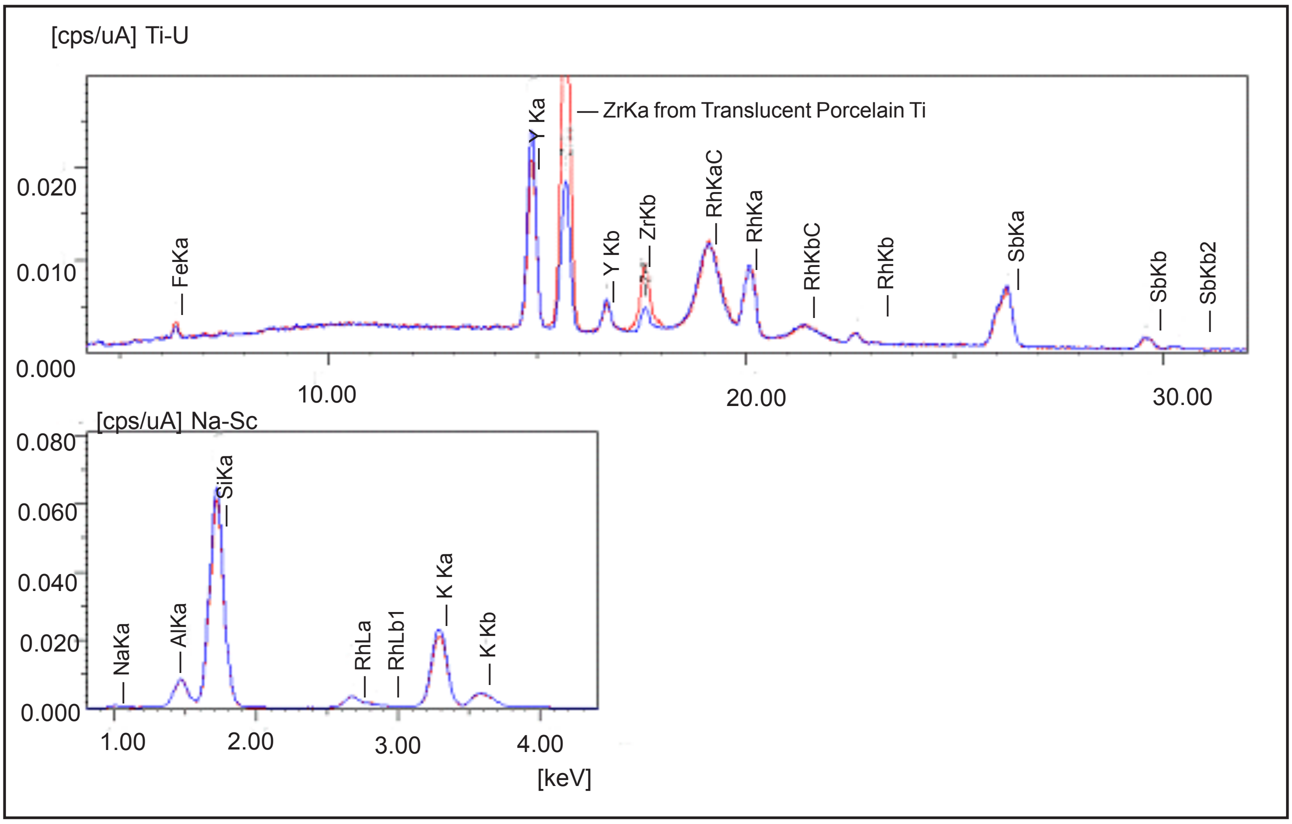


Fig.4: *Overlapped profile of porcelain crown and Porcelain T_1*

qualitative analysis for positive identification of manufacturers/porcelain samples was carried out for each crown by comparing the energy peaks of elements. The target portion of the porcelain crown for this analysis was the center of the labial surface.

RESULTS

A total of 14 elements (Si, Al, Ca, Mg, K, Na, Sb, Zr, Ce, Fe, Ti, S, P and Y) were detected in the porcelains selected, and the compositions were diverse and specific to the different kinds of porcelain (Table 2). Each porcelain contains, by weight, approximately 65-67% Si, 14-15% Al, 10-12% Na and 9-10% K. Differences in the presence of particular trace elements, namely Cerium and Zirconium, were also detected. Cerium was detected only in Tx porcelain powder (0.07%) and no Zirconium was detected in T_0, Tx and T Blue porcelain powders. Fig.3 shows the overlapped profiles from the five crown samples. The profiles from all porcelain crowns analyzed show the same peak patterns at each element energy level. The same element composition could be confirmed on the display. The profile from one of the five was then compared and overlapped with each of the other porcelain powders. The peaks in the spectrum from the crown samples were most similar to that from Translucent Porcelain T_1 (Fig.4), apart from a gap of the peak at the energy level of Zr.

DISCUSSION

Dental porcelains are appreciated as highly esthetic restorative materials with optimal properties that better simulate the appearance of the natural dentition. For the creation of the crown form a dental technician uses different kinds of porcelain powders (for opaqacity, dentin, enamel, incisal detail and translucency) in varying ratios and compositions to make artificial teeth reproduce as closely as possible the natural dentition. Manufacturers provide their own types of porcelain powders to represent the individual natural shade and variations exist between products.

Generally, to specify the shade of porcelain crown to be constructed, a shade guide is used to compare with the patient's remaining natural teeth. Apart from any special requirements in molding or staining, once a dentist has specified a shade, a dental technician will use a variety of porcelain powders to reproduce the same tooth shade according to the manufacturer's instructions. It is reasonable to

***Table 2:** Composition of the dental porcelain powder by EDXRE analysis*

	Oxide	Composition (wt. %)													
		E_1	E_2	E_3	T_0	T_1	T_2	T_x	LT_0	LT_1	T•B	S•B	C•E	C•W	I•A
1	SiO_2	67.49	67.32	67.0	67.27	65.88	65.44	64.54	64.95	65.37	66.25	66.27	65.22	62.66	65.03
2	Al_2O_2	15.17	15.25	15.74	15.60	15.70	16.08	14.98	15.84	15.79	15.84	15.63	15.54	15.66	15.52
3	CaO	1.26	1.28	1.32	1.34	1.27	1.30	1.49	1.56	1.63	1.71	1.42	1.71	1.58	1.52
4	MgO	0.11	0.15	0.15	0.13	0.15	0.15	0.26	0.11	0.11	0.12	0.18	0.17	0.12	0.17
5	K_2O	9.15	9.22	9.61	9.29	9.39	9.14	10.38	9.56	9.46	9.64	9.16	9.25	9.00	9.30
6	Na_2O	11.16	11.64	11.40	10.99	11.06	10.35	12.58	11.40	11.15	11.30	12.08	11.65	11.18	10.78
7	Sb_2O_3	1.60	1.64	1.63	1.65	1.56	1.60	1.90	1.70	1.68	1.70	1.64	1.60	1.36	1.58
8	CeO_2	-	-	-	-	-	-	0.07	-	-	-	-	-	-	-
9	ZrO_2	0.33	0.28	0.31	-	0.17	0.31	-	0.04	0.06	-	0.24	0.68	2.89	0.41
10	Fe_2O_3	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
11	TiO	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03
12	SO_3	-	-	-	0.03	0.02	-	0.03	0.02	-	0.02	-	-	-	-
13	P_2O_5	0.08	0.05	0.04	0.04	0.16	0.23	0.10	0.33	0.33	0.26	0.16	0.58	1.94	0.33
14	Y_2O	0.11	0.11	0.11	0.18	0.17	0.17	0.08	0.16	0.14	0.13	0.15	0.12	0.10	0.12

hypothesize that every powder may contain different substances. It means the identification of porcelain by the elemental composition differences among porcelains may bring out helpful information for identifying, firstly the porcelain manufacturer, and ultimately the unknown person.

Manufacturers are reluctant to provide complete information about the composition of their materials, including porcelains, as they consider this to be privileged information and do not wish their competitors to be aware of this information. We are aware of no published reports that describe, officially, a list of identity and composition of materials for forensic use. This study was undertaken to commence compilation of a database on the elemental composition of dental porcelain materials in Japan. Accordingly, for this preliminary study, we selected one manufacturer only and the shade of Vita-A3, which is a relatively popular shade for Japanese anterior teeth. According to the instruction in the manufacturers' guide for reproducing shade A3, a total of 14 designated porcelain powders were collected and measured for this study.

Silicon, Aluminum and Potassium were found to be the most dominant elements in the porcelain powders at similar concentrations, being virtually indistinguishable from one another in each porcelain powder. These elements might be derived from the main ingredients of potassium feldspar that is considered to be a raw material of dental porcelain. It is, therefore, the presence or compositional variation of other elements that provide the differences among dental porcelain manufactures. In the porcelain product tested, the presence or compositional weight variations for cerium and zirconium may be the characteristic elements.

Thus, there are local compositional variations of the element's present in the different porcelain powders even from one manufacturer. It will, therefore, be necessary to analyse, more dental porcelain powders normally used in crown construction in Japan to ensure reliability of the database. Further extremely accurate quantitative analysis by calibration curve method for each element will be needed to obtain reliable results for the comparative study of the composition of other trace elements present at concentrations of less than 1%.

To confirm the reliability of this method, the spectrum profiles by qualitative analysis for five porcelain-fused-to-metal crowns (Vita shade A3) produced by different dental technicians belonging to different laboratories were compared with each other. Their spectrum patterns were also evaluated against those from 14 different porcelain powders. It was correctly confirmed that the Translucent Porcelain T_1 was contained in the surface porcelain of the sample crowns.

This preliminary study has shown that surface analysis by EDX may have great potential for identifying the composition, and thereby the manufacturers of dental porcelain, which in turn may assist dental identification.

CONCLUSIONS

The dental porcelains examined were composed of 14 kinds of elements, and showed variation in the presence of some trace elements. By confirming the overlapped profile images obtained from the porcelain crowns and porcelain disc samples, it was possible to identify the porcelain manufacturer. Further study to analyze other manufacturers or other types of porcelains and searching for additional effective parameters for identifying individual porcelain powders will be needed for forensic case application.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the cooperation and technical advice from Mr. Hirotomo Ochi and Mrs. Satoko Minamitake of Shimadzu Analytical & Measuring Center, Inc. This project was partially funded by the Sato Fund, Nihon University School of Dentistry in 2003, 2004 and Grant-in-Aid for Scientific Research (B), The Ministry of Education, Culture, Sports, Science and Technology, Japan in 2002-2003 (No. 14370702).

REFERENCES

1. Brown KA. The identification of Linda Agostini. Am.J.Forensic Med Pathol 1982;3:131-41.

2. Midda MA. disclosing solution for synthetic filling. Br Dent J 1969;128:519-20.

3. Benthaus S, Duchesne A, Brinkmann B. A new technique for the postmortem detection of tooth-coloured dental restorations. Int J Legal Med. 1998;111:157-9.

4. Wozniak WT, Moore BK. Luminescence spectra of dental porcelains. J Dent Res 1978;57: 971-4.

5. Carson DO, Orihara Y, Sorbie JL, Pounder DJ. Detection of white restorative dental materials using an alternative light source. Forensic Sci Int 1997; 88:163-8.

6. Clark DH, Ruddick RF. Postmortem detection of tooth colored dental restorations by ultra violet radiation. Acta Med Leg Soc. 1985;35:278-84.

7. Pretty IA, Smith PW, Edgar WM and Higham SM. The use of quantitative light-induced fluorescence (QLF) to identify composite restorations in forensic examinations, J Forensic Sci.2002;47:831-6.

8. Suzuki K, Hanaoka Y, Minaguchi K, Inoue M, Suzuki H. Positive identification of dental porcelain in case of murder. Jpn J Legal Med 1991;45:330-40.

9. Yoshida H, Takei T. Identification of artificial teeth by fluorescent examination with an emphasis on metal bond porcelains. Jpn J Legal Med 1993;47:310-4.

10. Aboshi H, Takahashi T, Komuro T, Nogami T. Identification of the unknown body by component analysis of dental porcelain. Acta Crim Japon 2004;70:120-7.

11. Herglotz HK, Birks LS. eds. X-ray spectrometry, New York: Marcel Dekker, 1978.

12. Blakeslee RW, Renner RP, Shiu A. eds. Dental technology - Theory and practice -, St. Louis: CV Mosby, , 1980;224-53.

Address for correspondence:
Dr. Hirofumi Aboshi
Department of Legal Medicine,
Nihon University School of Dentistry,
1-8-13, KandaSurugadai, Chiyoda-Ku,
Tokyo, 101-8310 JAPAN
Email: aboshi@dent.nihon-u.ac.jp

THE USE OF DENTAL RADIOGRAPHS FOR IDENTIFICATION OF CHILDREN WITH UNRESTORED DENTITIONS

S Fridell, J Ahlqvist

Oral and Maxillofacial Radiology, Dept of Odontology, Umeå University, Sweden

ABSTRACT

The success of dental identification is often dependent on the extent of previous dental care and the location of detailed dental records. However, several factors limit available comparable data among children. There are often no clinical indications for dental radiography before the age of five and many children and adolescents have no restorative care. This reduces the amount of individualizing information suitable for comparative identification.

The aim of this study was to investigate matching of dental x-rays from children without fillings at different ages, and to see if radiographic expertise facilitated radiographic comparison. Five general dental practitioners (GDP) and five oral and maxillofacial radiologists (OMR) attempted to match bitewing examinations from 30 children.

The results showed that dentists are likely to match bitewing radiographs in these conditions. This likelihood is further enhanced when oral and maxillofacial radiologists compare images. This suggests that manual comparison of bitewings from children allow sufficient concordant visible points for identification to occur.

(J Forensic Odontostomatol 2006;24:42-6)

Keywords: Forensic odontology, identification, radiology, radiography, children

INTRODUCTION

On the 26th of December 2004 one of the largest disasters in history happened when a tsunami occurred in Southeast Asia. Hundreds of thousands lost their lives and many thousands more were affected by loss of family members, relatives, houses and employment.[1]

In Thailand the tsunami hit tourist areas and the people who lost their lives came from many different countries. Identification teams from 19 countries were sent to the area to identify the remains. The teams included police, criminal investigators, forensic pathologists, DNA experts, fingerprint technicians, and forensic odontologists.

In the identification work, postmortem data were collected from the bodies of those found. The police recorded various findings e.g. clothing, tattoos and fingerprints. The forensic pathologist performed a physical examination of the body including notation of scars, missing organs and other physical characteristics that might provide material to facilitate identification. A DNA sample was also harvested. The forensic odontologist examined the teeth and jaws and recorded the dental status by clinical and radiographic examination.

Antemortem data were collected from the missing person's dentist, family and others who had information about the missing person. All information about the missing persons and the bodies found were recorded on INTERPOL Disaster Victim Identification forms. Using computer software programs, antemortem and postmortem information was sorted, and likely matches were postulated. Manual comparisons were then undertaken to confirm or refute a putative match.[2]

Dental records, fingerprints and DNA alone can each serve as a basis for identification. In cases with partial information within these different disciplines, combined information can be used. Earlier studies, as well as experience from the tsunami disaster, show that dental identification is the method that predominates in disaster victim identification work.[3-5] This is due to the fact that a vastly larger number of people have antemortem dental records compared to the number of people who have antemortem fingerprints or DNA profile recorded.

However, the success of dental identification is partially dependent on the extent of previous dental intervention as recorded on the dental record.[4, 6-8]

This was clearly seen with the identification of children who lost their lives in the tsunami disaster.[5]

There are several factors that can limit the available comparable data among children. There are often no clinical indications for dental radiographs before the age of five and many children and adolescents have had no restorative care.[9-10] Another problem is that normal maturational changes occur with children such as loss of deciduous teeth and the development and eruption of permanent teeth. The latter process can, however, be used in reconstructive identification by establishment of the age at death.[11]

The lack of restorative therapy among many children means that there is limited information for comparison. Even if no fillings exist and treatment need is low, bitewing examinations are almost always a part of the dental record if the child has reached the age of five to six years.[9,10] These images contain radiographic information that could be used in an attempt to match x-rays of the same person taken some years later, including root and pulp structure. If extraoral images are available, the shape and size of the frontal sinus is regarded as unique for each individual and has been used for identification.[12] By looking at anatomical structures and by undertaking postmortem age stratification, a possible match might not be conclusive, but could be the basis for a combined investigation based on comparison of clothing and personal effects, fingerprints and/or DNA-analysis.

The aim of this study was to investigate manual matching of radiographic examinations from children without fillings in different age groups. In order to see if radiographic expertise facilitates radiographic comparison the matching was performed by both general dental practitioners and oral and maxillofacial radiologists.

MATERIALS AND METHODS

Bitewing examinations in the archives of the public dental clinic at the Dental school in Umeå, Sweden were used. Examinations from three different age groups were collected. From every age group the first ten children who had at least two bitewing examinations with a 1-3 year interval between examinations and who had no fillings were selected, i.e. a total of 30 children. The children were 6-7, 9-10 and 12-13 years old at their first examination and 0.8-3.2 years older at their second examination. Examinations with the longest time interval between were seen in the youngest age group with a mean value of 2.0 years. In the group 9-10 years, the mean value was 1.4 years and in the group 12-13 years the mean value was 1.5 years (Table 1).

Table 1: *Ages of children examined and elapsed time between the bitewing examinations*

	Minimum	Mean Value	Maximum
Age at first examination (year)	6.1	9.8	13.7
Time between examinations (year)			
6-7 year	0.8	2.0	3.2
9-10 year	0.9	1.4	2.0
12-13 year	1.2	1.5	2.1
All ages	0.8	1.6	3.2

To mimic the difficulty in finding missing persons among a large number of victims another 20 bitewing examinations from children without fillings and with ages corresponding to the ages at the second examination were selected.

There were seven in the youngest age group, six in the oldest age group and seven in the group in between.

The bitewings from the earlier examinations, simulating antemortem data from missing persons, were marked with letters. The bitewings from the latter examinations and the examinations that had no match simulated postmortem data. These were marked with numbers. The “antemortem material” also included information about sex, examination date, and age at “disappearance”. The “postmortem material” included information about sex.

All bitewing examinations were duplicated. One set was sent to the public dental clinic in Vimmerby, Sweden and the other to Oral and Maxillofacial radiology at the department of Odontology, Umeå University. An instruction and an answer form followed the examinations. In the answer form the examiner was asked to combine the number of an examination with the letter of an earlier examination from the same person and grade the confidence of the match as one of three levels; “without doubt”, “probably” and “possible”. In the confidence level “without doubt” only one proposal could be made. In the other two, “probable” and “possible”, more than one proposal was allowed.

Table 2: *Total result of matching and results in reference to age and gender of the children, elapsed time between bitewing examinations and examination groups*

Category	Amount correct/total	% correct	P-value
Total	265/300	88.3%	
Age at first examination			
6-7 year	80/100	80.0%	
9-10 year	91/100	91.0%	
12-13 year	94/100	94.0%	0.005[2]
Gender			
Boys	144/160	90.0%	
Girls	121/140	86.4%	0.371[1]
Time between examinations			
<1.5 years	142/150	94.7%	
>1.5 years	123/150	82.0%	0.001[1]
Examiner			
GDP	117/150	78.0%	
OMR	148/150	98.7%	<0.001[1]

[1] Fisher's exact test
[2] Person Chi-square text

Table 3: *Proportion correct matches in reference to age groups and examination groups*

Age at first examination/ examiner	Amount correct/ total	% correct	P-value[1]
6-7 year			
General dentist	32/50	64%	
OMR	48/50	96%	<0.001
9-10 year			
General dentist	41/50	82%	
OMR	50/50	100%	0.003
12-15 year			
General dentist	44/50	88%	
OMS	50/50	100%	0.027

[1] Fisher's exact test

Ten examiners compared the images individually, five general practitioners and five oral and maxillofacial radiologist. The number of correct matches were analysed with respect to time between bitewing examinations, age and gender of the children and examiner group. The results were compared using Fishers exact test when two parameters were compared e.g. general practitioners vs. oral and maxillofacial radiologists. If three parameters were compared the Pearson chi-square test was used. The level of significance was set at 5%.

RESULTS

A match was considered correct regardless of the confidence level of the match, i.e. if an examiner gave three answers under the heading "possible" and one of these was correct, this was considered a correct match. The reason for this is that when the possible matches are reduced to a small number the probability of achieving a positive identification based on the dental findings in combination with information from other disciplines (fingerprints, DNA) must be considered high.

The total number of correct matches was 88.3%. The average of general practitioners was 78.0% and for oral and maxillofacial radiologists 98.7% ($p<0.001$). The time between examinations influenced the possibility of making a correct match. If the time between bitewing examinations was <1.5 years the average correct match was 94.7% and if it was ≥1.5 years the correct match was reduced to 82.0% ($p=0.001$).

There was a statistically significant difference in the possibility of correctly matching images from children in different age groups. In the youngest age group, 6-7 years, (age at the first examination) 80.0% of the children were correctly matched. The corresponding figure was 91.0% in the 9-10 year group and 94.0% in the group 12-13 years of age ($p=0.005$). The difference between the two examiner groups was also statistically significant. The general dentists made correct matches in 78.0% of the cases and the oral and maxillofacial radiologists in 98.7% (Table 2).

There was also a difference in success rate in the different age groups between the general practitioners and oral and maxillofacial radiologists. The largest difference was seen in the age group 6-7 years where the general practitioners on average correctly matched 64.0% of the cases and the oral and maxillofacial radiologists on average correctly matched 96.0% of the cases ($p<0.001$). The difference in correctly matched cases was less pronounced, but still statistically significant, in the middle group ($p=0.003$) and the group 12-13 years of age ($p=0.027$). The oral and maxillofacial radiologists had a success rate of 100 % in these two groups (Table 3).

If the time between examinations was longer than 1.5 years the general practitioners suggested more than one number ("body found") to a letter ("missing

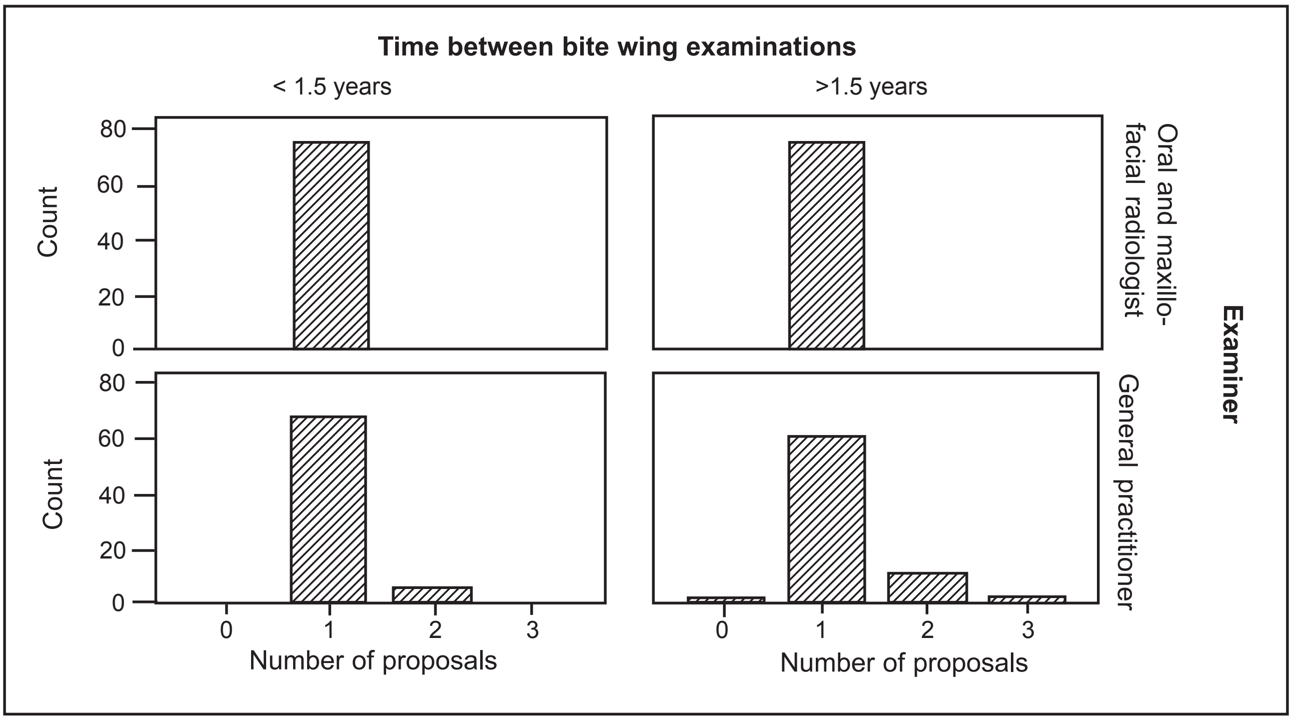


Fig.1: *Number of proposed matchings with reference to time between bitewing examinations, and examination groups*

person") more often than if the time was under 1.5 years. The oral and maxillofacial radiologists did not suggest more than one probable and/or possible match at all (Fig.1).

The answers of the oral and maxillofacial radiologists were more often found under the headings "without doubt" and "probably" compared to the general practitioners.

DISCUSSION

This study shows that it is possible to match bitewing examinations of children without fillings who have a 1-3 year interval between examinations. Ten dentists matched bitewing examinations to see how effective the method is. The examiners were general practitioners (five) and oral and maxillofacial radiologists (five). The results show that oral and maxillofacial radiologists have an advantage over general practitioners in matching x-ray images when the radiographic signs are limited to anatomy. Besides a higher score in correct matching, their answers were more often found under the heading "without doubt" and "probably" compared to the general practitioners answers, indicating that the oral and maxillofacial radiologists were more confident in their decisions.

None of the oral and maxillofacial radiologists used the possibility of correlating more than one "found body" to a "missing person" and the matches were almost 100% correct. It is most likely that their greater radiological experience in comparison to general practitioners was an advantage when analysing the radiographs.

The results show that it is more difficult to match images from younger children. This, combined with the fact that dental records from younger children often contain less information that can be used for dental identification than that seen in older children, teenagers and adults, can be one explanation for the relatively large proportion of Swedish children who are still missing after the tsunami disaster. Another explanation could of course be a complete lack of comparable data.

In this study the time that passed between examinations was longer in the youngest age group. From about 6 years and onward the dentition undergoes dramatic change. This is a probable reason for the greater difficulty matching the images in the youngest age group seen mainly in the results of the general practitioners.

The problem with changing anatomy has been discussed by Kirk, Wood and Goldstein.[12] In a retrospective study of 39 cases of identification using frontal sinuses comparisons they concluded that the method was valid for persons older than 20 years. The technique has, however, not been evaluated for young people were the sinuses undergo large changes. They predicted difficulties using the method in persons younger than 20 years.

In conclusion, this study shows that dentists are likely to match bitewing examinations from children without fillings. It also shows that this likelihood is further enhanced when oral and maxillofacial radiologists compare the images. This suggests the possibility that manual comparison of bitewings from children may lead to matches between radiographic data from missing and deceased persons. These matches can, in cases that are not conclusive from a dental point of view, be the basis for a combined investigation based on dental status, fingerprints and/or DNA-analysis.

REFERENCES

1. World Health Organisation. Moving beyond the tsunami: The WHO story. 2005. http://whqlibdoc.who.int/searo/2005/9290222425_eng.pdf

2. Andersen Torpet L. DVI System International: software assisting in the Thai tsunami victim identification process. J Forensic Odontostomatol 2005;23:19-25.

3. Mulligan ME, McCarty MJ, Wippold FJ, Lichtenstein JE, Wagner GN. Radiologic evaluation of mass casualty victims: Lessons from the Gander, Newfoundland, accident. Radiology 1988;168:229-33.

4. Clark DH. An analysis of the value of forensic odontology in ten mass disasters. Int Dent J June 1994;44:241-50.

5. James H. Ed. Thai tsunami victim identification-overview to date. J Forensic Odontostomatol 2005;23:1-18.

6. Clark DH. Dental identification problems in the Abu Dhabi air accident. Am J Forensic Med Pathol Dec, 1986;7:317-21.

7. McCarty VO, Sohn AP, Ritzlin RS, Gauthier JH. Scene investigation, identification, and victim examination following the accident of Galaxy 203: disaster preplanning does work. J Forensic Sci Jul,1987;32:983-7.

8. Brannon RB, Kessler HP. Problems in mass-disaster dental identification: a retrospective review. J Forensic Sci 1999;44:123-7.

9. Espelid I, Mejare I, Weerheijm K; EAPD (2003), EAPD guidelines for use of radiographs in children. Eur J Paediatr Dent Mar, 2003;4:40-8.

10. Andersson M, Stecksen-Blicks C, Stenlund H, Rangård L, Tsilingarisis G, Mejàre I. Detection of Approximal Caries in 5-year old Swedish Children. Caries Res 2005;39:92-9.

11. Maber M, Liversidge HM, Hector MP. Accuracy of age estimation of radiographic methods using developing teeth. Forensic Sci Int, May 2006;15:159 Suppl:S68-73. Epub 2006 Mar 14.

12. Kirk NJ, Wood RE, Goldstein M. Skeletal Identification using the Frontal Sinus Region: A Retrospective Study of 39 cases. J Forensic Sci 2002;47:318-23.

Address for correspondence
Jan Ahlqvist
Department of Odontologi
Umeå University
SE-901 85 Umeå
SWEDEN
Tel: +46 706176172
Email: jan.ahlqvist@odont.umu.se

CRANIOFACIAL IDENTIFICATION BY COMPUTER-MEDIATED SUPERIMPOSITION

S Al-Amad,[1,2,3] M McCullough,[1] J Graham,[2] J Clement,[1,2] A Hill[2]

1 Oral Anatomy, Medicine and Surgery, School of Dental Science, University of Melbourne, Australia
2 Centre for Human Identification, Victorian Institute of Forensic Medicine, Australia
3 National Institute of Forensic Medicine, Ministry of Health, Jordan

ABSTRACT

Mass disasters are associated with a large number of fatalities, with victims being visually unidentifiable in most cases. Dental identification, although being an important and valuable identification method, is subject to the availability and quality of antemortem and postmortem dental records. This paper presents a simple-to-use method of human identification using an antemortem photograph showing anterior teeth with superimposition onto a postmortem image using specific features of Adobe® Photoshop®.* We present cases and discuss the benefits and difficulties of this method.

(J Forensic Odontostomatol 2006;24:47-52)

Key words: superimposition, identification, Adobe Photoshop, victim; tsunami, disaster

INTRODUCTION

The identity of the dead is important for well-appreciated reasons. In most cases a family member or acquaintance is able to identify the deceased visually, but this method is sometimes inapplicable if the deceased has lost facial features. Cases of incineration, decomposition or skeletalization necessitate the use of a scientific identification method. The use of dental characteristics is an identification method that has significant utility due to its accuracy, cost and time effectiveness by comparison with other identification methods. Postmortem dental material can sustain harsh circumstances, such as fire and petrifaction, and still retain utility as an identification method. However the greatest problem is often the lack of sufficiently detailed antemortem records to allow for a meaningful comparison. If these limitations occur other methods of identification need to be approached and photographic superimposition is one such method.

In this paper, we present cases which were identified using Adobe® Photoshop® version 7*. We discuss the technique with emphasis on its value as a supplementary identification method in mass disasters where forensic odontologists might be challenged with victims whose antemortem dental records are inadequate or are absent.

Case one

A middle aged male died in the Indian Ocean tsunami disaster. His body was decomposed and was visually unidentifiable at the time of postmortem examination. Dental examination revealed extensive restorative work and missing upper lateral incisor teeth. More than seven months after his death, the dental reconciliation team was able to find a possible antemortem dental record which showed missing upper lateral incisor teeth and only one restoration on the upper right second molar. Both features were consistent with the postmortem findings, but were considered insufficient for identification to be established.

Considering that the anomaly of missing upper lateral incisors is uncommon, an attempt to perform superimposition was undertaken. Several antemortem portraits showing anterior teeth were obtained from the next of kin. One of these showed upper anterior teeth in reasonable resolution. The antemortem photograph was scanned at 600 dpi and a series of postmortem photographs was taken from different angles by using a three-step ladder (five horizontal positions, approximately thirty centimeters apart, and three vertical positions from each horizontal position, approximately fifteen centimeters apart) with a digital single-lens reflex camera.** Postmortem images with the closest viewing angle to that of the antemortem portrait were selected; then superimposition, using Adobe® Photoshop®, was performed and successfully resulted in a consistent dental and craniofacial match (Fig.1). DNA analysis

*Adobe Systems Incorporated, California USA 2002

**Canon EOS 300D, Canon Inc. Tokyo, Japan

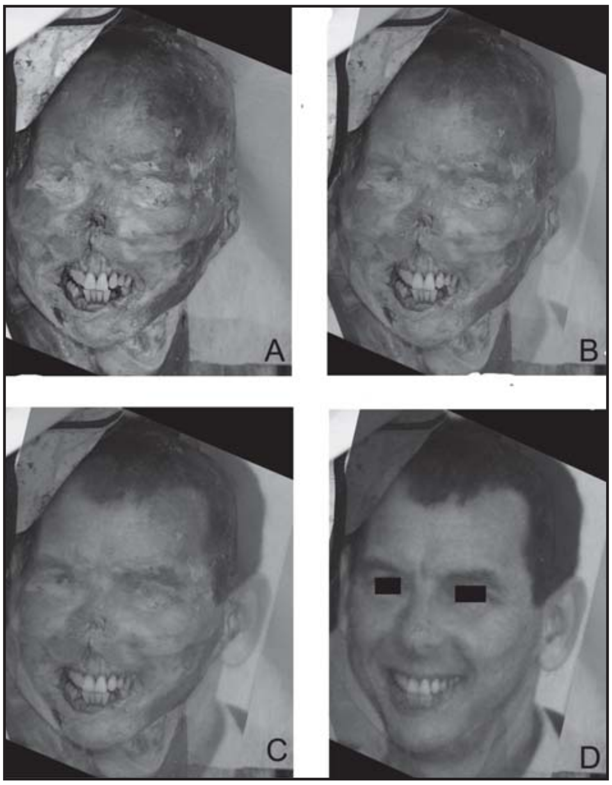


***Fig.1**: Case one. A through D show superimposition of portrait onto postmortem remains using the anterior teeth as a guide. Opacities were for: A 1%, B 25%, C 50% and D 90%*

was performed later and confirmed the positive identity.

Case two

A child, aged approximately twelve years, who was a victim of the Indian Ocean tsunami disaster was skeletalized at the time of postmortem examination. The child had fissure sealants on all first molars and had fixed orthodontic appliances on the upper and lower teeth. Antemortem records of children of approximately the same age and with fixed orthodontic appliances were collected (forty records of both genders) and each case was carefully examined. One of these antemortem records contained a recent model of the upper and lower teeth that showed irregular incisal edges of the upper two central incisor teeth. A series of photographs was taken of this model from different angles of an imaginary grid (using the same camera as in case one), to try to reproduce the camera angle at which the postmortem picture was taken. When a satisfactory angle was reached, superimposition was performed using Adobe® Photoshop® which resulted in a compelling match (Fig. 2). No further identification methods were considered necessary.

Case three

A tooth was recovered from a suspected crime scene and was the only human remains found. The tooth was identified as a human lower right lateral incisor. The tooth showed evidence of periodontal disease with traces of subgingival calculus, oblique attrition of the incisal edge and a fractured root apex. The antemortem record consisted of a written dental treatment card and an orthopantogram (OPG) of the suspected victim taken seven years previously (Fig.3A). It showed the lower right lateral incisor tooth with similar pattern of wear. In order to obtain a comparable image, we converted the tooth into an OPG image by fitting it in its corresponding position in a dentate acrylic skull replica (Fig. 3D and E). The radiology service where the antemortem OPG was performed was located and its staff confirmed that they have been operating the same OPG machine for more than seven years. The tooth in the acrylic skull was radiographed using that same machine which produced a comparable image (Fig.3B). Both radiographs were scanned at 600 dpi and superimposition, using Adobe® Photoshop®, was performed. There was a compelling match between the outline, including the pattern of attrition of the right lower lateral incisor tooth of both images (Fig. 3C) which proposed a positive identification.

Technique

Antemortem and postmortem images are opened within Adobe® Photoshop® and the areas of interest cropped using the **crop tool**. One image can then be either “dragged and dropped” or “copied and pasted” onto the other image which will automatically become the background layer resulting in an overlaid image. One layer can be expanded or shrunken against the other in order to obtain a one-to-one relationship. This can be performed using the **free transform** tool in the edit menu or simply by clicking **Ctrl-T**. This tool will create a rectangle around the highlighted layer. Changing the size of this rectangle can be undertaken by “dragging” one of its corners. Holding the **shift** button while resizing the image is necessary to prevent distortion and will keep changes to the x and y axes consistent. This tool also gives the operator the advantage of rotating the highlighted image in the x and y axes.

The resizing and rotation of the overlaid image can be performed only if one layer is semi-transparent so that the operator can see the outline of the

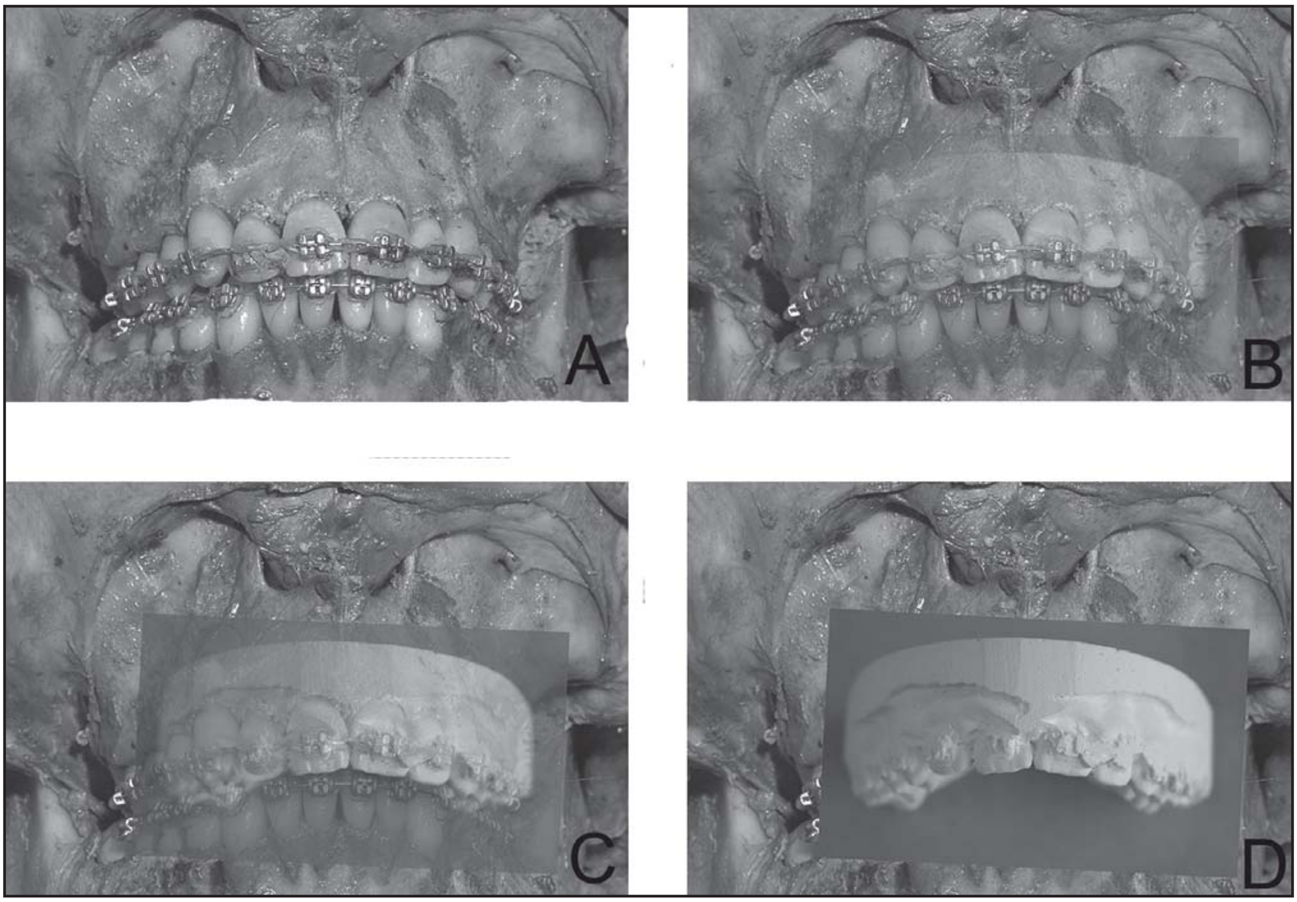


***Fig.2**: Case two. A through D show increasing ratio of opacity while superimposing an antemortem model of upper jaw onto postmortem remains. Opacities were for: A 1%, B 30%, C 60% and D 100%*

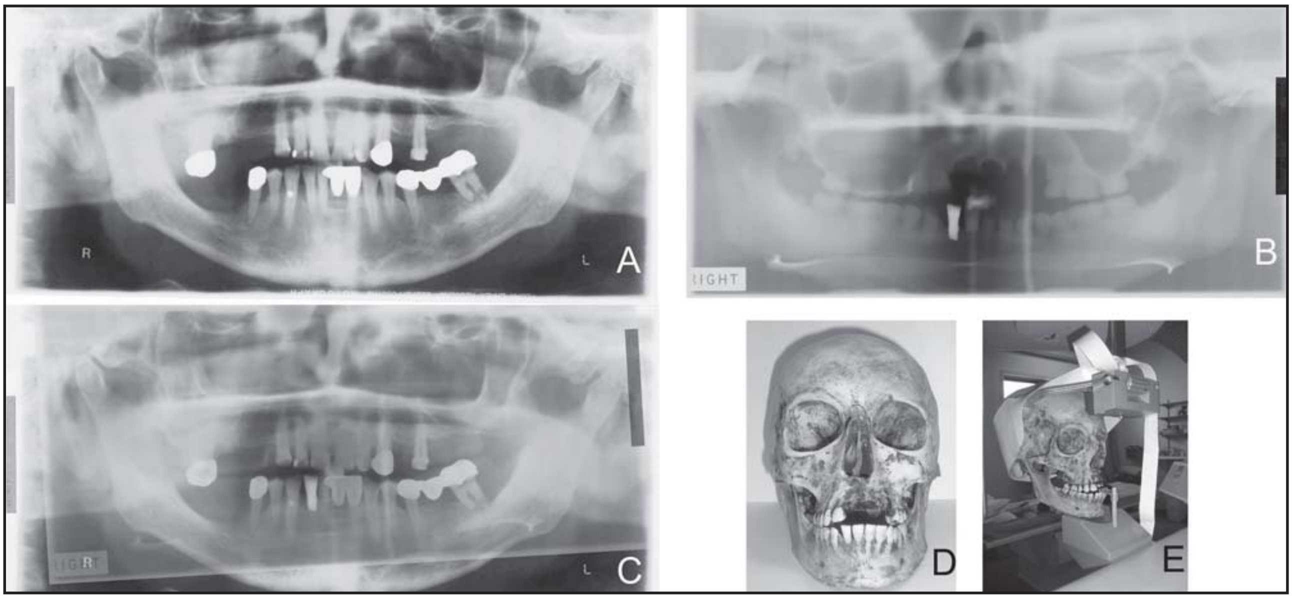


***Fig.3**: Case three. A antemortem OPG, B postmortem OPG of an acrylic mandible and skull with tooth 42 embedded in its assumed anatomical position, C superimposition of both radiographs at opacity 50% showing consistent outline of tooth 42 without resizing either image. D and E show tooth 42 embedded in the acrylic mandible during radiography*

background layer. The **opacity** slider on the layers palette gives values ranging from 0% to 100% transparency. Values in between will allow the operator to see the outline of both images while moving, rotating and resizing the overlaid image.

Anterior teeth are attempted to be matched by trial and error until the outline of both antemortem and postmortem teeth is consistent or otherwise. When sufficient concordance between anterior teeth is reached, other anatomical landmarks are examined for consistency. Magnifying a field might be useful and can be achieved using the **zoom** tool. This technique is illustrated in Figure 4 (For further details on relevant tools of Adobe® Photoshop® the reader is advised to visit ref. 12).

DISCUSSION

In a review, Taylor and Brown[1] discussed attempts to superimpose a face in a photograph taken during life onto a skull to determine if there was concordance between the two. The technique involved hand tracing the outline of the skull and that of a portrait followed by overlaying them using transparent paper. Photographic superimposition gained special attention when it was employed in a homicide case for the first time in 1937.[2] When introduced in the seventies, video superimposition revolutionalised this identification technique by allowing it to become a "live" process.[3] This technique involved one image being viewed continuously while the other one was being incorporated. It produced a more realistic result simply and quickly by avoiding standard photographic methods and provided better comprehension of the identification procedure by a lay audience, such as a court jury. This technique, however, required expensive equipment and technical expertise, which was sometimes difficult to justify due to the infrequency of cases requiring superimposition.

The technique described in this paper is based on specific features of the Adobe® Photoshop® image editing software and is performed using a basic personal computer. It is a comparison of two digital images by over-laying one onto another using the program's multilayer function. The opacity is reduced to allow semi-transparency and then maximum concordance is reached -or otherwise- by resizing and rotating the overlaid image by trial and error.

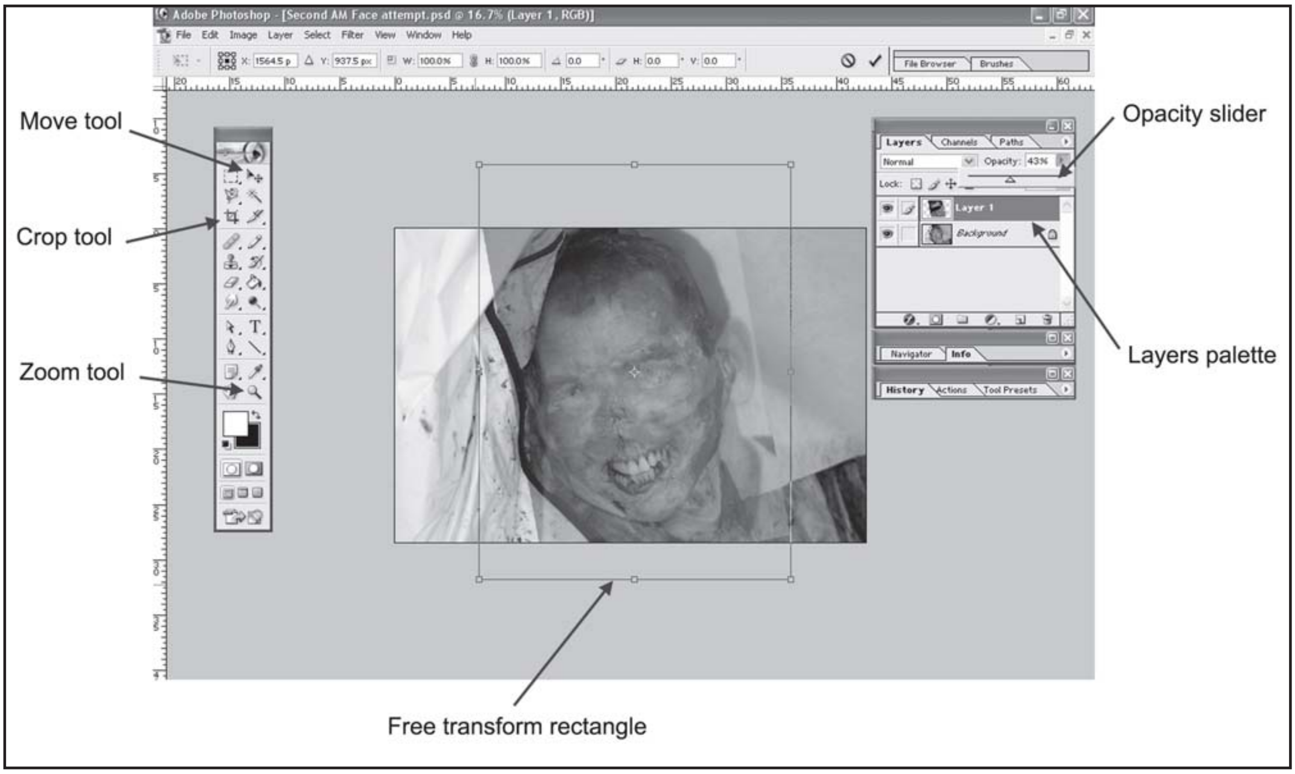


***Fig.4**: tools used for Adobe® Photoshop®-mediated superimposition illustrated on case one*

Demonstrating the steps which lead to the conclusion that identity is established or not is a valuable advantage of this technique when an expert opinion is requested by a legal system.

Reproducing the same camera angle of the antemortem photograph and reaching a 1:1 scale between antemortem and postmortem images are the two major steps for any superimposition attempt and much work had been done to facilitate those two steps.[3-5] Forensic experts have attempted to use objects within the vicinity of the face at approximately the same distance from camera.[2,6] McKenna *et al* used the anterior dentition as a guide to enlarge and to match images by tracing the outline and comparing anatomical landmarks.[7] Their approach was based on the fact that the upper anterior teeth are the only hard tissues that project from the skull and can be analyzed from both antemortem and postmortem images. In the method described in this paper, anterior teeth are of paramount value. They will not only serve as a reference to reach 1:1 relation between the two images, but also as a key to rotate the overlaid image over the background image in order to reproduce the angle on the x and y axes. If the skull and the photograph belong to the same individual, then all other facial anatomical landmarks should be in the best fit possible as was demonstrated in case one.

This technique was beneficial in the identification of few of the victims of the Indian Ocean tsunami (December 2004). Portraits of smiling faces (with the anterior teeth showing) compensated for the lack of dental records which can be expected when a disaster affects certain communities with little or no dental work or with poor record keeping (case one). The technique proved useful in identifying children who would normally have no restorative dental work done as was shown in case two, and more importantly, it is a technique that is simple to learn and perform and can substitute the sophisticated equipment used in video superimposition.

Forensic odontology is based on the fact that teeth are unique to each individual.[8] Unfortunately we could not find any studies that investigated the pattern uniqueness of anterior teeth, mainly the upper anterior teeth that usually appear in smiling portraits. For this reason, forensic experts must select candidate cases carefully should the need for superimposition arise. Photographs showing the anterior teeth have to be clear and in focus, with good resolution and well illuminated. An anomaly, as in case one, or a special pattern, as in case two, suggest the use of superimposition, but it must be remembered that teeth and their positions are changeable during life either accidentally (falls), intentionally (dental treatment including orthodontics) or as part of growth (closure of a median diastema). It is essential to make certain that the antemortem photographs, or models as in case two, are recent. Cases whereby anterior teeth are absent (either antemortem or postmortem), or are not showing in portraits are not suitable for identification with this method.

Seeking more than one photograph of the suspected deceased individual and from different angles will produce reliable results. In one study, video superimposition, without using anterior teeth, resulted in 9.1% false positive identifications. This dropped to 0.6% when a second antemortem photograph from a different angle was used.[9]

Reproducing the camera angle from which the antemortem portrait was taken is by trial and error. In our first two cases, we made a series of digital photographs following an imaginary grid which helped produce images from different view angles. Several images of those were then selected and each attempted to superimpose onto the antemortem portrait (case one) and postmortem image (case two). Previous studies have suggested methods in an attempt to make this step easier.[3-6,10]

Quantifying superimposition was attempted previously.[7,11,13] Adobe® Photoshop® provides measuring tools which are described by Johansen and Bowers for bite mark analysis[12] and radiographic comparisons.[13] In the cases presented in this paper we did not perform measurements. More work needs to be done to utilize those tools to reach reproducible and quantitative results.

Case three is an application of this technique to superimpose radiographs and study the outline of teeth. Objective comparison between antemortem and postmortem radiographs was previously performed using Adobe® Photoshop®[13]. In our case, the same OPG machine with the same settings was used to produce the antemortem and postmortem radiographs. Hence we assumed that -without resizing either image- the outline of the tooth in the postmortem OPG would not fit that of the alleged victim if both teeth belonged to different persons. The outcome, as shown in Fig. 3, demonstrated satisfactory concordance between both radiographs, which proposed a positive identification.

The remarkable increase in the use of digital cameras has made photography a fashionable hobby. The availability of portraits, as a consequence, is becoming an antemortem record worth considering in craniofacial identification. The method we used here demonstrates the use of Adobe® Photoshop® as a user-friendly tool to overlay antemortem and postmortem images and to analyze their consistency in a reliable, speedy and easy manner which might compensate for the lack of comparable dental records. Further studies are required to determine the specificity and sensitivity of this technique.

ACKNOWLEDGEMENTS
The authors acknowledge all the support by the Australian Federal Police and by Dr. Stephen Knott and Dr. David Griffiths during Operation Cawdor. We also thank Dr. Alex Forrest for his input into case one and Professor Emeritus Peter Reade for his linguistic assistance.

REFERENCES

1. Taylor JA, Brown KA. Superimposition techniques. In: Clement JG, Ranson DL. Eds. Craniofacial identification in forensic medicine. London: Arnold, 1998:151-64.

2. Glaister J, Brash JC. Medico-legal aspects of the Ruxton case. Edinburgh, E & S Livingstone, 1937:144-70.

3. Brown KA. Developments in cranio-facial superimposition for identification. J Forensic Odonto-Stomatol 1983;1(2):57-64.

4. McGivney J. Facial superimposition. In: Bowers CM, Bell GL. Eds. Manual of forensic odontology. 3rd edn. American Society of Forensic Odontology, 1995:42-4.

5. Brocklebank LM, Holmgren CJ. Development of equipment for the standardization of skull photographs in personal identifications by photographic superimposition. J Forensic Sci 1989;34(5):1214-21.

6. Chee LF, Cheng CT. Skull and photographic superimposition: a new approach using a second party's interpupil distance to extrapolate the magnification factor. J Forensic Sci 1989;34(3):708-13.

7. McKenna JJ, Jablonski NG, Fearnhead RW. A method of matching skulls with photographic portraits using landmarks and measurements of the dentition. J Forensic Sci 1984;29(3):787-97.

8. Adams BJ. The diversity of adult dental patterns in the United States and the implications for personal identification. J Forensic Sci 2003;48(3):497-503.

9. Austin-Smith D, Maples WR. The reliability of skull/photograph superimposition in individual identification. J Forensic Sci 1994;39(2):446-55.

10. McKenna JJ. A method of orientation of skull and camera for use in forensic photographic investigation. J Forensic Sci 1988;33(3):751-5.

11. Bassed R. Victorian Institute of Forensic Meidicine, Australia. Personal communication 2003.

12. Johansen RJ, Bowers CM, eds. Digital analysis of bite mark evidence using Adobe® Photoshop®. California: Forensic Imaging Services, 2000.

13. Bowers CM, Johansen RJ. Digital imaging methods as an aid in dental identification of human remains. J Forensic Sci. 2002;47(2):354-9

Address for correspondence:
Suhail Hani Al-Amad
National Institute of Forensic Medicine
PO Box 484
Amman
JORDAN
Tel: +962 7 763 73 703
Fax: +962 6 4785 192
Email: suhail_amad@hotmail.com

CLINICAL AND HISTOPATHOLOGICAL EXAMINATION OF EXPERIMENTAL BITE MARKS *IN-VIVO*

SL Avon, JT Mayhall, RE Wood

University of Toronto, Laval University and Office of the Chief Coroner of Ontario, Canada

ABSTRACT

Under rigorously controlled laboratory conditions, mechanically induced simulated human bite marks were made on pig skin to enable the clinical and histopatholgical study of experimental bite marks *in-vivo*.

A series of bite marks were created on the abdomen and thorax of live anaesthetized juvenile pigs at specific times just prior to and after death. Following the release of the biting force clinical observations of antemortem wounds revealed slow diminishment of the bite indentations presumably due to dermal elastic recovery. Minutes after euthanasia of the animals, the indentations of the teeth from the postmortem bite marks faded rapidly. After the biting process the animals were placed on either the right or left side and this side was maintained until necropsy to examine for dependant and non-dependent side differences. All bite mark injuries located on the non-dependent side revealed specific pattern characteristics. However, on the dependent side whether the bite mark was antemortem or postmortem in areas of livor mortis, no clear pattern was visible. Histologically, the observations for each bite mark specimen were categorised by the presence or absence of extravasated red blood cells in the fatty or muscle layers.

The histopathological findings correlate with the clinical observations of antemortem and postmortem bite marks located on the non-dependent side in regard to muscular erythema and extravasated red blood cells. It is clinically difficult to comment on temporal relationship of a bite mark in relation to time of death in areas affected by blood-pooling seen on the dependent side. In these situations, histopathological studies could be a reliable alternative to provide information regarding antemortem or postmortem injuries.
(J Forensic Odontostomatol 2006;24:53-62)

Key words: bite mark, skin, histopathology

INTRODUCTION

Bite marks comprise a physical alteration in a medium caused by forceful contact of teeth either alone or in combination with other parts of the mouth.[1,2] Human bite marks vary in location, appearance, and severity. They are usually identified by their clinical appearance, a circular or oval injury consisting of one arch or two arches.[3] Along the periphery of the arches are a series of individual abrasions, contusions and/or lacerations reflecting the size, shape, arrangement and distribution of the features of the contacting surfaces of teeth.[4]

Several factors contribute to the appearance of a bite mark. These include resiliency of the material bitten; anatomic location; force applied during the bite; tongue pressure; suction during biting; dragging movements from relative movement of the biter and victim; whether the person is living or deceased at the time of the bite mark; and the time lapse between when the bite is produced and the examination.[1,5] Table 1 presents an overview of some of the factors in relation to the biter and the bitten that might influence the quality of bite marks on human tissue.[6]

Of these factors, both the mechanism and forces influence the appearance of bite marks. There is certainly a biting force produced by the teeth but there may also be a combined sucking and tongue thrusting force which has been defined in the past as the suckling force.[7-9] In general, as bite pressure increases the forms of the cutting edges, especially from the lower incisors will leave an impression on the skin. In wide biting, the palatal surfaces of upper incisors can leave an impression on the skin that can play a major role in determining the appearance of a wound.

Skin is a poor medium for registration of patterned injuries left by various tools, weapons or teeth.[2] The thickness of the epidermis, composition of the underlying dermis, musculature, adipose tissue,

Table 1: Factors which affect the quality of bite marks on human skin

Biter (usually the assailant)	Bitten part (usually the victim)
Mental state Position and action (static/dynamic) Dentition: Natural/synthetic Occlusion Force of bite Sucking Calculus and oral flora	Mental state: passive/struggling/consensual Position and action (static/dynamic) Race: pigmentation Gender Age Weight Type of tissue bitten (clothing)

curvature, looseness or adherence to underlying tissues will vary with anatomical location and within and between individuals[10]. From the time the injury is made until the information is obtained, skin may continue to change. The presence of elastic fibres allows stretching of the skin during the biting process or when the evidence is collected. The degree to which this phenomenon occurs depends on different factors and properties of the skin.[11] The non-linear nature of skin forms pre-existing tension lines similar to Langer's Lines.[9] These directional variations alter with movements and changes in body position. Distortions in bite marks, which are produced by such directional variations, will therefore be dependent on the position of the subject during biting as well as the location of the bite.[8,9] Due to the elastic fibres in the dermis, skin tension varies greatly with the location of the bitten area. The resulting pattern depends on factors such as whether the bite was made into loose or firm skin, on a flat or curved surface or whether the body part was flexed or extended.[2,12]

If the victim is alive, bruising may appear, if deceased, then postmortem changes will occur.[13] Many variables can affect the complex biologic events occurring within an injury. Table 2 presents a list of variables affecting the appearance of bruises.[14]

Histologically, leukocyte infiltration is the first sign of vital reaction at a damaged site. However, the degree of intensity of leukocyte infiltration indicative of a vital response is controversial.[15] In a living individual during the first few hours of wound healing, polymorphonuclear leukocytes accumulate in the wound periphery, but they do not yet constitute a well-defined zone around the wound. For some, cellular infiltration becomes well marked within 1-2 hours,[16,17] 2-6 hours,[18] 4-8 hours,[19] and can extend up to 24 hours after wounding.[20]

Presently there are no textbooks or papers that convincingly age bite mark contusions in relation to time of death although a few studies have described color changes in the healing bruises in live human skin.[12,17,18] It is the capillaries of the subcutaneous tissues, which make the greatest contribution to bruising. Extravasated blood will spread along any line of cleavage in tissue producing a discoloured area. In the live subject, further colour changes take place as haemoglobin breaks down.[14] The shape of a bruise may or may not therefore reflect the shape of the object causing it. All of this will further vary with the physical properties of the tissues: the local vascularity, the time elapsed since injury and the degree of injury.[14]

Table 2: List of variables affecting the appearance of bruises

Evolution of bruise colour Inherent skin pigmentation Tissue structure and vascularity Age Gender Subcutaneous fat content and victim's weight Rate of resolution Body temperature	Antemortem vs. postmortem Rapidity of death after injury Environmental conditions Clothing between biter and tissue Metabolic rate state of health and diseases (hypertension, coagulation disorders, liver dysfunction, medications)	Mass and velocity of impact Depth and force of injury Other physical deformation (stab wounds, overlap) Observer's subjectivity and degree of expertise Ambient light at time of observation Gravitational effects as time passes

The mechanical properties affecting the quality of a bite mark on human skin may be applicable to pig skin. Just how the pattern varies and how it is related to changes in the epidermal-dermal tissues remains unknown. A recent study provided information showing that clearly demarcated bite marks occur at or around the time of death.[21]

Animal skin differs morphologically from that of humans, making extrapolation to human histology problematic. Species-to-species variation is observed in terms of epidermal and dermal thickness, types and arrangements of hair follicles, and adnexal structures. Variation is also present in the morphology between regions of the body in an individual animal.[22] While similarities between pig and human skin are numerous in regard to structural, functional and biochemical characteristics, there are differences with respect to structure, immunohistochemistry and function.[23] Nevertheless, pig skin possess an epidermis and dermis comparable to human skin making it the most suitable animal that can be used as a model for the study of pattern injuries.[24,25]

PURPOSE OF THE STUDY

The purpose of this study was to examine experimental bite mark wounds inflicted at known intervals before and after death on an *in-vivo* porcine model. The study included clinical and histopathological observations to evaluate the usefulness of microscopic versus macroscopic examinations of bite marks as a method of deciding if such injuries were inflicted before or after death.

MATERIALS AND METHODS

Biting device

An instrument was constructed to mechanically produce simulated human bite marks on skin. This device was previously used for studies of ageing of bite marks.[21] The biting device consists of removable chrome-cobalt upper and lower dentitions fixed to a locking C-clamp #11 vice-grip.* A pressure-sensitive load cell and a pre-configured indicator** were added to the device to display live loads for pressure consistency at a pre-selected incisor tooth. Studies have shown that the pressure exerted by human incisor teeth with range from 6.0 to 23.5 kg with a mean of 8.9 to 11.4 kg.[26,27] Pressure consistency was selected at 23 kg to represent the "maximum" force applied by human incisor teeth.

Biting procedure on porcine skin

Ethics and Animal Care Committee approval was obtained from the Division of Comparative Medicine (DCM) of the University of Toronto.

Three young female Yorkshire pigs were used as recipients for antemortem and postmortem bite mark injuries. The mean age of the three pigs was 12 weeks with a mean weight of 36.2 kg. The pigs were purchased by the DCM 5 days prior to the procedure. The pigs were acclimated in a temperature (22°C), light-dark (12h/12h) regulated facility and received complete examination and blood tests to rule out any systemic diseases or haematological disorders.

On the day of the experiment, all the results from the blood tests were normal. Sedation of the pigs was achieved with an intramuscular injection of 16.0 cc of ketamine (100 mg/ml) in the right thigh. The abdominal region of the pig represents the widest surface and the thinnest epidermis and cornified layer.[28,29] The cleavage lines are mostly transverse in arrangement[30] and are similar in orientation to the tension lines of human skin. The bite marks were made at specific anatomical regions on the pig's abdomen and thorax. Comparison was possible because the antemortem and postmortem locations were reproduced from pig to pig, but did not overlap with each other (Fig 1). Therefore, anatomical antemortem and postmortem locations could be compared. Both sides of the pig's abdomen and thorax were bitten to study the effect of postmortem lividity since after biting, the animals were laid on one side until the time of the necropsy the next day.

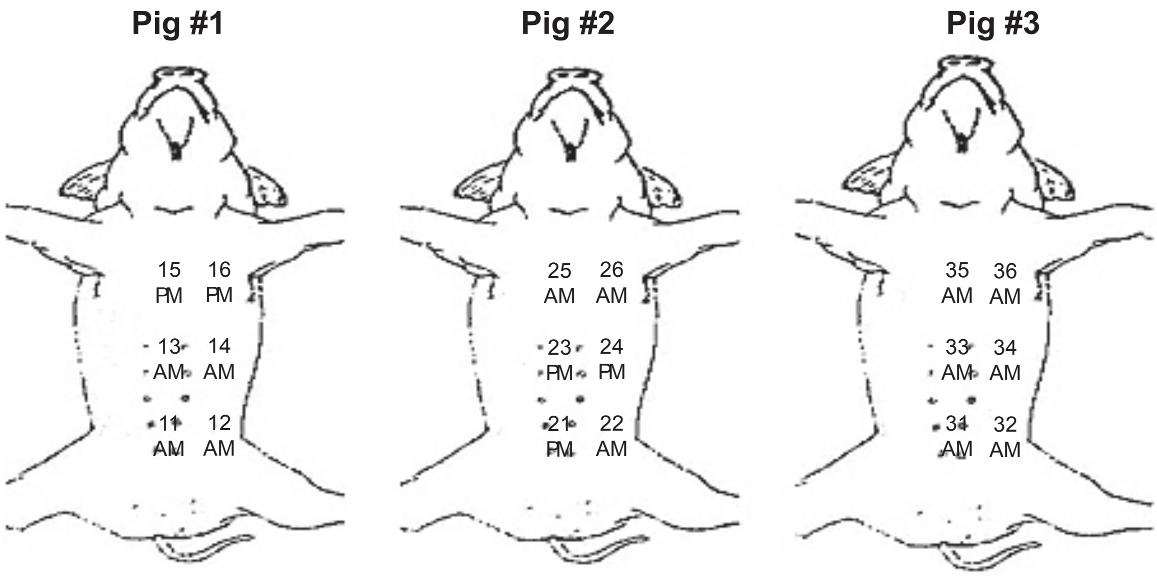
A series of simulated bite marks were created on the abdomen and thorax with the biting device using a pressure consistency of approximately 23 kg held for 60 seconds around the time of death. Each pig received 6 bite mark injuries (4 antemortem and 2 postmortem) located at specific sites on the abdominal and thoracic surfaces. With the animals under general anaesthesia, four antemortem bite marks were made one after the other with the time ranging from 10 minutes to 2 minutes before clinical death. Approximately 2 minutes after the fourth antemortem bite mark, the pigs were sacrificed with intravenous Tanax®*** Four minutes after clinical death, postmortem bite marks were made with the times of bite application ranging between 4 minutes and 9 minutes after death.

After the procedure, the pig was positioned on one side to allow settling of blood by gravitational forces.[31] This side was termed the "dependent" side

* MasterCraft® Canadian Tire Corporation Toronto, ON, Canada

** A-Tech Instruments Ltd., Scarborough, ON,Canada

*** Intervet Canada Ltd, Whitby, ON, Canada



First number:	Pig identification
Second number:	Location of bite mark on abdomen or thorax
AM:	antemortem
PM:	post mortem

Fig.1: *Distribution of ante mortem and post mortem bite marks among the three animal subjects*

allowing for bite mark comparisons from the dependent to the "non-dependent" side. After the bite mark procedure, the pigs were transported to the Coroner's Office of Ontario where they were stored under standard mortuary condition (4°C) until necropsy the next day.

Necropsy bite mark data collection

Analysis of the bite marks was done the following day. A supporting plastic matrix was fixed to the pig's skin using cyanoacrylate and silk sutures to preserve the original anatomical configuration of the skin during necropsy.[32] Each ring had a reference number for identification and reference points for anatomical orientation. After the rings were fixed to the animal, the specimens were excised *en bloc* and studied in their fresh state and again following 15 days in a 10% formalin fixative solution.

Scale photographs,[33,34] were exposed for visual observations before and after skin fixation to the plastic rings as well as fresh and formalin fixed status.

Biopsies of bite marks

Once photography was completed, the bite mark specimens were biopsied for histopathologial study. A piece of tissue was removed in the area of the incisors. The biopsies were made with a #22 scalpel removing *en bloc* the epidermis, the dermis, adipose tissue and muscle layers. Each specimen was immediately placed in a plastic jar containing 10% formalin fixative solution for 15 days. The contents were labelled in a manner corresponding to their anatomical bite mark location on each animal.

Microscopic observations of bite marks

Microscopic evaluations and interpretations were performed by the principal investigator (SLA) using a light microscope Olympus BX41 (U-TVo.5XC-2, Japan). Photomicrographs were taken with a digital camera connected to an Olympus microscope (PixeLink model PL-A662, Japan).

The tissues biopsies were examined according to a scoring sheet developed by the principal investigator to evaluate the correlation between antemortem and postmortem tissues as well as the effect of livor mortis (see Table 3 for scoring sheet). Evidence of blood vessels, blood vessel dilatation and congestion along with extravasated red blood cells in the various tissue layers were all evaluated. The evaluation was semi-quantitative using a score of plus (+) and minus (–) signs according to the presence or absence of the characteristic studied. The blood vessels and vasodilatation were evaluated at 20X magnification. Extravasated red blood cells were confirmed in the tissue type in which they were found whether it was connective tissue, fat or muscle tissue. The observed samples were graded "–" if there was no extravasated red blood cells, "+" if extravasated red blood cells were seen in at least one area, "++" for two to three areas, and "+++" if more than three areas were seen in the tissue. This scoring sheet allows a better depiction of the histopathological situation and facilitates correlation with clinical characteristics observed on antemortem and postmortem tissue reaction.

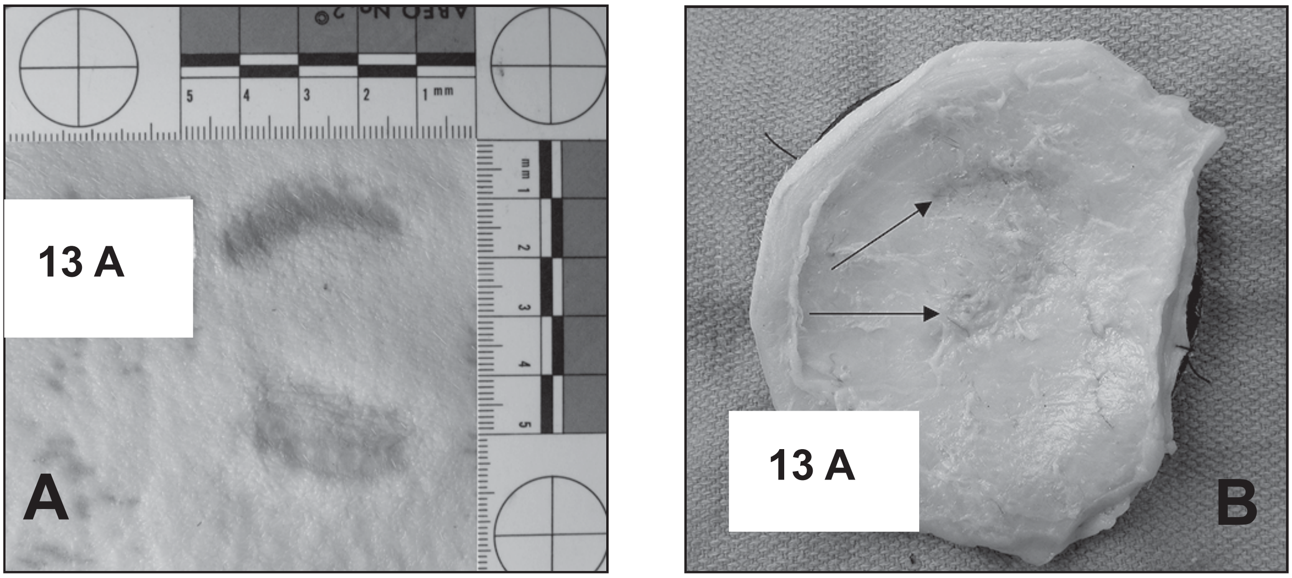
RESULTS

Clinical observations of bite marks

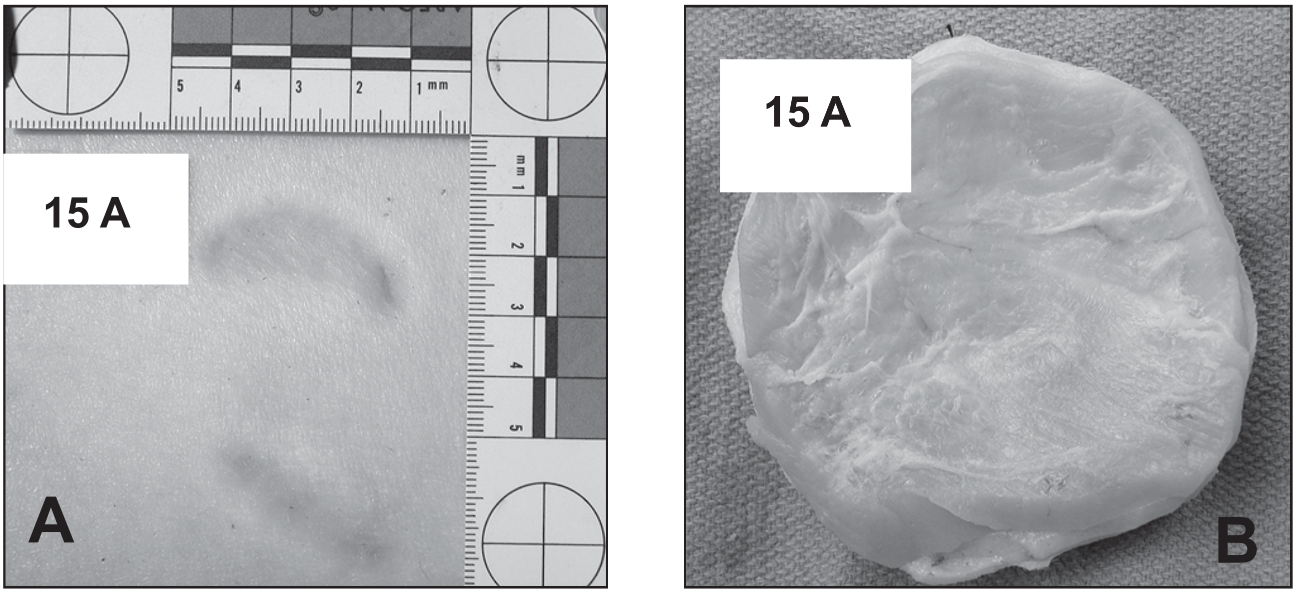
On the day the injuries were inflicted the markings were clearly evident and viewable as distinctive oval patterns. On some specimens, the cutting edges of the incisors left an impression on the skin while on other specimens, the palatal surfaces of upper incisors could be appreciated. Antemortem clinical observations after release of the biting force revealed slow but progressing fading of the impressions due to elastic recovery of the skin. After clinical death, bite mark indentations faded rapidly. Approximately 18 hours after the biting procedure, clinical observations revealed rigor mortis and livor mortis on the dependent side on the three pigs.

All bite marks on the non-dependent side revealed detailed pattern characteristics. The most stable and detailed bite mark injuries were those made five minutes prior to death followed by those made five minutes after death. Antemortem bite marks on the non-dependent side showed pale central indentations surrounded by red outlines (Figs 2 A and B). The class characteristics represented by linear or triangle shapes and individual characteristics with teeth angulations or rotations were recognizable even when the tissue was excised. The postmortem bite marks from the non-dependent side were homogenous, pale and less defined. They lacked central white indentations and showed less class and individual characteristics than the antemortem ones (Figures 3 A and B). Only antemortem bite marks from the non-dependent side exhibited areas of erythema.

The anatomical location of the antemortem and postmortem bite marks did not influence the pattern characteristics on the abdomen or the thorax of the animals.



Figs 2 A and B: *Antemortem bite mark present on the non-dependent side. A. Skin surface side showing white indentation with peripheral erythema. B. Deep tissue aspect (muscular side) showing intramuscular erythema caused by the bite (arrows)*



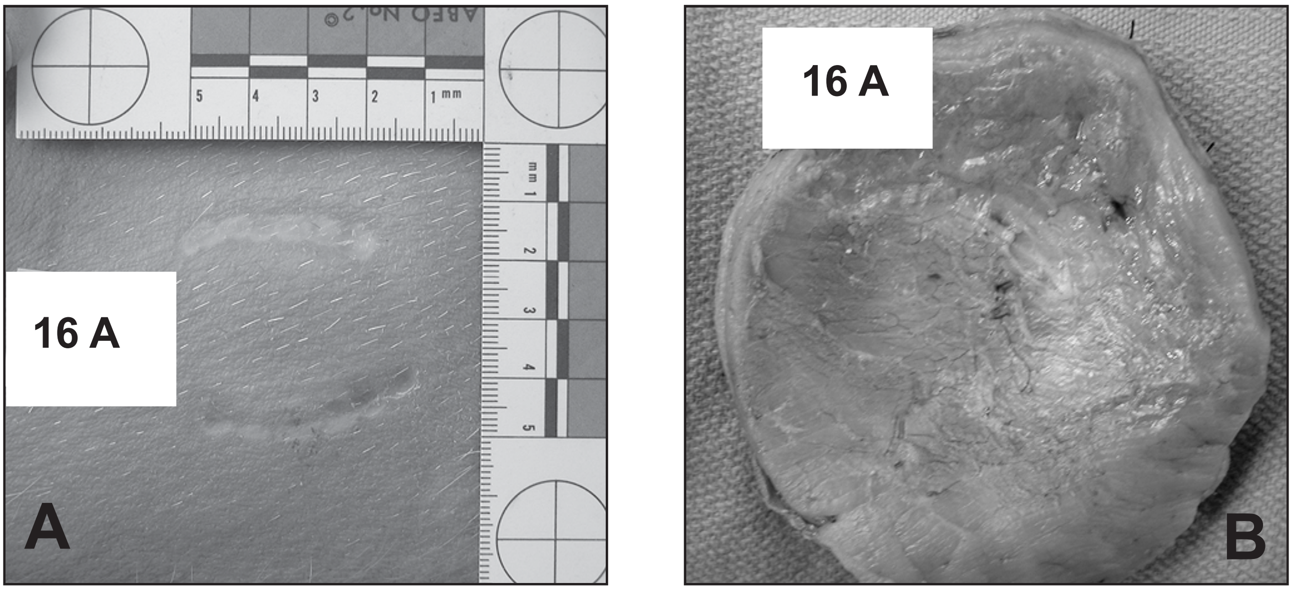
Figs 3 A and B: *Postmortem bite mark present on the non-dependent side. A. Skin surface side showing pale, homogenous redness at the side of indentation. B. Deep tissue aspect (muscular side) showing no intramuscular erythema*

.

The pattern injury of the bite marks was influenced by the presence of livor mortis. Bite marks located on the dependent side, where areas were discoloured by the settling of blood by gravitational forces within vessels, showed clear white indentations on a purplish blue background. Whether the bite mark was made antemortem or postmortem did not show any particular pattern characteristics of the tissues in a livor mortis area (Figs 4 A and B).

Histopathological observations of bite marks

Microscopic observations of all the examined tissues showed orthokeratinised stratified squamous epithelium with underlying connective tissue, adipose tissue and muscle. The observations for each specimen depended upon whether the biopsied tissue was antemortem, postmortem or if the tissue was affected by livor mortis. Table 3 shows a semi-quantitative evaluation for each specimen according to blood vessel configuration and the presence of extravasated red blood cells.



Figs 4 A and B: *Postmortem bite mark present on the dependent side. A. Skin surface side showing white indentation. B. Deep tissue aspect (muscular side) showing redness caused by livor mortis*

Table 3: *Semi-quantitative histopathological scoring sheet of bite marks*

Bitemarks	Blood vessels	ERBC conn. tissue	ERBC fat	ERBC muscle
11-nd (am)	+	-	+	+
12-d (am)	+++	-	+++	+
13-nd (am)	++	-	++	++
14-d (am)	+++	-	+	+
15-nd (pm)	+	-	-	-
16-d (pm)	+++	-	-	-
21-d (am)	++	-	++	++
22-nd (am)	+	-	++	+
23-d (pm)	+	-	-	-
24-nd (pm)	+	-	-	-
25-d (am)	+	-	++	+
26-nd (am)	++	-	++	++
31-nd (pm)	+	-	-	-
32-d (pm)	+++	-	-	-
33-nd (am)	++	-	+	++
34-d (am)	+++	-	+++	+
35-nd (am)	+	-	++	+
36-d (am)	+++	-	+	+

Legend:
First number - Pig identification
Second number: Location of bite mark on the abdomen or thorax
AM: Antemortem bite mark
PM: Postmortem bite mark
ERBC: Extravasated red blood cells
nd: Non-dependent side
d: Dependent side

All the antemortem bite marks showed extravasated red blood cells in the adipose tissue (Fig 5) and to a lesser extend in the muscle layers (Fig 6). The amount of red blood cells varied from one specimen to the other. No extravasated red blood cells were seen in any of the superficial connective tissue of the bite mark specimens.

Microscopic observations of the postmortem bite mark tissues showed no extravasated red blood cells either in the connective tissue, adipose tissue or muscle layers.

The influence of postmortem lividity was visible as vasodilatation and congestion of the vessels (Fig 7). The blood vessels in the tissue were more obvious and easier to locate as a result of settling of blood by gravitational forces within dilated, toneless capillaries.[31] This situation was observed only in the areas affected by livor mortis and not by the side of the pigs.

Discussion

There are many situations where the evaluation of dermal injuries at autopsy may suggest whether an injury was created prior to or after death. Such conclusions are legally important. Forensic pathologists frequently use macroscopic characteristics of a wound and their practical experience to determine if the wound occurred before of after death. For some authors, if the wound was obviously inflicted on a living individual, the

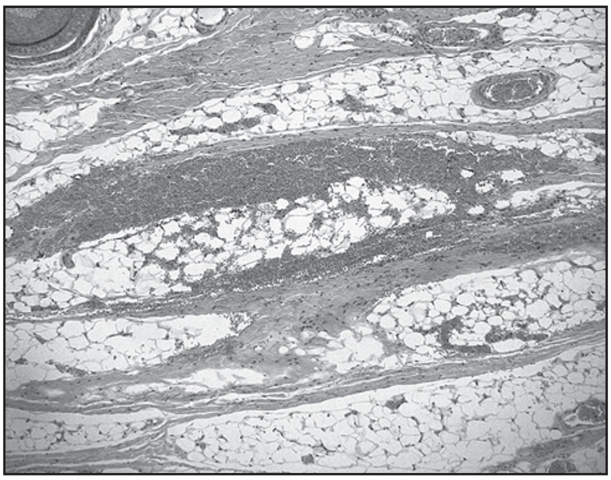


Fig.5: *Photomicrograph showing extravasation of red blood cells in the adipose tissue of an antemortem bite mark located on the dependent side (Haematoxylin and Eosin stain at 200X power field)*

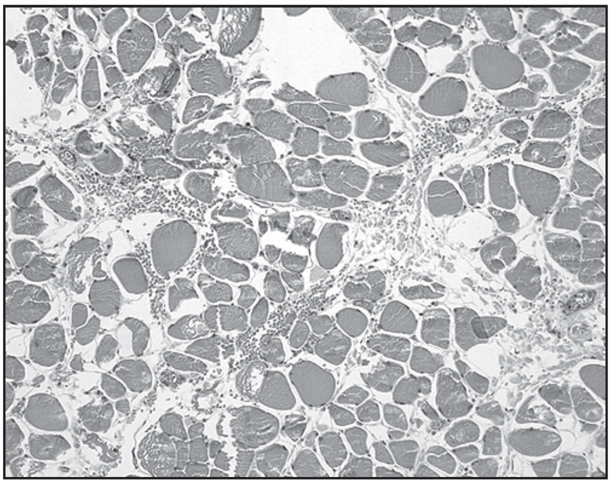


Fig.6: *Photomicrograph showing extravasation of red blood cells in the muscle tissue of an antemortem bite mark located on the non-dependent side (Haematoxylin and Eosin stain at 200X power field)*

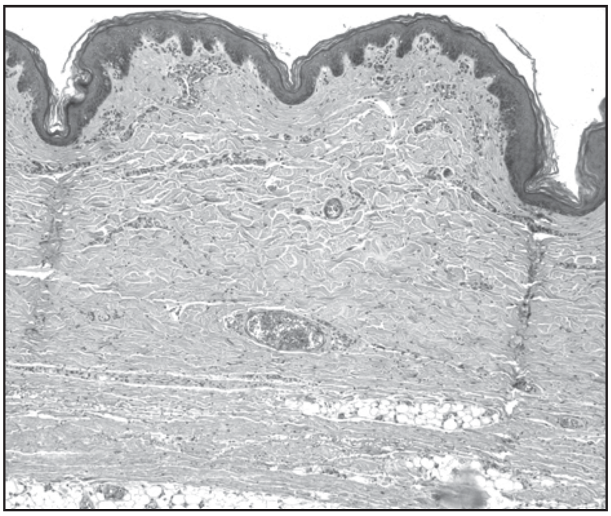


Fig.7: *Photomicrograph of an antemortem bite mark on the dependent side showing congestion of the blood vessel from livor mortis. No extravasated red blood cells can be seen in the superficial connective tissue. (Haematoxylin and Eosin stain, magnification X100 power field)*

injured tissues, mainly skin, show the typical characterised inflammatory signs namely, erythema, swelling, heat, pain.[15] Conversely, if the wound was inflicted on a deceased individual, these macroscopic features will be absent due to the absence of a vital reaction. If the wound was inflicted close to the time of death, it is difficult to make such a determination. It is well established that there is no exact boundary between life and death.[15] The period between life and cellular death is variable and depends on factors such as the cause of death, individual susceptibility, and duration of pain, amongst other. Furthermore, different tissues die at different rates depending on their ability to withstand anoxia.[15] Discoloration of tissues occurring after death is due primarily to postmortem haemolysis of blood. This haemolytic staining may at times be difficult to differentiate from antemortem haemoglobin breakdown. Eventually, and at varying rates of speed, all of the tissues of the body undergo autolysis. There is a considerable difference in susceptibility of the various structures of the body to this process. The important differential point is that postmortem autolysis evokes no inflammatory or cellular response typically found in antemortem injuries.

Whether it be pig or human skin, it must be understood that at the time of the bite mark injury, particular tooth mark indentations will be present. The passage of time, however, results in loss of these depressions. The latter phenomenon can occur as a result of oedema due to injury, postmortem change, or the ability of the skin dermis and sub dermal tissues to reconstitute the original contour of the body surface. The status of the tissue (antemortem or postmortem), the time elapsed between the biting and when the evidence is collected, the condition of the skin injured, the clearness of the marks, and the site of the wound must all be considered in determining the utility of bite mark evidence.[1,7]

Bite mark injuries located in an area affected by postmortem lividity on the dependent side did not demonstrate a specific pattern in regard to time of death compared to the ones present on the non-dependent side. Livor mortis seem to modify the pattern characteristics of the tissue. If an area of the bite mark is located on a region not affected by postmortem lividity than the typical pattern characteristics previously mentioned would be observed. If a bite mark is located on a dependent side affected by postmortem lividity it would be problematic to make any clinical assumptions on whether the injury was made before or after death.

The histopathological findings correlate with the clinical observations of antemortem and postmortem bite marks. The presence of erythema and extravasated red blood cells in the tissues helped to differentiate areas of injury made before or after death within regions affected by livor mortis.

CONCLUSION

Oedema from antemortem injuries, postmortem changes including livor mortis, and the ability of the dermis and sub dermal tissues can contribute to modification in the pattern and tooth characteristics of a bite mark. Numerous variables influence the appearance of bite marks. Additionally no form of artificial biting can precisely replicate bite mark mechanics or tissue response. This study provided information on the clinical observations and histopathological features of bite mark injuries in pigs *in-vivo*. When it is clinically difficult to comment on the status of a bite mark in relation to time of death in areas affected by livor mortis, histopathological studies could be a reliable alternative to provide information regarding antemortem or postmortem injuries.

REFERENCES

1. Levine LJ. Bitemark evidence. Dent Clin North Am 1977;21:145-58.

2. Wagner G. Bitemark identification in child abuse case. Ped Dent 1986;8:96-100.

3. Sweet D, Pretty IA. A look at Forensic Dentistry - Part 2: Teeth as weapons of violence - Identification of bite mark perpetrators. Br Dent J 2001;190:415-8.

4. Sweet DJ. Manual of forensic odontology. 3rd ed. London: Manticore, 1997:148-69.

5. Wood RE, Miller PA, Blenkinsop BR. Image editing and computer assisted bitemark analysis: A case report. J Forensic Odontostomatol 1994;12:30-6.

6. Dorion RBJ. Bite mark evidence. J Can Dent Ass 1982;12:795-8.

7. Sebata M. Medicolegal studies on bite marks. Bull Tokyo Dent Coll 1963;4:83-98.

8. Barbenel JC, Evans JH. Bite marks in skin - Mechanical factors. J Forensic Sci Soc1974;14:235-8.

9. Harvey W, Millington P, Barbenel JC, Evans JH. Dental identification and forensic odontology. London: Henry Kimpton, 1976:124-44.

10. Zhang Z, Monteiro-Riviere NA. Comparison of integrins in human skin, pig skin and perfused skin: An in vitro skin toxicology model. J Appl Toxicol, 1997;17:247-53.

11. Sheasby DR, MacDonald DG. A forensic classification of distortion in human bite marks. Forensic Sc Int 2001;122:75-8.

12. DeVore DT. Bitemarks for identification? A preliminary report. Med Sci Law 1971;11:144-5.

13. Stimson PG. Manual of Forensic Odontology - Publication of the American Society of Forensic Odontology. New York: Sperber and Seigel, 1991:143.

14. Robertson I, Mansfield RA. Antemortem and postmortem bruises of the skin. J Forensic Med 1957;4:2-10.

15. Hernandez-Cueto C, Girela E, Sweet DJ. Avances in the diagnosis of wound vitality. A review. Am J Forensic Med pathol 2000;21:21-31.

16. Hirvonen J. Comparative histochemical studies on the inflammatory and/or vital reaction after infliction of incised wounds in the skin and adipose tissue of guinea-pigs. J Forensic Med 1968;14:161-72.

17. Langlois NEI, Gresham GA. The ageing of bruises: A review and study of the colour changes with time. Forensic Sci Int 1991;1:17-25.

18. Dailey JC, Bowers CM. Manual of forensic odontology. 3rd ed. London: Manticore, 1997:184-90.

19. Raekallio J. Determination of the age of wounds by histochemical and biochemical methods. Forensic Sci 1972;1:3-16.

20. Contran RS, Kumar V, Collins T. Robbins pathologic basis of diseases 6th ed. Pennsylvania. W.B. Saunders. 1999: 50-88.

21. Avon SL, Wood RE. Porcine skin as an *in-vivo* model for ageing of human bite marks. J Forensic Odontostomatol 2005;23:30-9.

22. Yager JA, Scott D. The skin and appendages. Pathology of domestic animals, 4th ed. San Diego: Academic Press, 1993:531-3.

23. Lavker RM, Dong G, Zheng PS, Murphy GF. Hairless micropig skin. A novel model for studies of cutaneous biology. Am Pathol 1991;138:687-97.

24. Sullivan TP, Eaglstein WH, Davis SC, Mertz P. The pig as a model for human wound healing. Wound Repair Regen 2001;9:66-76.

25. Meyer W. Schwarz R, Neurand K. The skin of domestic mammals as a model for the human skin with special reference to the domestic pig. Curr Prob Dermatol 1978;7:39-52.

26. Hannam AG. The regulation of the jaw bite force in man. Arch Oral Biol 1976;21:641-4.

27. Williams WN, Lapointe LL, Blanton RS. Human discrimination of different bite force. J Oral Rehab 1984;11:407-13.

28. Smith J, Calhoun M. The microscopic anatomy of the integument of newborn pig. Am J Vet Res 1964;25:165-73.

29. Marcarian HQ, Calhoun ML. Microscopic anatomy of the integument of adult swine. Am J Vet Res 1966;27:765-72.

30. Wakuri H, Kawamura IK, Mutoh, K. Anatomical Observations on Cleavage Line Patterns of the Skin in adult Pigs. Okajumas Folia Anat 1993;70:181-94.

31. Perper JA. Time of death and changes after death – Part I – Spitz and Fisher's Anatomical Considerations. Medicolegal Investigation of Death. Guidelines for the Application of Pathology to Crime Investigation, 3rd ed. Illinois: Charles C Thomas, 1993:14-49.

32. Sweet DJ, Bastien RB. Use of an Acrylonitrile-Butadiene-Styrene (ABS) plastic ring as a matrix in the recovery of bite mark evidence. J Forens Sci 1991;36:1565-7.

33. Krauss T. Photographic techniques of concern in metric bite mark analyses. J Forens Sci 1984;29:633-8.

34. Hyzer W, Thomas P, Krauss T. The bite mark standard reference scale - ABFO No.2. J Forens Sci 1988;33:498-506.

Address for correspondence:
Sylvie Louise Avon
Faculté de médecine dentaire
Université Laval
Cite universitaire
Ste-Foy, Québec
CANADA G1K 7P4

A PILOT STUDY TO DETERMINE THE EFFECTS OF SKIN CONTACT ON TWO COMMONLY USED DENTAL IMPRESSION MATERIALS

N. Steyn[1] S.J. Botha [2] P.D. Brand[3] H. Bernitz [1]

1. Department of Oral Pathology & Oral Biology, School of Dentistry, University of Pretoria, South Africa
2. Centre of Stomatological Research, School of Dentistry, University of Pretoria, South Africa
3. Department of Materials, School of Dentistry, University of Pretoria, South Africa

ABSTRACT

Impression materials used in the analysis of bite marks are required to maintain their stability and integrity for extended periods. It has been observed that certain impressions taken of skin lose their properties with time, becoming sticky and unusable as evidence. The objective of this study was to investigate the onset of "stickiness" in two commonly used dental impression materials when brought into contact with skin. The two materials tested were Impregum and President. They were syringed into glass rings positioned on the upper arms of 28 volunteers. Changes in stickiness were monitored over a four-month period using a tensile testing machine. A metal plunger was lowered onto the impression material and then retracted measuring the adhesive force of the material to the lower surface of the plunger. Over the research period 17 of the 28 rings of Impregum became sticky and changed colour from purple to turquoise. The remaining 11 Impregum samples, all the President samples and all control samples remained unchanged over the 120 day period. The results of this study show that certain factors present in or on skin are responsible for the loss of surface integrity of Impregum. The factors responsible for these changes have not been established.

(J Forensic Odontostomatol 2006;24:63-6)

Key words: Impression material, skin, stickiness

INTRODUCTION

When analysing a skin bite mark it is often necessary to take accurate impressions of the affected area.[1-4] Dental impression material used in these analyses are required to maintain their dimensional stability for extended periods of time, as tooth mark evidence is often given months or years after the crime was perpetrated. The impressions are an integral link in the chain of evidence, but can also be used in the physical comparison.[3] Expert dental evidence relies heavily on the accurate reproduction of the marks present on the victim's body or on inanimate products found at crime scenes.[3]

Two groups of dental materials are generally used to take impressions of bite marks, namely silicones and polyethers. Ciesco *et al*[5] state that polyether materials yield superior stability when compared to silicones and polysulfides, while Lacy *et al*[6] found that polyvinylsiloxanes demonstrated superior stability over polyethers but neither study investigated the medium to long-term stability of these impression materials. From experience the authors observed that Impregum* (polyether) impressions taken of skin lose their physical properties with time, becoming sticky and unusable as evidence in court cases.

This research aimed to investigate the possible cause and onset of "stickiness" in two commonly used dental impression materials.

MATERIALS AND METHODS

The research was carried out on 28 dental students from the School of Dentistry, University of Pretoria, South Africa. The sample included an equal number of males, females, Negroids, and Caucasians aged between 21 and 25 years of age. As the procedure was non-invasive, only oral consent was obtained.[7]

Two commonly used dental impression materials were tested, namely Impregum* and President** (type 1, low viscosity). Sterile glass tubes measuring 20mm with a diameter of 18.4 mm and 1.8mm

* 3M ESPE, PO Box 926, Isando, Johannesburg, South Africa.
**Colténe Whaledent, Altstätten, Switzerland

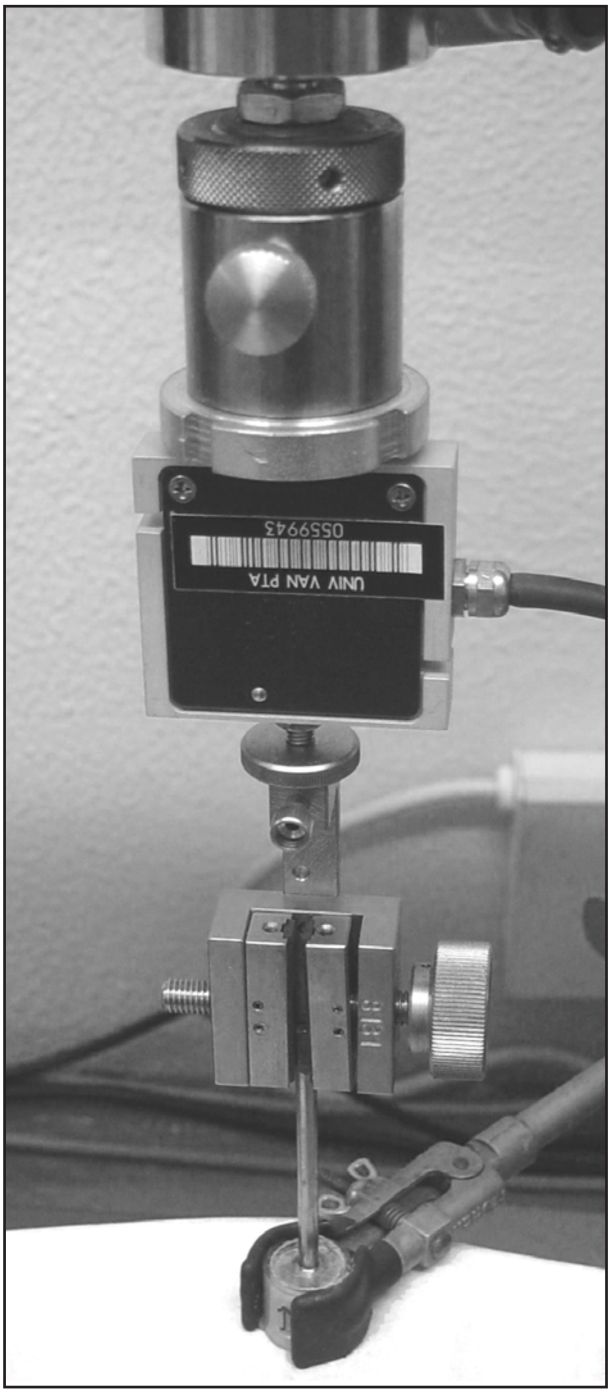


Fig 1: *The specially designed metal plunger in the Zwick Z1010 compression tester.*

thick were positioned on the upper arms (over the Deltoid muscle) of the volunteers. The contact areas were not cleaned in any way. The volunteers were given gloves and asked to hold the glass tubes firmly in position to obtain a flat contact surface with the skin. Each impression material was mixed according to the manufacturers instructions and injected into separate tubes. One set of impressions

Fig 2: *The retraction of the plunger in a "sticky" Impregum sample is demonstrated at 120 days.*

including each of the two products was taken from each volunteer.

Seven control samples of each impression material were taken with the glass rings positioned against cleaned and sterilised glass plates. The oils and creams that had been applied to the skin in the research area were recorded. After the recommended setting times the impressions were stored at a constant temperature of 21 degrees centigrade and a controlled relative humidity of 29%. The onset of stickiness, and colour changes were monitored at monthly intervals. The "stickiness" of the exposed surfaces of the different impression materials was initially tested at 48 hours and then again at 30, 60 and 120 days. Stickiness was measured by using a specially designed metal plunger in the Zwick Z1010*** compression tester (Fig 1) which was passively positioned on the surface of each specimen and then retracted, as illustrated in Fig 2. The onset of "stickiness" was documented when a negative force, measured in Newtons was required to retract the plunger.

RESULTS

The control samples in both impression materials showed no colour change or development of "stickiness" throughout the research period. No "stickiness"

***Warsaw Scientific and Precision equipment, Johannesburg, South Africa.

was measured or colour changes observed in any of the President samples within the four-month period of observation. The colour change and onset of “stickiness” observed in the affected Impregum samples commenced simultaneously from the skin contact surface of the impression material.

After the first month one Impregum sample, that of a female Caucasian showed a measurable degree of “stickiness” and colour change. Eleven of the 28 Impregum samples showed both ‘stickiness” and colour change after 60 days with the number increasing to 17 after a 120-day period. The number of “sticky tubes” as a function of the volunteer profile is illustrated in Fig 3. The mean force required to retract the plunger from the affected samples ranged from 0.7N on day 30 to 2.43N on day 120 (Fig 4**)** The final number of “sticky” samples observed at four months in volunteers who had applied either oils or creams to their skin is illustrated in Fig 5.

At the conclusion of the research period 17 of the 28 rings of Impregum impressions had become “sticky” and changed colour from purple to turquoise. Of the 28 volunteers 18 had applied creams or lotions to their skin of which 10 had become “sticky”. Nine Impregum samples remained unchanged by day 120. Seven of the ten Impregum impressions taken of volunteers who had applied no creams or lotions to their skin also became “sticky”.

DISCUSSION

The results demonstrated that a substantial number of Impregum impressions which came into contact with skin during their setting period underwent rapid changes in their physical properties, while the control samples of both impression materials remained unaffected, as did the President samples exposed to skin. The changes that took place were observed on the impression surfaces that were in contact with the volunteer’s skin surface. The force required to retract the plunger in the affected sample increased with time, indicating a progressive deterioration and increase in stickiness.

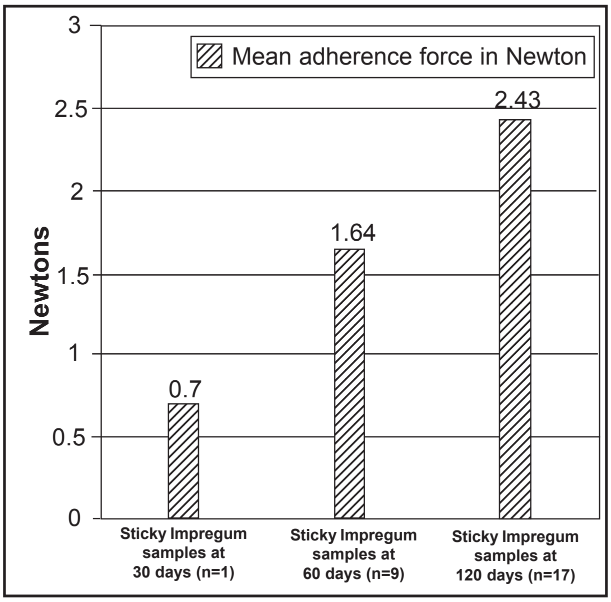


Fig 4: *The mean Newton force required to retract the plunger from the affected samples at four time intervals*

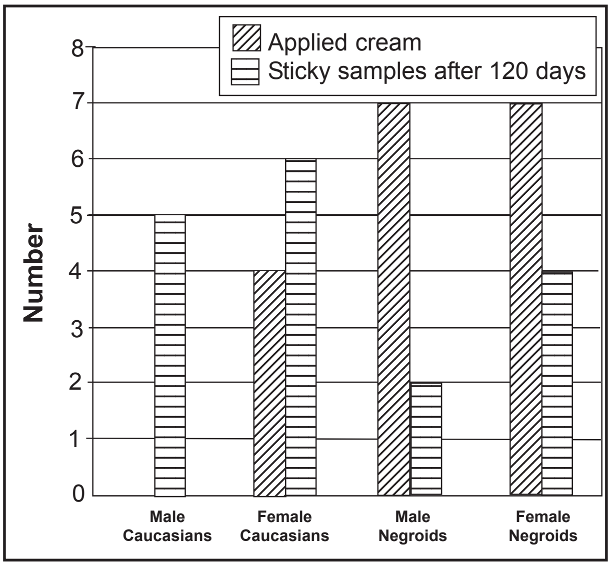


Fig 5: *The number of sticky Impregum samples and oils/ creams applied, in the volunteer profile after 120 days*

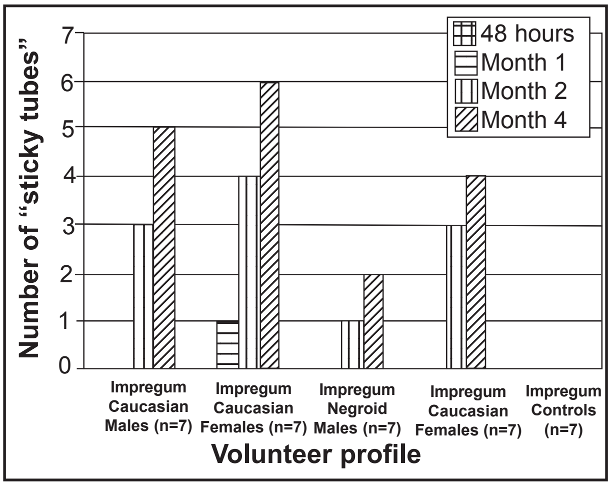


Fig 3: *Number of samples showing sticky formation at four time intervals*

Further research is needed to establish if a prolonged period of time will in fact affect more of the Impregum samples. The changes that were evaluated were macroscopic and can be regarded as gross dimensional alterations of the impression material. No measurable changes were observed after 48 hours, but an increased sensitivity in the analysis technique may produce different results. Creams and lotions did not seem to be the causative factors as seven of the ten Impregum samples in contact with un-creamed skin became sticky.

It is postulated that substances present on the skin could be responsible for the degradation of Impregum impression material.

CONCLUSION

The authors recommend that Impregum impression material not be used in any applications involving skin impressions e.g. forensic investigations. The contact of Impregum impression material with un-gloved hands in general dentistry should also be investigated. Further research should involve a larger volunteer sample over a longer period of time. The nature of the altered chemical reaction in Impregum should be determined, and possible causative factors in the skin should be investigated.

REFERENCES

1. Bernitz H, van Niekerk PJ. Bungled bite mark evidence collection: a proposed protocol for the prevention thereof. J Dent Assoc S Afr 2003; 58:16-9.
2. Stimson PG, Mertz CA. Forensic dentistry. Boca Raton, Florida, USA: CRC Press LLC; 1997
3. Bernitz H, Kloppers BA. Comparison microscope identification of a cheese bitemark: a case report. J Forensic Odontostomatol 2002;20:13-6.
4. Mc Cabe J. Applied dental materials. 7th ed. London: Blackwell Scientific; 1995
5. Ciesco JN, William MS, Malone FP, Sandrik JL, Mazur B. Comparison of elastomeric impression materials used in fixed prosthodontics. J Prosthet Dent 1981;45:89-94.
6. Lacy AM, Fukui H, Bellman T, Jendresen MD. Time-dependent accuracy of elastomer impression materials: Polyether, polysulfides, and polyvinylsiloxane. J Prosthet Dent 1981;45:329-33.
7. Council SAMR. Guidelines on ethics for medical research. 3rd ed. Cape Town: South African Medical Research Council, 1993:32-43.

Corresponding author:
Prof Herman Bernitz,
Department of Oral Pathology and Oral Biology,
School of Dentistry, University of Pretoria
P.O. Box 1266,
Pretoria 0001, Gauteng,
SOUTH AFRICA.
Tel & Fax: +27 013 2826419.
E-mail: bernitz@iafrica.com