ISSN 2219-6749

I·O·F·O·S

The Journal of Forensic Odonto-Stomatology

Volume 9, n. 1 - Jun 1991

OFFICIAL PUBLICATION OF THE
INTERNATIONAL ORGANIZATION FOR
FORENSIC ODONTO-STOMATOLOGY

The Journal of

Forensic Odonto-Stomatology

Contents

RESEARCH

CASE REPORTS

REVIEWS

ALLOMETRIC RELATIONSHIPS OF THE DENTITION OF THE GREAT WHITE SHARK, CARCHARODON CARCHARIAS, IN FORENSIC INVESTIGATIONS OF SHARK ATTACKS.

Phrabhakaran Nambiar, T.E. Bridges and K.A. Brown

Forensic Odontology Unit, Department of Dentistry, The University of Adelaide, G.P.O. Box 498, Adelaide, South Australia 5001, Australia.

Abstract

As a result of a systematic morphometric study of shark dentitions, a system of notation for describing the location of shark teeth has been developed and is proposed as a standard to be adopted for use in similar studies in the future. The macroscopic morphology of White Shark teeth has been characterised in order to gain quantitative data which might assist in identification of these sharks from bite marks on victims or objects or from shark carcasses. Using these data, a nomogram has been developed which can be used to estimate the body length of a White Shark from measurements of tooth or bite mark morphology. An example of the forensic application of such allometric data is provided as it applied to a recent fatal attack on a diver by a White Shark.

Keywords: Shark dentition; allometric relationships; shark attacks; forensic odontology.

Introduction

Australia is considered to be one of the highest areas of risk in the world for shark attacks on humans. It is the White Shark, *Carcharodon carcharias* in particular, which is responsible for most of these attacks. Members of this species are the largest of the flesh eating sharks and mainly inhabit the temperate coastal waters. They are the most feared and thus the most publicised of all the sharks and generally, whenever these sharks are mentioned, their awesome array of teeth immediately springs to mind.

Carcharodon carcharias is also known as the White Shark, Great White Shark, White Pointer or, colloquially, as "White Death". These names refer to the white underbelly which is exposed to view as the shark bites and rolls.[1] The White Shark attains maturity when it reaches approximately 2.5 metres in length while the body length of an adult can range from 3.5 to 5.5 metres. Occasional reports of White Shark specimens of much greater length have not been verified by accurate measurement. They have almost perfect hydrodynamic efficiency in their conico-cylindrical body form which facilitates very fast swimming and attack speeds.

Sharks have achieved a very efficient dentition in which their teeth are continuously replaced.[2,3,4,5] This provides for wear, breakages or loss and is naturally of great benefit to a predator, in addition to allowing the teeth to increase in size so as to match the needs of the growing animal.

In view of the fact that the tooth shape of adult sharks varies markedly between species[1], and since the teeth are the most durable part of the skeleton, they can be of great value in the identification of shark species from fossil or skeletal remains. The teeth of the shark are not attached directly to the jaw cartilage but are held in place by a collagenous membrane in a shallow depression called the tooth bed.[6] This flexible mode of attachment is quite distinctive and is characteristic of sharks. It is believed that prehensile movement of the teeth safeguards against the great mechanical stress to which they may be subjected whilst feeding.[7]

Tricas and McCosker[8] state that the feeding habits and predatory success of the White Shark are both intimately related to their changing tooth morphology during maturation. The small White Sharks have narrow teeth which are very similar to the awl-like teeth of the Mako, the Grey Nurse and the Sand Shark which are best suited to grasping small fish. When the White Shark grows larger than about 3 metres however, it develops the characteristic, triangularly shaped, minutely serrated teeth. These teeth are then suited to gouging and cutting prey which is too large to swallow intact and constitute the efficient weapon for which the shark has become well known.

In attacks upon humans by White Sharks the victims are released after the initial assault and the shark usually retreats a short distance from the injured or immobilised prey. This allows the victim to lapse into a state of shock or bleed to death. This "bite and spit" behaviour has been erroneously interpreted as a reaction to something distasteful or offensive in the human flesh and/or the neoprene wet suit material. It is more likely to be an adaptive behaviour to reduce the chance of injury to the shark which may result from the teeth and claws of an actively struggling prey.[9]

Sharks annually injure about 100 persons world-wide and kill perhaps 25. In Australian waters, there are on average about two attacks and one death each year.[10]

Marks caused by teeth on or through material can themselves be sufficiently indicative of a shark attack. In most instances, a curved arch is present with tooth marks in characteristic numbers, positions and intervals. It may however require the qualitative/quantitative analysis of each tooth mark (preferably presented as a serrated scraping) from non-biological items to determine whether the damage was caused specifically by the teeth of a White Shark.

The problem of identifying the individual shark responsible for an attack, however, remains. We have shown elsewhere that there is no predictable pattern in the size or arrangement (periodicity) of the peaks (serrations along the edges of the teeth), within or between individual sharks. Indeed, each shark tooth was found to be unique.

In this investigation we attempted to apply commercial bar-codes and bar-code readers (digitisers) as a means of categorising numerically the disposition of peak size and periodicity. Unfortunately none of the several commercial code systems available provided sufficient variables to render it suitable for this purpose. The notion is attractive, however, and we are currently investigating the possibility of developing a specific bar code for this application.

Case Report Of A Fatal Shark Attack On A Diver In South Australia.

An experienced diver was reported to have disappeared off O'Sullivan's Beach and Marino Rocks in South Australia on 18 September, 1987. Some items of diving equipment were recovered. These items displayed cuts, tears and markings which prompted investigators to propose that a shark attack was the probable cause of the disappearance. The deep indentations on the lead weight,the severed surfaces of the rubber inflation nozzle of the buoyancy vest and the rubber (intermediate) air pressure line provided evidence. The markings were consistent with the pattern of serrations on the margin of the teeth of a large White Shark while the quantitative peculiarities of the bite marks on the anterior portion of the vest and lead weights were thought to be particularly consistent with those caused by the teeth of the upper jaw.

A female White Shark was captured about ten weeks later at the site of the alleged disappearance of the diver. As no human remains were retrieved from the stomach contents the shark could not be positively identified as the killer shark; however, neither could it be excluded. It is believed that sharks have the ability to disgorge stomach contents to eliminate inedible material.[6]

As a consequence of this report, a study was initiated to estimate the total body length of a shark from indentations left on inanimate objects. A morphometric study was performed to determine whether variations in tooth size and position (within and between individual White Sharks) followed a pattern sufficiently predictable to enable various parameters to be of use for forensic purposes.

Materials and Methods

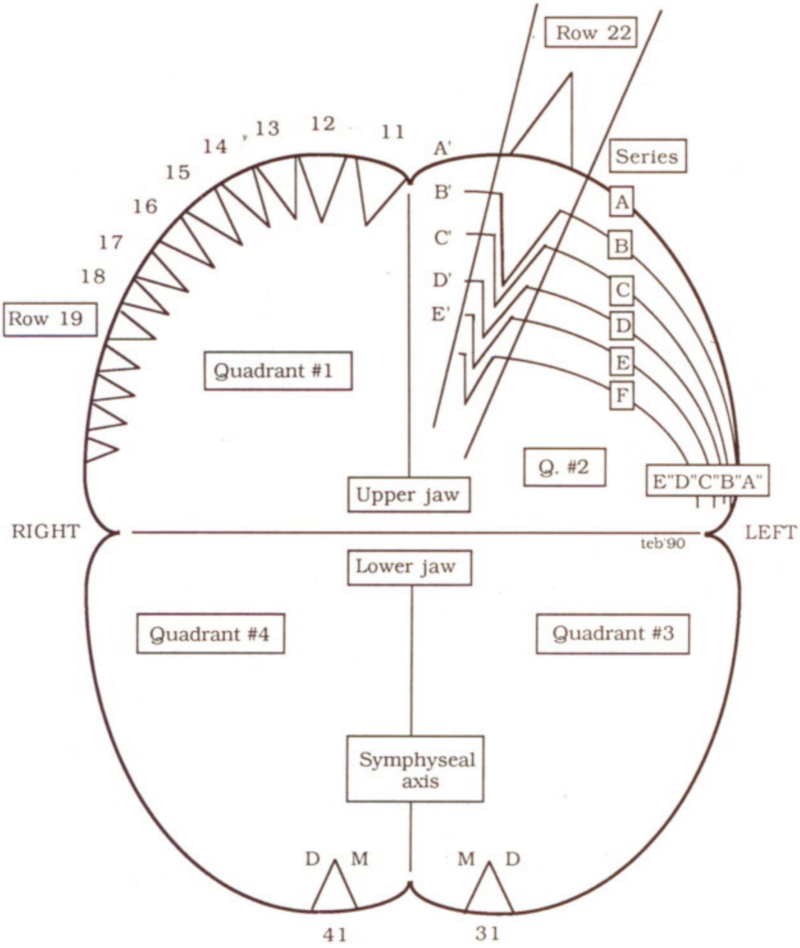
The cleaned and dried jaws of two White Sharks were made available for this study. One of these was prepared from the shark (Shark I) which was alleged to have been the killer shark (see case report above) while the other was a museum specimen. A juvenile shark (Shark III) was later captured and donated to the South Australian Museum collection. This carcass was preserved *in toto* (body length 1.80 metres) and was subsequently made available to us for the purpose of conducting measurements. Body lengths of the first two sharks were given as: Shark I, 3.2 metres and Shark II, 4.3 metres

Notation and Nomenclature

The teeth of the shark were numbered sequentially to assist in identification. To facilitate this, the Federation Dentaire International (F.D.I.) system of notation for human teeth was employed and modified slightly to allow for the greater number of teeth present in the shark.

A vertical line drawn through the midline (corresponding to the symphysis) of the upper and lower jaws differentiates the jaw into four quadrants and the first digit of the two-digit F.D.I. system identifies the particular jaw quadrant. The second number denotes the actual tooth, with the numbering started from the tooth nearest the symphysis (mid-line) and then proceeding

Figure 1: Diagram of shark jaw showing the annotation system used.



M = Mesial margin of tooth (the side closest to the symphyseal axis)
D = Distal margin of tooth (the side furthest from the symphyseal axis)

sequentially outwards along a line of teeth towards the jaw articulation or hinge (see Fig.1). Each of the parallel lines of teeth were termed series and given a single letter code, with Series A being the outermost line and those behind sequentially coded B to F.

In the example shown in Fig.1, the position of the second row of teeth from the symphyseal midline in the upper left quadrant of the jaw (Quadrant 2) would be designated Row 22 and individual teeth in that row would be labelled 22A, 22B, 22C, etc., according to the series in which each tooth is situated.

All functioning teeth of the adult White Shark have smooth points but are finely serrated on the margins. The serrations consist of alternating depressions and elevations and to distinguish them in the present study, the depressions have been termed notches and the elevations termed peaks. The point or summit of the tooth has been termed the tip.

Measurements

The individual functional teeth on the outermost margin of the jaws were photographed and printed on 5" x 7" (13cm x 18cm) photographic paper at an enlargement of exactly 3.5 times. An image of the tooth was then drawn on to tracing paper and the following measurements were made:

a) Tooth height (A'-A") was measured along a line drawn perpendicular from the tip of the tooth to a line joining the first basilar peaks (B'- B") (Fig. 2).

b) The length of the mesial and distal margins of the tooth were measured using an HP 9874A computing digitiser (Hewlett Packard Australia Ltd., Blackburn, Australia 3130). This enabled the distance representing the sum of all individual peak to peak distances, from the first basilar peak to the tip of the tooth, to be accurately determined (Fig. 2)

These measurements were reduced by the factor of 3.5 to give the actual (life) size of teeth shown in Fig. 3 and Table 4.

Results and Discussion

Randall[11] provided a scatter diagram describing a relationship between the tooth height of the largest tooth (symphyseal tooth) in the upper jaw and the

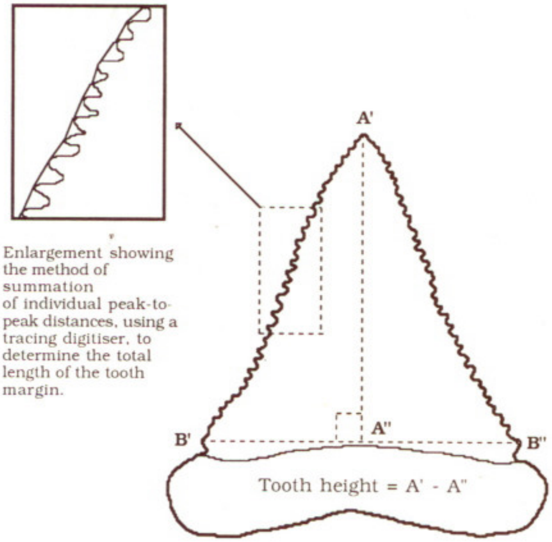
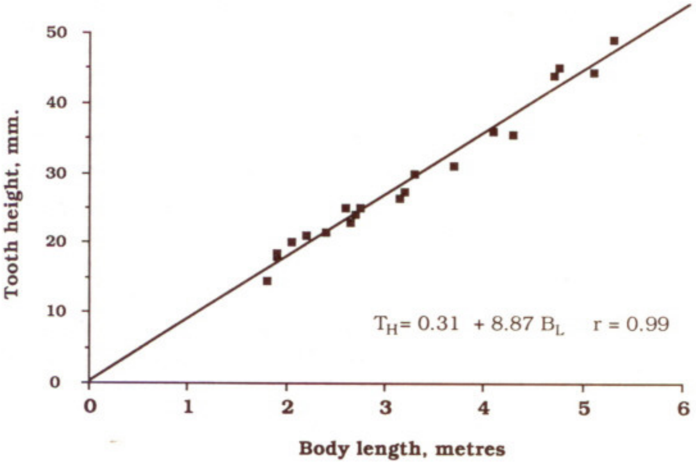


***Figure 2:** Diagram showing the methods used to measure tooth height and the length of the mesial and distal tooth margins.*



Data used are those for the present study combined with those of Randall (1973), used with the kind permission of Dr J.E. Randall.

***Figure 3** The variation of the height of the upper symphyseal tooth with body length in the White Shark.*

measured body length of the White Shark. This revealed a positive correlation between the two variables and indicated the existence of an allometric relationship. Our measurements of the shark body length and the equivalent tooth height confirm the line of best fit derived from the data of Randall.

A combined data set using our values and those of Randall[11] (used with permission) was plotted (Fig. 3) and an allometric equation describing this linear relationship derived. This confirmed the high degree of correlation (r = 0.99) between tooth height and body length over the complete size range of sharks available and is shown as Equation A below:

$$T_H = 0.31 + 8.87\, B_L \qquad r = 0.99$$

where T_H = symphyseal tooth height (mm)
and B_L = body length of shark (m)

The predictability of this relationship will be of value in forensic science. For example, by determining the height of the largest tooth (symphyseal tooth no.11 or 12) of a shark, it is possible to establish its body length by calculation using Equation A or derivation from the graph in Fig. 3.

It was clear from our study that the heights of bilaterally situated teeth (on either upper or lower jaw) are similar (data not presented here). The same relationship applied to the marginal lengths of the teeth (both mesial and distal) on either side of each jaw. In addition, a trend was observed in the reduction in height and marginal lengths of the teeth from the anterior to the posterior part of the jaws. This trend is observable in the mean values of each parameter (height, mesial and distal length) of bilaterally corresponding teeth relative to the mean of that parameter for the two symphyseal teeth. In Tables 1a, 2a and 3a, which show these relationships, the symphyseal tooth has been given the reference value of 1.00 and the other teeth a proportional value. Using these tables, the size of a tooth missing from a known jaw position can be calculated by reference to the symphyseal tooth size.

Conversely, the height or length of the upper symphyseal tooth can be estimated by dividing the given tooth height or length by the appropriate value for that tooth, as given in these Tables. The resulting value can then be used for an estimation of the length of the shark using the allometric data (Equation A or Fig. 3) which relates upper symphyseal tooth height to body size. In this way the body length of a shark can be estimated even in cases where the symphyseal teeth are absent.

Tables 1b, 2b and 3b show the mean value of each parameter (height, mesial length and distal length) of symphyseal teeth (no. 41/31) of the lower jaw relative to the mean of the same parameter of the symphyseal teeth (no. 11/21) of the upper jaw. These Tables will be useful in allowing allometric calculations to be made in cases where data are only available from the symphyseal teeth of the more easily separated lower jaw.

Overall, these data allow the mean height of the symphyseal teeth in the upper jaw, as required for the allometric equation, to be estimated from the measured height of any tooth provided that the position of that tooth in the jaw is known.

It can be seen from the relative data in Tables 1b, 2b and 3b that teeth in the upper jaw are some 25 - 30% larger than the corresponding teeth in the lower jaw of the mature Sharks I and II. This difference is not apparent in the dentition of the juvenile Shark III.

It seems likely that in an attack by a mature shark the lower teeth contact first to secure the large prey and the larger upper teeth are used to gouge and tear large sections of flesh from it. The juvenile shark, on the other hand, most often feeds on small prey by swallowing it whole and would have no need for any tooth size differential between upper and lower jaws.

Marks caused by shark teeth may be sufficiently detailed for determination of the tooth margin length (mesial and distal) which can lead to an estimation of the tooth height. Since this process involves a double, rather than a single interpretational step, a greater degree of error in the body length prediction may occur. Nevertheless, such an estimate may still be of significant value as forensic evidence.

Table 4 gives the mean relationship (expressed as a normalised ratio) between the height and length of margin of the symphyseal teeth in the three sharks used in this study. It is evident from these data that a constant relationship exists between the two parameters and thus marginal length can be taken to be a reliable parameter for the estimation of the height of symphyseal teeth and to be valid for both the juvenile and adult sharks. In cases where the marginal length of a tooth can be measured, it will therefore be possible to calculate the tooth height and, if the tooth position is known, the body length of the shark can be estimated.

Table 1a

Height of each toth relative to mean symphyseal tooth height.

Upper jaw

Tooth number	1	2	3	4	5	6	7	8	9
Shark I	1.00*	0.86	0.61	0.64	0.74	0.70	0.55	-	0.23
Shark II	1.00*	0.99	0.65	0.72	0.87	0.78	0.59	0.40	0.26
Shark III	1.00*	1.00	0.64	0.80	0.88	0.86	0.66	-	-
Mean =	1.00*	0.95	0.63	0.72	0.83	0.78	0.60	0.40	0.25

Lower jaw

Tooth number	1	2	3	4	5	6	7	8	9
Shark I	1.00*	1.06	0.80	0.77	0.74	0.61	0.45	0.32	0.18
Shark II	1.00*	1.05	0.83	0.76	0.70	0.58	0.45	0.28	0.15
Shark III	1.00*	1.08	0.76	0.73	0.71	-	-	-	-
Mean =	1.00*	1.06	0.80	0.75	0.72	0.60	0.45	0.30	0.17

Table 1b

Ratio of mean height of the upper symphyseal teeth to that of the lower symphyseal teeth

Shark I	Shark II	Shark III
1.25	1.25	1.04

Table 2a

Length of the mesial margin of each tooth relative to the mean mesial length of the symphyseal teeth.

Upper jaw									
Tooth number	1	2	3	4	5	6	7	8	9
Shark I	1.00*	0.99	0.70	0.82	0.91	0.88	0.75	–	0.37
Shark II	1.00*	1.10	0.64	0.89	0.94	0.87	0.73	0.52	0.32
Shark III	1.00*	1.07	0.67	0.94	1.00	0.95	0.74	–	–
Mean =	1.00*	1.05	0.67	0.88	0.95	0.90	0.74	0.52	0.35

Lower jaw									
Tooth number	1	2	3	4	5	6	7	8	9
Shark I	1.00*	1.08	0.82	0.81	0.77	0.66	0.51	0.41	0.26
Shark II	1.00*	1.09	0.86	0.81	0.76	0.65	0.52	0.36	0.27
Shark III	1.00*	1.11	0.79	0.79	0.74	–	–	–	–
Mean =	1.00*	1.09	0.82	0.80	0.76	0.66	0.52	0.39	0.27

Table 2b

Ratio of mean mesial margin length of the upper symphyseal teeth to that of the lower symphyseal teeth

Shark I	Shark II	Shark III
1.32	1.35	1.05

Table 3a

Length of the distal margin of each tooth relative to the mean distal length of the symphyseal teeth.

Upper jaw									
Tooth number	1	2	3	4	5	6	7	8	9
Shark I	1.00*	0.97	0.78	0.73	0.84	0.75	0.62	–	0.32
Shark II	1.00*	1.02	0.72	0.72	0.86	0.78	0.59	0.42	0.29
Shark III	1.00*	0.97	0.71	0.79	0.86	0.86	0.67	–	–
Mean =	1.00*	0.99	0.74	0.75	0.85	0.80	0.63	0.42	0.31

Lower jaw									
Tooth number	1	2	3	4	5	6	7	8	9
Shark I	1.00*	1.04	0.83	0.77	0.74	0.61	0.47	0.34	0.22
Shark II	1.00*	1.02	0.85	0.82	0.73	0.60	0.48	0.32	0.23
Shark III	1.00*	1.08	0.77	0.73	0.74	–	–	–	–
Mean =	1.00*	1.05	0.82	0.77	0.74	0.61	0.48	0.33	0.23

Table 3b

Ratio of mean distal margin length of the upper symphyseal teeth to that of the lower symphyseal teeth

Shark I	Shark II	Shark III
1.25	1.22	1.01

Table 4

The relationship between the marginal length of a tooth and its height, using the upper symphyseal teeth (mean value of 11/21) as an example, for each of the three sharks studied.

	Height, H (mm)	Mesial length, M, (mm)	Ratio H/M as %	Distal length, D, (mm)	Ratio H/D, as %
Shark I	26.7	29.9	89.3	29.0	92.1
Shark II	35.4	41.7	85.0	38.7	91.4
Shark III	14.5	15.9	91.2	15.9	91.2
Mean:			88.5%		91.6%

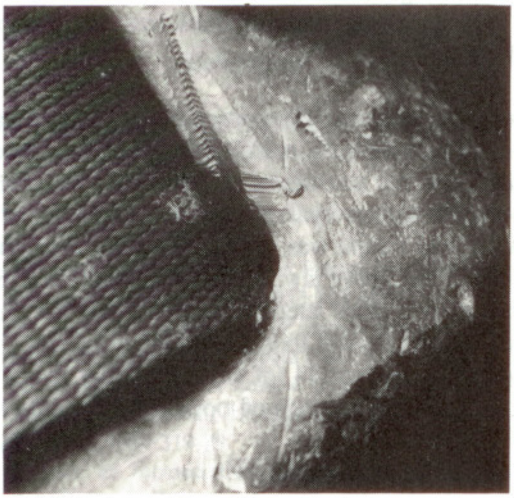


Figure 4: *Tooth marks adjacent to belt slot in lead weight.*
(South Australian Police Department photograph, used with permission)

Observations from the case study

Examination of one of the lead weights recovered from the sea bed near the site of disappearance of the diver revealed a deep and complex indentation (Fig. 4). This consisted of two segments with an interval bridging the space made by the slot for the belt. This indentation appeared to be consistent with the margin of a tooth of the White Shark and in particular, the linear grooves made by the serrated margin. This indentation proved vital for the possible estimation of the body length of the shark responsible for the diver's demise. Impressions of the indentation were made using silicone impression material and provided a positive reconstruction of the actual shark tooth margin. The tip of the tooth was well defined after which there was a gap before resumption of further serrations.

The length of the margin was measured from the first peak present to the tip of the tooth and was found to be 36.8 mm. This was taken to be a minimum length value since the first peak on the impression was not necessarily the basilar peak of the tooth that produced the indentation.
Furthermore, the margins of the teeth are usually curved and therefore this linear measurement would be short of the actual margin length. The longest margin of the largest tooth (the symphyseal teeth of the upper jaw) of the shark alleged to be the killer measured 30.1 mm. This fell short of the measurement of the length of the indentation, which measured 36.8 mm, and was sufficient to exclude that particular shark from being responsible for the attack on the diver.

The nature of damage to the anterior portion of the vest and lead weights was thought to be consistent with the markings having been caused by the teeth of the upper jaw. From our assessment of individual tooth marks or tears and their position and distances apart, it was tentatively concluded that the indentation on the lead weight was caused by the distal margin of the fourth tooth (right side) in the upper jaw, namely tooth no.14. It is evident from Table 3a that the relative distal length of tooth no.14 is 0.75 times that of the distal margin of the symphyseal tooth. Since the minimum estimated length of the distal margin of tooth no.14 (of the actual killer shark) measured 36.8 mm, then length of the distal margin of tooth no.11/21 could be calculated to be 36.8/0.75 = 49.1 mm.

It was found that the height of tooth no.11/21 was 91.6% relative to the length of its distal margin (Table 4) and that its calculated height was 49.1 x 91.6% = 45.0 mm. Having calculated the tooth height, it was then possible to estimate the body length of the shark using Equation A ($T_H = 0.31 + 8.87$ BL, where T_H = tooth height of shark [45.0 mm] and B_L = body length of shark).

The minimum body length of the shark which could have produced the indentation would therefore have been 5.0 metres, showing the killer shark to have been a particularly large specimen of White Shark.

It is proposed that this type of allometric estimation will prove useful for determining the actual length of a shark involved in attacks on humans. It is hoped that with this knowledge, the indiscriminate killing of sharks in the vicinity of the attack, may be prevented. Furthermore, it is emphasised that reliable estimates of the body length of sharks can be calculated in this way even when only parts of the shark jaw are available.

Acknowledgements

We are particularly grateful for the generous assistance of Tasman Brown and Jack Randall and we also acknowledge the help and advice of Masatsugu Hashimoto, Jane Taylor, Barry Bruce, Ian Gordon, Andrew Georgescu, Timothy Tricas, John Glover and Neville Pledge. The study was supported by grants from the National Health and Medical Research Council, The University of Adelaide and the South Australia Police Department.

References

1. Stevens JD, Compagno LJ, Creagh C, Hodgson ES, Maisey JG, Tricas TC, eds. Sharks - an illustrated encyclopædic survey by international experts. Sydney: Golden Press, 1987
2. Breder CM. The shedding of teeth by Carcharias littoralis(Mitchell).Copeia 1942;1:42-4.
3. James WW. The succession of teeth in Elasmobranchs. Proceedings of the Zoological Society of London, J Zool 1953;123:419-75.
4. Strasburg DW. The diet and dentition of Isistius brasiliensis, with remarks on tooth replacement on other sharks. Copeia 1963; 1:33-40.
5. Moss SA. Tooth replacement in Lemon Shark, Negaprion brevirostris. In: Gilbert PW, Mathewson RF, Rall DP, eds. Sharks, Skates and Rays. Baltimore: Johns Hopkins Press, 1967:319-29
6. Moss SA. Sharks: an introduction for amateur naturalists. New Jersey: Prentice-Hall, 1984
7. Cawston G. Succession of teeth in sharks, Selachii. Brit Dent J 1938;65:573-80.

8. Tricas TC, McCosker JE. Predatory behaviour of the White Shark (Carcharodon carcharias) with notes on its biology. Proc Calif Acad Sci 1984;43:221-38.
9. McCosker JE. White Shark attack behaviour: observations of and speculations about predator and prey strategies. Southern Calif Acad Sci 1985;9:123-35.
10. Meimeyer N. The greatest fish on earth. Readers' Digest, 1989;131:47-50.
11. Randall JE. Size of Great White Shark (Carcharodon carcharias). Science 1973;181:169-70.

AMALGAM TATTOO AS A MEANS FOR PERSON IDENTIFICATION

H. Slabbert, G.L. Ackermann and M. Altini

Department of Oral Pathology, University of the Witwatersrand

Correspondence: Professor M Altini, Department of Oral Pathology, School
of Pathology, University of the Witwatersrand,
Private Bag 3, Wits, 2050 South Africa

Abstract

Person identification from the teeth depends on establishing a number of points of correspondence between ante- and postmortem dental data, but a single characteristic, if unique enough, may be sufficient. The use of amalgam tattoos in establishing identity has not been reported in the literature.

Two cases in which amalgam tattoos were used in conjunction with other dental data to establish identity are reported. Ante- and postmortem radiographs showed the presence of amalgam within the adjacent alveolar bone and periapical tissues, respectively. Attempts were made to duplicate the angulation of the original antemortem radiographs so that a direct comparison could be made of the amalgam fragments.

The antemortem radiographs date from 1984 and 1985 in the two respective cases. In both instances the pattern of amalgam remained fairly similar, differences being ascribed to angulation which could not be reproduced exactly.

From these results it seems that amalgam tattoo may be a reliable method of identification, even though a number of years may have elapsed since the ante- and postmortem radiographs were taken. The pattern of amalgam dispersal may be sufficiently unique so that identity can be established using this single characteristic.

Key words: identification, amalgam tattoo, dental radiographs

Introduction

The essence of dental identification consists of a detailed comparison of data obtained from ante- and postmortem dental records with a view to establishing points of correspondence. These data must be presented in such a way that the relevant authorities become convinced that identification has been proven beyond all reasonable doubt.[1]

We present two cases where apart from the usual dental data, radiopaque material, thought to be amalgam, was used as an adjunct to the identification procedure.

CASE REPORTS

Case 1

Extensive decomposition and severe mutilation of human remains recovered during the course of a murder investigation resulted in a request for dental identification The disarticulated mandible and a fragment of maxilla were received together with bitewing radiographs, dated 9-2-84, and a dentist's record of treatment, but no charting.

The ante- and postmortem dental findings are summarised in Figure 1. Although the right maxilla was not recovered a number of points of correspondence as well as 2 explainable points of difference were established. In addition, the presence of material believed to be amalgam, was identified (Fig.2a, inset) within the soft tissues mesial to the root of tooth 34 in both antemortem and postmortem radiographs. Tracings of the amalgam fragments performed on enlarged photographs showed the morphology of the fragments to be similar (Figs.2a and 2b).

If the dental data only were considered, the points of correspondence would be insufficient to prove identity beyond reasonable doubt. However, the similar morphology of the amalgam fragments was considered unique enough to make a positive identification.

Case 2

This case concerns dental identification subsequent to exhumation of a body 6 months after burial. The deceased was identified at the time of death by several acquaintances, and since he was indigent was buried in a

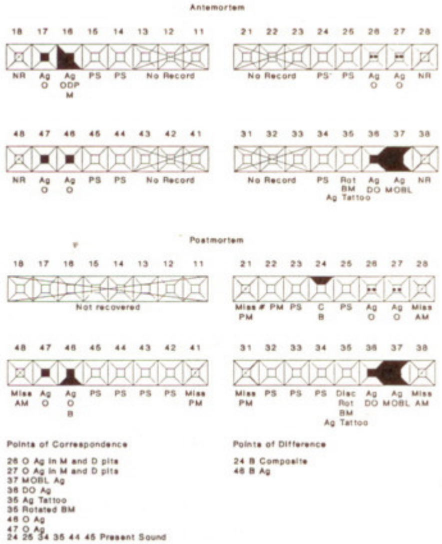


Figure 1: Case 1: Ante- and postmortem dental findings showing points of correspondence and points of difference (Ag - amalgam; AM - antemortem; B - buccal; C - composite; Car - carious; Cr - crown; D - distal; Disc - discoloured; L - lingual; M - mesial; Miss - missing; NR - no record; O - occlusal; PM - postmortem; PS - present sound; Rot - rotated).

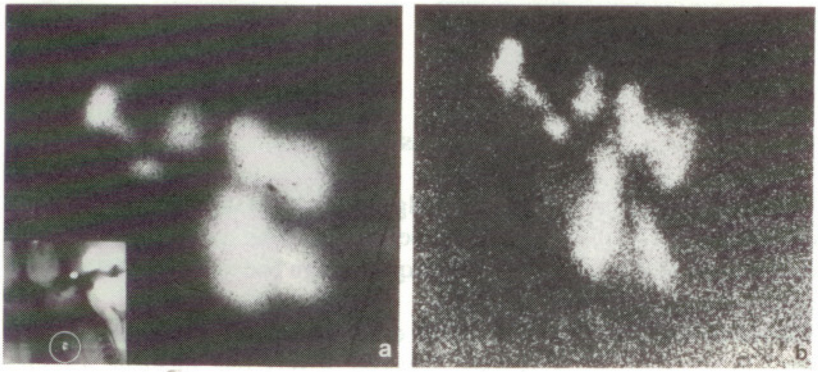


Figure 2: Case 1: Ante- (a) and postmortem (b) radiographs showing the morphology of the radiopaque material which has maintained its spatial configuration (magnification x 45). Inset: radiograph showing original size of amalgam fragments (circled).

pauper's grave. Six months later his family applied for reburial in Ireland and because they wanted confirmation of his identity a dental identification was requested.

The specimen received consisted of a disarticulated mandible and fragments of maxilla, an upper partial chrome/cobalt denture, a dentists record of treatment and 2 periapical radiographs, dated 24-6-85. Due to the advanced state of decomposition a number of the teeth had been lost postmortem.

The dental findings are summarised in Figure 3. The antemortem record reflects extensive dental treatment but the teeth concerned were not recovered.

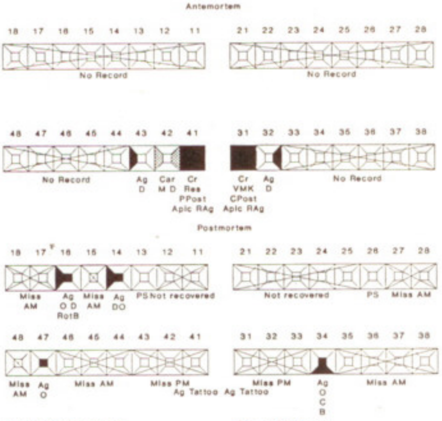
Close examination of the ante- and postmortem periapical radiographs of the mandibular incisor area demonstrated a number of amalgam fragments (Figs.4a inset and 4b inset). Tracings of the amalgam fragments performed on enlarged photographs showed the spatial configuration of the fragments to be similar (Figs.4a and 4b).

Although some routine points of correspondence could be established between ante- and postmortem dental data, these were insufficient for us to make a definite identification based on the material we received. The similar amalgam fragments, however, were regarded as sufficiently unique to establish identity.

Discussion

During routine dental treatment amalgam is often lodged in the oral soft tissues or jaws where it remains permanently as an amalgam tattoo, constituting the most common radiopaque foreign body in the facial region.[2]

The fate of amalgam deposited in the oral tissues has been documented by Eley.[3] In histologic sections some dispersal of very fine amalgam particles occurs with selective binding to vessels, nerves, collagen fibres and basement membrane. The degree and mechanism of this is unknown. Selective binding occurs after tin and mercury are lost from the implanted amalgam particles; the resultant dissociated granules which contain silver and sulphur subsequently attach to the various connective tissue elements much like a reticulin stain .[3,4]



Points of Correspondence

31 Periapical bone loss
31 Ag Tattoo
41 Periapical bone loss
41 Ag Tattoo
Partial upper C/C denture

Points of Difference

None

Figure 3: *Case 2: Ante- and postmortem dental findings showing points of correspondence and points of difference (Ag - amalgam; AM - antemortem; ApicRag - apicoectomy and retrograde amalgam; B - buccal; CPost - cast post; C-composite; Car - carious; Cr - crown; D - distal; L - lingual; M - mesial; Miss - missing; NR - no record; O - occlusal; PM - postmortem; PPost - preformed post; PS - present sound; Res - resin; Rot - rotated; VMK - porcelain fused to metal).*

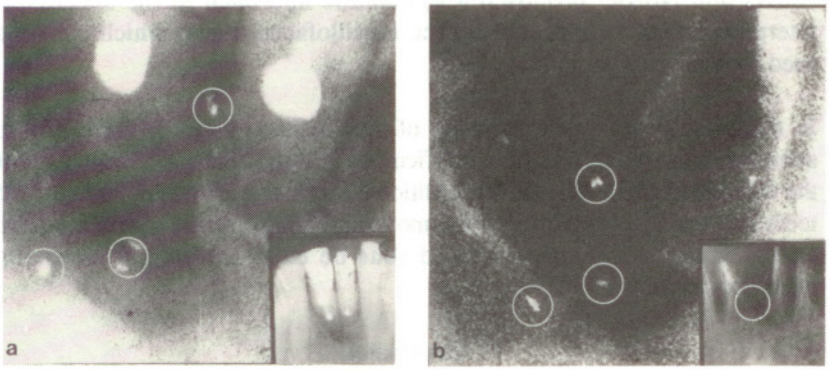


Figure 4: *Case 2: Ante- (a) and postmortem (b) radiographs showing the configuration of the radiopaque material (circled) in the anterior mandibular incisor area (magnification x 45). Inset a: antemortem radiograph showing original size of amalgam fragments. Inset a: postmortem radiograph showing original size of amalgam fragments (circled).*

Cases in which amalgam tattoos were used as an adjunct to dental identification have not yet been reported in the literature. The possible use of root filling material in the surrounding periapical tissues as a criterion for dental identification was alluded to by Nortje and Harris[5] but its actual use in a dental identification has similarly not been documented.

We present 2 cases in which amalgam tattoos were used in dental identification. In one the amalgam was present primarily in the gingival soft tissues while in the other apicoectomies had been performed and the amalgam was present in the alveolar bone of the anterior mandible.

In both cases the amalgam had been deposited in the tissues 5 years prior to death. This suggests that larger fragments of dental amalgam remain localised in the tissues for extended periods of time, maintaining their morphology and spatial configuration and may therefore be of considerable value in dental identification.

Of crucial importance in the radiological comparison of amalgam tattoos is the reproduction of the angulation with which the antemortem radiographs were taken. Differences in angulation could result in distortion, elongation, superimposition and apparent shift in the position of the particles. Wood, Harris and Nortje[6] proposed a systematic approach to the successful interpretation of radiopacities in the maxillofacial region which could be used for amalgam particles.

In the second case exact matching of the amalgam particles could not be achieved probably as a result of difficulties in reproducing the angulation of the antemortem radiographs. An additional factor may be postmortem loss of teeth and autolysis resulting in the movement of fragments within the bone and soft tissues; caution should thus be exercised when assessing decomposed tissues.

Conclusion

The presence of amalgam particles in the oral soft tissues and jaws can serve as an additional means for person identification. The morphology and arrangement of the amalgam fragments may be so varied and so unique that in some instances identification could be made on this single characteristic. Further work needs to be done to assess more fully the tissue reactions, dispersal and stability of amalgam in the oral tissues.

Case 2 was also a stark example of inadequate record keeping which would otherwise have helped identification considerably.

References

1. Keiser-Nielsen S. Person identification by means of the teeth. 1st ed. Bristol: John Wright & Sons, 1980:6-8.

2. Stafne EC, Gibilisco JA. Oral roentgenographic diagnosis. 4th ed. Philadelphia: WB Saunders, 1975;358.

3. Eley BM. Tissue reactions to implanted dental amalgam including assessment by energy dispersive X-ray micro-analysis. J Pathol 1982; 138:251-72.

4. Peters E, Gardner DG. A method of distinguishing between amalgam and graphite in tissue. Oral Surg 1986; 62:73-6.

5. Nortje CJ, Harris AMP. Maxillo-facial radiology in forensic dentistry: A Review. J Forensic Odontostomatol 1986; 4:29-38.

6. Wood RE, Harris AMP, Nortje CJ. Radiologic interpretation of radiopaque foreign bodies of the maxillofacial region - a review. J Forensic Odontostomatol 1987; 5:25-40.

POST-MORTEM DENTAL RADIOGRAPHY: A USEFUL INNOVATION

Marie-Josephe du Saucey*, Kenneth A. Brown**

**Marie-Josephe du Saucey, Faculty de Medicine-Dentaire, Rabat, Maroc*

***Kenneth A. Brown, Forensic Odontology Unit, University of Adelaide*
GPO Box 498, Adelaide, South Australia, 5001

Paper presented to the 3rd INDPAC Conference on the Forensic Sciences, Madras, India. September, 1989.

Abstract

Post-mortem Intra-oral radiographs can reveal the entire status of the crowns of teeth when visual access is limited or impossible and afford a reliable means of achieving identification by a comparison with ante-mortem clinical records. Difficulties are often encountered in placing and retaining intra-oral films in the mouths of deceased persons whose mandibular musculature has been fixed in rigor mortis or by the effects of incineration. These difficulties may be minimised by the use of balloon catheters which can be inflated within the oral cavity and serve to support the film in place during radiographic exposure.

Key words: identification, radiographs, balloon catheters, forensic odontology

Introduction

Dental radiographs have long been recognized as important means for confirming identification of deceased persons by dental comparison. Diagnostic intra-oral radiographs, either periapical or bitewing, are routinely used in dental practice and these form part of the patient's clinical record. They reveal minute details of the presence of restorations, caries and hard tissue structures which can be compared directly with post-mortem films, and such comparisons alone may be sufficient to achieve reliable identifications. Furthermore, both post-mortem periapical and bitewing radiographs can reveal important characteristics which may be overlooked in the course of visual examination when direct access to the mouth is limited.

The technique of making good quality intra-oral radiographs of living patients and skeletonised jaws is straight forward and presents few problems. However, when radiographs must be taken in the mouths of deceased persons whose soft tissues have lost their elasticity or become rigid, retention of the film in its correct position between the tongue and the lingual surfaces of the teeth often presents great difficulty. An innovative solution for this problem utilizes the balloon catheters designed for reducing mid-maxillary fractures* and was proposed by Renson for taking intra-oral radiographs for handicapped patients.[1]

Method

When access to the mouth is clear, the periapical or bitewing film is inserted into the mouth using forceps and located against the lingual surfaces of the teeth. The deflated rubber balloon of the catheter is then placed between the film and the tongue and inflated by means of a 20cc syringes. After clamping the catheter the inflated balloon holds the film against the teeth and allows the position of the film to be adjusted as may be required. After exposure the balloon is deflated by releasing the clamp and withdrawn from the oral cavity together with the film which is then processed.

Access to the mouth is impossible, however, when the teeth are clenched and the muscles of the jaws are fixed in rigor mortis or following incineration, when the tongue may be protruded and swollen and covering the anterior teeth. Under such circumstances great care must be exercised in attempting to open the mouth to avoid accidental damage to the teeth and restorations present, and removal of the jaws by painstaking dissection may be necessary.

Such radical measures can be avoided if the dental radiography is deferred until the autopsy has been completed by the pathologist. Since the routine autopsy examination requires the removal of the tongue from the floor of the mouth through the pharynx the oral cavity is thus vacated and the periapical film and balloon may be introduced through the opened pharynx

---

Porges France, Rue Leon Blum, 91124 Palaiseau, Cedex, France.

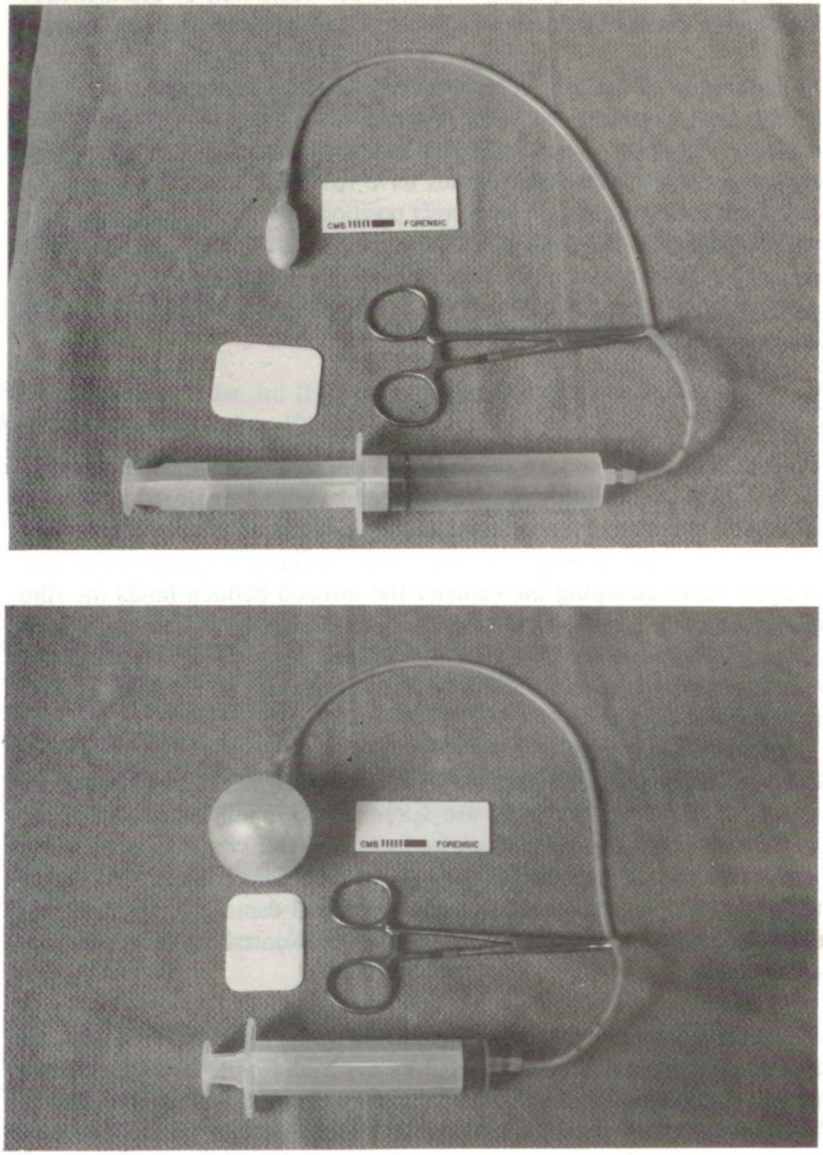


Figure 1: *(a) Balloon catheter (deflated), disposable syringe, intra-oral film and artery forceps. (b) As above, showing balloon catheter inflated.*

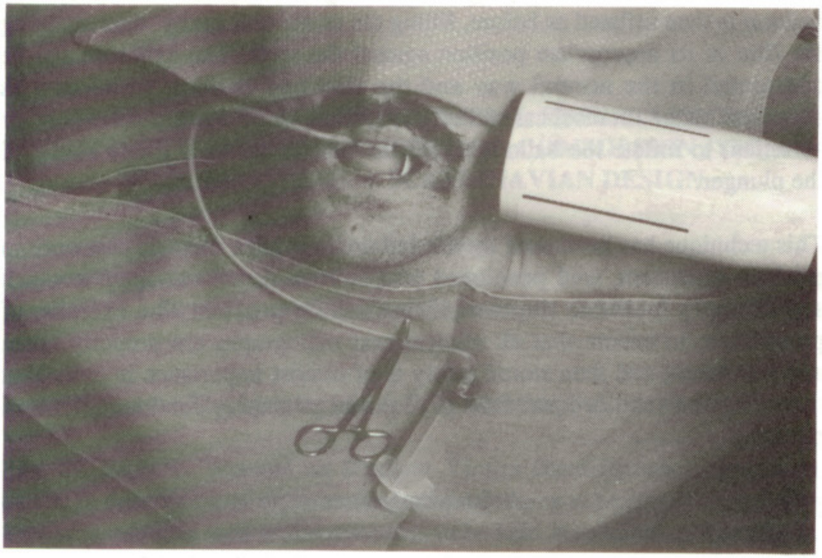


Figure 2: Balloon catheter inflated in mouth with intra-oral film in situ.

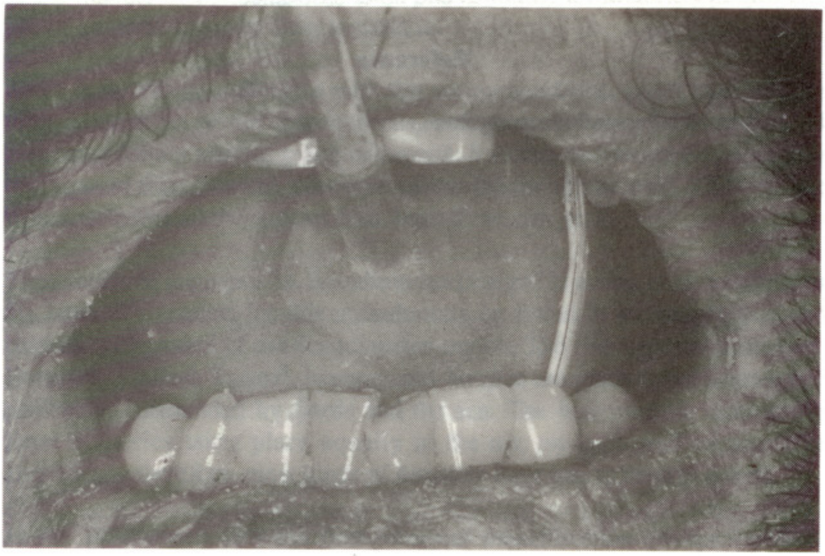


Figure 3: Close-up view of inflated balloon and film in situ in mouth.

and the film placed correctly against the lingual surfaces of the teeth. The balloon is then inflated as before, filling the entire oral cavity, thus retaining the film in its appropriate position against the teeth. The exposure can be completed in the normal way and the film and balloon withdrawn as described above. In most cases the 20cc syringe will provide a volume of air sufficient to inflate the balloon to fill the oral cavity by a single stroke of the plunger.

This technique has been used by the authors in routine forensic casework to produce consistent, well positioned post-mortem dental radiographs which significantly facilitate the total identification process. The exercise of proper care to ensure that all clinical oral radiographs are properly taken and processed, and then stored safely is of utmost importance in order that they may be readily available if required promptly for identification purposes.

Acknowledgements

This study was carried out under a grant from the South Australian Government to whom grateful acknowledgement is made. Special thanks is due to Drs J. Taylor, T.E. Bridges, P. Nambiar, Mr. D. Eitzen, Mr. M. Billet and Mrs E. Formenti for technical and other assistance.

Reference

1. Renson, J. Personal communication

UTILIZATION OF FORENSIC DENTAL EXPERTS FROM A "VISITING" VICTIM IDENTIFICATION COMMISSION (VIC) IN MASS DISASTERS. A SCANDINAVIAN DESIGN

Jan Jakobsen

Royal Dental College of Copenhagen, Denmark

Paper read at the 12th Meeting of I.A.F.S., Adelaide, S.A., Australia 1990

The INTERPOL "Manual on Disaster Victim Identification" contains a thorough description of organization and procedures to be implemented after a mass disaster, as well as the resources to be held in readiness. The present paper refers to a short chapter mentioning the international cooperation, when, after a disaster, victims are not all from the country in which the accident took place. One of the underlined recommendations from this part of the manual is that identification experts should travel immediately to the site of accident and offer their assistance.

There is no reason to disagree with this recommendation, but it may be wise to examine some of the consequences, and particularly the positive ones of assistance from a visiting group of experts. It is easy to foresee two opposing reactions to this: "we can take care of the job using our own VIC" or "we would welcome all the support from outside we can get."

The subtitle of the paper "A Scandinavian Design" is meant as an example of the latter. The reason for this attitude may be found in the geographic and cultural background of the Scandinavian region. The five national territories, Denmark, Finland, Iceland, Norway and Sweden are made up of islands and peninsulas surrounded by fjords and the sea. The heavy traffic connecting these countries takes place equally in the air, on land, and on sea. Not surprisingly therefore, most kinds of disasters have had to be coped with.

In the 1930's and 40's the first informal identification groups - police, forensic pathologists and dentists - were in action in Norway and Denmark. More permanent groups of experts could be relied upon during the 1960's and 70's and now in the 80's and 90's all the Scandinavian countries have officially appointed VIC's.

During the past 15 years annual meetings and continuing contact between the national VIC's have secured standard procedures in mass disaster identification in Scandinavian countries.

Such cooperation is an important precondition for a cooperative effort by, say 2 VIC's. Anyone who has participated in the hectic activity after a major disaster will surely admit that there is no need for additional problems, for instance interference in planning from a visiting and uninvolved group of experts, even if they are colleagues! In order to establish confidence in the cooperation between VIC's it is necessary that ongoing contacts in what could be named "quiet times" should reach a stage of personal acquaintance between experts involved.

In the past, the first cooperation between three of the Scandinavian countries in a mass disaster identification took place in Saudi Arabia following a crash of a Danish charter plane in 1972. The 112 passengers came from four of the five countries, mainly Denmark. There were only four dentists at work and doing their best, but it was after that event that it was decided to organize more efficiently. After the latest disaster, which occurred at Easter 1990, cooperation between Scandinavian VIC's was thoroughly tested. The Norwegian VIC became responsible for the task and dentists from Denmark and Iceland participated.

It was the type of accident that had almost been waited for. One of the many ferries sailing Scandinavian waters was struck by fire; the vessel was wearing the apposite name "Scandinavian Star", licensed for 1300 passengers but fortunately only carried 490 passengers and crew members. Poisonous smoke killed 158 people and many were incinerated as the fire went on for 36 hours, and the rescue operation and identification work turned out to be complicated. The survivors among passengers were set ashore in 3 different countries, the burning ferry was hauled to a Swedish harbour and the VIC work took place in the capital of Norway. The Norwegians invited the Danish VIC to support their work.

At its peak the assignment for VIC members involved 18 dentists: Norwegians, 4 Danes, and 1 from Iceland. In total, more than 100 experts from different categories of police, medical staff, laboratory assistants and dentists contributed to the identification of all victims within 17 days.

Following the Norwegian plan two teams of experts worked at the scene of the disaster; they were guided by police technicians who were sufficiently experienced to operate in areas of the ship where a search for human remains should be carried out. Four teams of forensic pathologists and dentists (2 dentists on each team) worked for 5 days in the mortuary at the Institute of Forensic Medicine in Oslo, while 6-8 dentists were at work at the Police Headquarters, also in Oslo. It was here too that the ante-mortem information from the missing persons was collected and processed and led to the comparisons with post-mortem findings.

The success of the operation is put down to skilful organization by the Norwegian authorities, in particular the placing of forensic and dental expertise right at the site of the disaster.

Considering the circumstances of this kind of work it is surprising that most of the parties involved in this operation were left with an impression of smoothness and efficiency. One reason for this was the utilization of additional invited manpower.

Conclusion

The following advances are clearly to be gained by cooperation between more than one victim identification commission:

1) The supplementation of available dental manpower will limit the daily working hours and reduce the amount of mistakes in the handling of data.

2) Interpretation of ante-mortem and post-mortem findings from foreign citizens among the disaster victims is improved.

3) The future preparedness can be strengthened when sufficient manpower is available. It allows the dentists to work in pairs in the mortuary, one experienced worker together with a less experienced colleague.

Experiences after the fire on the ferry, Scandinavian Star, showed that it is beneficial to invite fellow experts from a neighbouring country to assist in DVI following a mass disaster provided that the home team is adequately prepared. The Scandinavian Design may be of interest in other small countries or among federal states.

NATIONAL CHARACTERISTICS OF DENTAL TREATMENT IN DISASTER VICTIM IDENTIFICATION

E. Kraft,* E. Liebhardt, G. Lindemaier***

* *Poliklinik fuer Zahnaerztliche Prothetik der Universitaet Muenchen*
Goethestraße 70, 8000 Muenchen 2, Germany

** *Institut fuer Rechtsmedizin der Universitaet Muenchen*
Frauenlobstraße 7a, 8000 Muenchen 2, Germany

Paper read at the 12th Meeting of I.A.F.S., Adelaide, Australia, 1990

Abstract

In this age of mass tourism it is necessary to identify repeatedly a great number of casualties. In otherwise hopeless cases of identification dental alloys can be broken down by energy-dispersive X-ray microanalysis and an scanning electron microscope to furnish valuable clues as to the country of their origin.

It is a fact that the teeth, being the hardest mineralized substance in the human body offer maximum resistance to all post-mortem influences. Unfortunately in this age of mass tourism and the disasters that go with it, it is necessary to identify repeatedly a great number of casualties as quickly and as accurately as possible within a short time.

Identification must be reliable for social, religious and legal reasons and must be rapid in order to save families from the agonizing doubts of whether their loved one was a casualty or a survivor.

The high degree of destruction caused by an explosion and the subsequent disfigurement by incineration make the use of conventional identification procedures impossible. For example recognition of a corpse by friends or relatives requires a mostly intact corpse or if recognition is to be effected from personal belongings it must be remembered that these may have been changed with or without criminal intention. Identification by fingerprints often fails because they have either not been taken before the accident or because it is impossible to take them afterwards. By contrast, the dentition is very efficiently protected by the soft tissues of cheeks, lips and tongue and survives the severest of fires in the majority of cases. The human dentition has a vast variety of variables including 32 teeth with 5 surfaces each, that is 160 surfaces, each one with a unique combination of shapes, restorations, colours and defects (Fig.1). The teeth are influenced by an almost countless number of genetic factors and combinations of dental treatment, as well as characteristics of technology both in the choice and use of materials.

A useful feature of identification of air crash casualties is the passenger list, which includes the nationalities involved. Given this knowledge and the fact that national characteristics in treatment are known and recognizable, then a rough division into smaller groups can be made. This smaller group can then be subjected to further, more specific observation.

There can be no doubt that there is a wide rift between dental care in the rich, industrialized nations and in the less prosperous agricultural countries or even the third world nations. Thus a dentition which shows no sign of

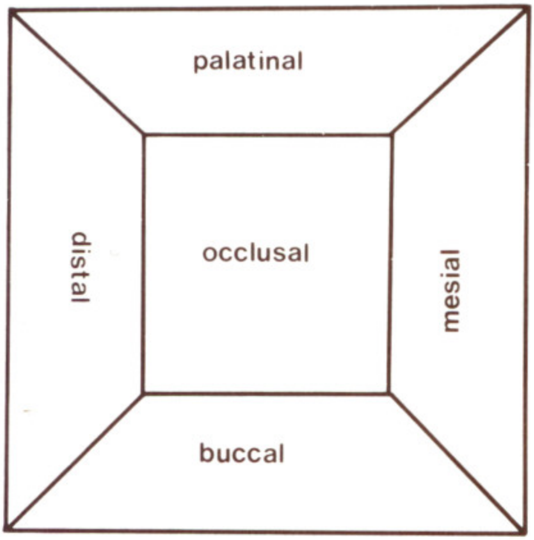


Figure 1: Five observable surfaces of a tooth

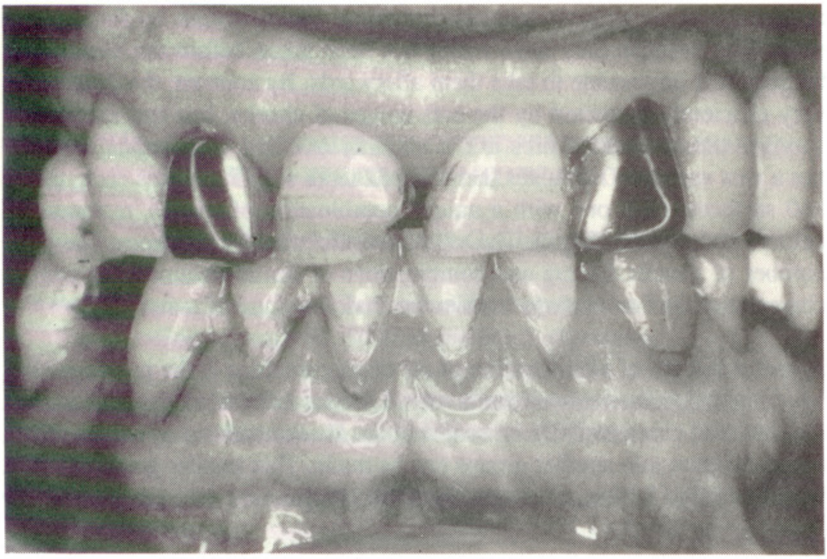


Figure 2: *Gold crowns of a Turkish patient*

treatment although there would be an obvious need for it, may give a hint as to the regional origin of the victim. Such situations are sometimes met with in the Mediterranean area, the south of Italy, Spain, Malta and Greece.

In this respect the Turkish population occupies a special position in the Mediterranean. Here the anterior dental arch often contains bridges and crowns of gold without any facings (Fig.2). The crowns are partly made of jewelry-quality gold or, as dental technicians call it "Turkish gold", which is an alloy of gold with a high percentage of copper.

In the countries of eastern Europe, inexpensive pre-fabricated crowns are common and fitted to the stump of the tooth, as opposed to the custom made gnathologically correct technique of the western world. Furthermore, gold imitations such as "Sipal" are commonly found. This alloy contains palladium instead of gold.[1]

All these alloys referred to above can be broken down by energy-dispersive X-ray microanalysis and a scanning electron microscope to furnish valuable clues as to the country of their origin. Figures 3 and 4 show two samples of alloy which vary greatly in their composition. The percentage of silver ranges from 67% as commonly found in Germany to 21% for India.

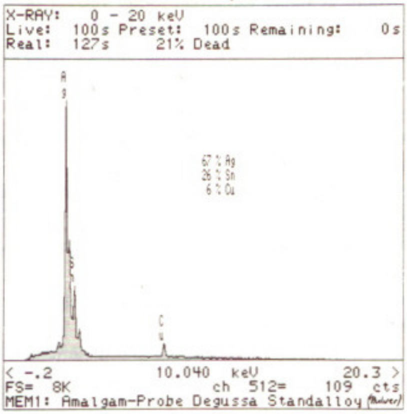


Figure 3: Spectrum of German amalgam

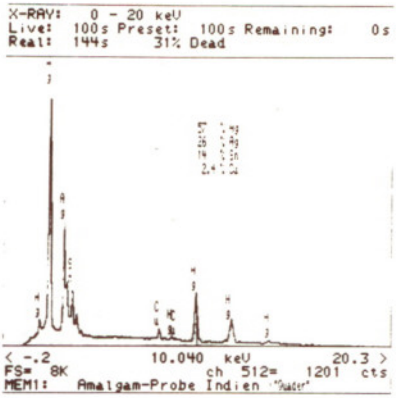


Figure 4: Spectrum of Indian amalgam

Knowledge of the differences in social security systems also allows conclusion as to the provenance of dental work. In the United Kingdom National Health Service for example, only simple restorations and partial dentures without clasps or supports are mostly encountered. In Germany, however, this practice is frowned on because a denture could be swallowed or aspirated.

In conclusion, it is planned to collect, analyse and document as many different dental alloys as possible so as to have on hand a set of data for reference when otherwise seemingly hopeless cases of identification present themselves.

Reference

1 Rotzscher K, Mende S, Flachowsky J, Geisler M, Wehran HJ: Neutron activation analysis of dental metals with regard to forensic odontology (Dental Identification). Journal of Radioanalytical Chemistry 1973; 15:317-28.