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Contents

DENTAL IDENTIFICATION IN THE PIPER ALPHA OIL RIG DISASTER

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At 21h58 in the evening of July 6th 1988 a gas explosion and severe fire occurred on the North Sea Occidental Petroleum oil rig Piper Alpha situated 100 nautical miles east of Wick in Scotland. The severe fire, fed by hydrocarbon gas at 1800 psi produced a fireball rising 700 feet. The accommodation module became detached and sank 470 feet to the sea bed.

There were on board at the time 229 persons. Rescue vessels, hampered by the severe heat, managed to pick up 62 survivors, many of whom had jumped 100 feet into the sea. One hundred and sixty seven persons died, of whom 136 were eventually recovered. Only 57 bodies were recovered in the first few days. The recovery of the module from the sea bed was a major marine engineering exercise involving lifting the module on to a barge and subsequent towing to Flota Harbour in the Shetland Islands before being searched for further bodies. This was undertaken 110 days after the accident when 74 victims were recovered and flown by a helicopter shuttle service to the temporary mortuary at Aberdeen airport. Five further victims were recovered when trawling of the sea bed took place. The United Kingdom has 52 separate police forces responsible for county and metropolitan areas. The North Sea off-shore policing responsibilities are undertaken by Grampian police force with headquarters in Aberdeen. This police force is the most experienced force in mass disaster management in the U.K. having dealt with the Sumburgh air accident in 1986 where 45 died, and with a number of fatal helicopter accidents. The emergency plans for such disasters include a temporary

mortuary facility in a hanger used for storing snow clearing equipment at Aberdeen airport. This airport is used by a number of scheduled airlines and is 1 hour 15 mins flying time from London; it is also the busiest helicopter base in the world, serving the off-shore oil and gas industry.

Shortly after the disaster Grampian police opened their casualty bureau in their Aberdeen headquarters and the first bodies were delivered to the temporary mortuary facility direct by helicopter from the on-site rescue vessels.

Dental manpower

The first forensic odontologist was placed on standby, by Kenyon Emergency Services, two hours after the explosion and arrived at the temporary mortuary the morning following the accident. The dental postmortem examinations of the first 17 victims, recovered at that time, were completed on the first day.

A second forensic odontologist was on site on day 3 to assist with the antemortem data being received and to assist with further victims being recovered.

Three forensic odontologists were on site for one week when the accommodation module was raised, after which one remained available at the mortuary during the trawling period up to November 2nd. There was thus at least one forensic odontologist present on site for a period of 118 days. On three occasions after this date human material was recovered and a forensic odontologist flew up from London to undertake the dental postmortem, returning the same day. The last flight being made on November 23rd, 139 days after the incident.

The cover for this disaster was provided by 4 individual forensic odontologists. Because of the small number of bodies recovered over the first few days (57) and the long delay before the raising of the accommodation module, there was no requirement for a separate team to collect antemortem records. This accident was unusual in that antemortem records were obtained for the majority of the victims before they were recovered.

ANTEMORTEM DENTAL INFORMATION

On the afternoon of the first day an antemortem dental record collection centre was set up in the headquarters of Grampian Police in Aberdeen with the assistance of two police officers. A system was put into operation whereby, on receipt of the name address and telephone number of the missing person's dentist, supplied by the adjacent casualty bureau, the police officer would make initial telephone contact requesting that the dental surgeon confirm that the missing person was his patient. Having established this the dentist was then requested to call back when he had sufficient time to check the notes and prepare a composite charting. On receipt of the incoming call from the missing person's dentist, usually within the hour, this was transferred to the forensic odontologist who took a telephoned charting and then informed the dentist that a police officer from the local force would collect the record. This was then arranged by the police officer working with the forensic odontologist.

Within Aberdeen itself, where many of the victims had received treatment, dentists delivered the records personally to the police headquarters. Within Scotland a dispatch rider delivered the records. Those in England were rapidly delivered by air or by the fastest means available. The majority of the records were received within 4 days of the incident. A small number of records were also obtained from Canada and the U.S.A.

The victims worked for a number of companies under subcontract, none of whom employed a company dentist. Dental treatment was either obtained in the victim's home town or locally in Aberdeen when on shore leave.

The majority of the victims had received treatment in North East Scotland. One hundred and thirty two antemortem records were obtained (79.04% of the total victims).

POSTMORTEM DENTAL INFORMATION

One hundred and thirty six victims were examined. The state of decomposition varied between nil in the first 17 to totally skeletonised in the last victim examined 139 days later. One hundred and twenty four had dental conservation which included 34 with a total of 55 crowns and 6 bridges.Twenty eight victims were found to have dentures of which 11 were full upper and lower (Table 1).

Table 1

Details of dentures involved in the identifications

Denture type	Antemortem	Postmortem
Full upper/full lower	3	11 (2)
Full upper only	6	4
Full lower only	0	1
Part upper/part lower	0	1
Part upper only	19 (1)	9
Part lower only	0	1
Total	31	28

(1) 6 partial upper dentures not recorded in the dentists' records, information from relatives.

(2) 1 full lower denture not recovered.

Only one dentate victim had no restorations. All were males within the age range 20 to 60 years, mean age 35.46 (s.d. 11.87)

Three cases illustrate some of the problems encountered and the lengths that had to be gone to to solve them.

Case 1

A victim, provisionally identified by other means, had a full upper denture with an acrylic cold-cure repair to one tooth. The relatives of the provisionally identified victim had given the name of a dentist who had retired. The dentist was traced and the denture was delivered to him for examination. He could not recognise the repair or denture. The denture was then taken to the dental technician used by the dentist before retirement, the technician recognised the repair as his own work and this evidence was used to corroborate identification by other means. Fifteen man hours were involved in this one exercise.

Case 2

Another case had a lower partial cobalt-chromium denture with unusual clasping due to the position of the imbricated lower teeth. In order to confirm a positive dental identification, where no other means existed, it was considered advisable for the dentist of the provisionally identified missing person to actually view the resected jaws and denture. It was arranged that the dentist would be taken by the local police force to the nearest airport (Manchester) to meet the forensic odontologist carrying the material on a scheduled flight from Aberdeen. The resected jaw and denture were viewed in the police office at the airport, a positive identification was made and the forensic odontologist flew back on the return flight.

Case 3

Another victim was provisionally identified by a non-dental method. At postmortem examination 12, 11, 21, 22 had been lost postmortem, 13 had a post crown. The dentist stated that the patient had been seen recently and there was definitely not a crown on 13, teeth 12, 11, 21, 22 were crowned. On receipt of the actual records it was noted that a poorly positioned bite wing radiograph showed a post crown to be present on 13, the dentist's notes being incorrect.

Results

Of the 132 antemortem records obtained 107 related to bodies recovered, resulting in 90 positive dental identifications with dentistry assisting in a further 14 (76.47% of those recovered). An analysis of the ante-and postmortem records indicated an accumulation of discrepancies (Table 2).

Table 2

Discrepancies found in the dental records

	AM	PM	Difference
Total teeth recorded present	2487	2407	80
Total teeth restored	701	1021	320
Percentage restored	28.19%	42.42%	14.23%
Total surfaces restored	1445	2156	711
Total number of restorations	768	1204	436

Other methods of identification in this incident were:-

1. Clothing 38, several were wearing the standard oil rig survival suit.
2. Jewellery and property 41.
3. Documents 19.
4. Fingerprints 36.
5 Tattoos 24.
6. Physical 1.
7. Visual 13.

Discussion

Forensic odontologists have frequently commented on the poor standard of clinical dental record keeping, in particular the failure of the dental profession to undertake a full mouth charting of all the restorations present when a new patient first attends for treatment. There is no legal requirement for this to be undertaken in the United Kingdom. Many of the Scottish dental records were on forms which did not contain an odontogram capable of recording conserved surfaces with any accuracy (Fig. 1). The discrepancy between the number of restorations recorded on the records and those found at postmortem was extremely large (14.23%), almost double the highest previously found in other disasters (Zeebrugge). Many of the victims had moved to the Grampian area of Scotland from other parts of the U.K. in

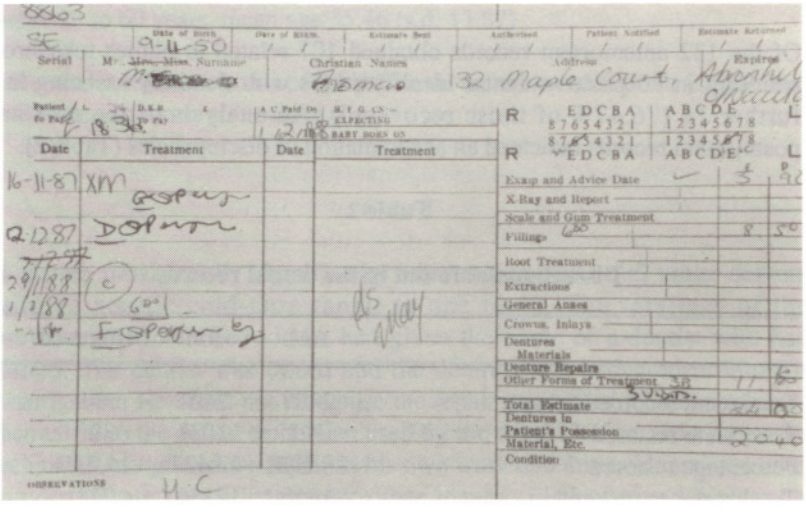

Fig. 1 One of the dental records showing absence of odontogram.

order to obtain work. When on shore leave these workers received dental treatment from dentists in their new area of residence, most of whom failed to record existing restorations. In view of the nature of the patient's occupation it would appear wise to have this recorded.

1. It is not usual for a dentist in the U.K. to ask the occupation of his patient, therefore the dentist may not have known.
2. It is not a mandatory dental requirement or a recommendation from oil companies that detailed dental records should be maintained, such a recommendation to workers might suggest that their company was unsafe. There is also the mentality that says, "accidents don't happen to our company", a reply often made by airlines to the suggestion that crew should have accurate records.
3. Dentists tend to undertake only those items of treatment for which they are paid, they are not paid for the additional work involved in marking dentures or full mouth chartings.

In this disaster, as in other disasters handled by British forensic odontologists, the most effective method of obtaining antemortem dental information was by direct telephone conversation with the presumed missing person's dentist. Occasionally, dentists are concerned about the confidentiality of their records and are reluctant to provide actual records to the police, the use of dentist to dentist contact over the telephone was reassuring for the dentist asked to part with his records. The reluctance to part with dental records is largely due to advice given by the British Dental Association[1] which states, "It is prudent to adhere to the principle of absolute confidentiality of patients' records. However, if a practitioner feels that there are compelling reasons for producing information about missing persons the police should be asked to provide assurances (preferably in writing) that:

1. there is good reason to believe that the person may be dead,
2. any dental information provided would never be used to identify a living person, and
3. the record would be destroyed as soon as it had served its immediate purpose and would not be filed for future reference."

Although, in this disaster, we followed a slightly different procedure from our norm, with the initial call to the dentist being made by one of the two

police officers assisting us, the dentist was immediately informed that he would be providing the information requested to a forensic odontologist. Following this contact the actual records were collected by the local police forces. We made a decision that where the records would not reach us within 10 hours then the local police force would transmit a facsimile of the actual records first. The only value then found in having the actual records were the radiographs.

Solheim and van den Bos[2] noted that where it was the task of the police to contact the dentist it was found that in a number of cases this had not been undertaken. We believe that a dentist should be in charge of the antemortem record collecting centre with good police support and not *vice versa.*

The initial telephoned odontogram information was not always accurate but there were no major errors. Previous experimental work in dictating dental information over the telephone using a number of dental practices had shown that 37.5% of the dentists participating in the experiment failed to dictate a charting that completely matched the original record.[3] It is therefore important that all information obtained over the telephone should be followed by at least a facsimile of the record. Although in this disaster there were very few records required from foreign countries the same system was adopted, telephoning the practice during its working hours. The actual records were air mailed direct to police headquarters in Aberdeen marked "For the attention of the Piper Alpha forensic dentist". The word "odontologist" was deliberately not used as it is not a term immediately recognised by police officers. Why did we not use Interpol? Our experience in past disasters has shown that records sent by this route have never been received in under three weeks if they are received at all. Once the record leaves the hands of the missing person's dentist it becomes "in transit" and untraceable until such time, maybe months later, it turns up at the police force HQ. Solheim and van den Bos[2], discussing the "Alexander Keilland" disaster,were particularly critical of British dentists, noting that British records began to arrive two weeks after the Norwegian identification commission had finished its work. He states that these were only received after several requests were made through Interpol and the British embassy in Oslo. Criticism was also made that no British identification experts were sent to assist with the work. No British forensic odontologist was ever contacted by Interpol or any other organisation. The Norwegian identification Commission require that all overseas enquiries are made through Interpol. We believe that these criticisms support our view that direct international contact between the on-site forensic odontologist and a forensic odontologist

of the country from whom a record is required is by far the most efficient method, this is where the International Organisation for Forensic Odonto-Stomatolgy can be so valuable by supplying an annually updated list of names, telephone and facsimile numbers for each country. We feel that defective international co-operation is not the fault of individual members of IOFOS but more likely due to the methods by which forensic odontologists on site are only permitted by their country's laws and disaster regulations to use official channels.

In the Air India disaster 1985, the British and Irish forensic odontologists had the task of obtaining a foreign dental record for each victim, none of whom came from the UK. Although there were many different routes employed in obtaining dental records from Canada and India the most successful method by far was directly contacting an IOFOS member in Canada who set up an antemortem record collecting centre in Niagara Falls, Ontario supported by a non-dental member of the Kenyon Emergency Services team experienced in the international transmission of freight (in this case the nightly transmission of dental records).

The problems associated with visual identification have been commented upon by numerous authors.[4-6] Thirteen victims who were amongst the first group recovered were visually identified by their work mates. This was corroborated in all cases by additional methods.

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CRANIOFACIAL CHARACTERISTICS AS DETERMINANTS OF AGE, RACE AND SEX IN FORENSIC DENTISTRY - A HANDS-ON GUIDE

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Age, race and sex determinationion together with dental identification and a facial reconstruction on the skeletal material are procedures that the forensic odontologist should try to master. The most difficult is the facial reconstruction as this requires artistic skills normally not developed in the average dentist.

Age determination in a dentate skull is usually not a problem up to the age of approximately 21 years. Radiographs of the developing and/or erupted teeth are made and compared with charts indicating the normal eruption and crown/root development dates.[1] After eruption root development and apical closure of the wisdom teeth make age determination more of a problem[2], Gustafson's method of age determination[3] for example uses six regressive changes, namely, attrition, recession of the gingiva, secondary dentine, cementum deposition, root resorption and transparency of the root which provides a scientific method of age assessment of fully developed teeth.

The ages at which skull sutures close is another indicator in age determination. Some authorities[4] believe, because of the large discrepancy between endo- and ectocranial suture closure dates, that this is not a reliable method.

TABLE 1: Average Age of Sutural Closure in Males [4].

Suture	Endocranial Initial	Ectocranial Termination
Sagittal	22	35
Sphenoparietal	29	65
Coronal	24	38
Squamosal	37	81*
Sphenotemporal	30	67
Lambdoid	26	42
Masto-occipital	26	72
Sphenofrontal	22-26	64

*Rarely undergoes complete closure

Some ethnic and sexual differences in sutural closure are apparent. For example populations of African ancestry tend to exhibit earlier initial and final closure than populations of European ancestry. Moreover, sutural closure in females tends to initiate and terminate earlier than it does in males. Suture closure in ageing may be corroborative, but it is scarcely definitive.[4]

Obliteration of the cartilaginous spheno-occipital synchondrosis is usually not complete until the 14th to 18th years.[4] Gustafson's[3] method and skull suture closure dates enables the forensic odontologist to assess the age of a dentate skull reasonably accurately.

Anatomical and chemical changes in the jaws and teeth can be utilized to complement the tests outlined above. Changes in the angle of the mandible and changing position of the mental and mandibular foramina have been related to increasing age but with little success.[5] But cemental annulation, where the usual number of years for the eruption of a particular tooth is added to the annulation count can also be used to determine age.[9]

Chemical changes have been investigated such as the increasing mineralization of the bones of the jaws, but variations in mineralization are too great to allow reliable age determinations. Also unreliable are the increase in nitrogen content of enamel causing progressive darkening[6] and the fluoride content of enamel and dentine as an age indicator.[7] Lysine and hydroxylysine in transparent dentine may be a useful, measurable clue to

chemical dental age determination and aspartic acid, an amino acid found in enamel, exhibits increasing racemization with age.[8] This measurable biochronologic tool was regarded in 1977 by Sognnaes[7] as then one of the most exciting recent additions to chemical age determination.

Diagnostic traits for sex in the cranium and mandible can be determined by utilizing certain non-metrical features and many tables are available comparing male and female characteristics of the skull. The forensic odontologist who is routinely involved in sex determination of skeletal remains may benefit by using a check list, devised and compiled after consulting the available tables.[4,10]

TRAITS DIAGNOSTIC OF SEX IN THE CRANIUM AND MANDIBLE[4,10]

NON-METRICAL FEATURES

	TRAIT	MALE	FFMALE
1.	General Size	Large	Small
2.	Architecture and Muscular Ridges eg.Temporal lines and Nuchal crests	Well developed/ Rugged	Smooth
3.	Glabellar Prominence	Moderately to markedly curved	Flat or slightly curve
4.	Superciliary Eminence	Moderate to marked development	Absent or slight
5.	Superior Orbital Margin	Rounded	Sharp
6.	Mastoid Process	Medium to large	Small to medium
7.	Mastoid Crest	Slight to moderate	Marked
8.	Digastric Fossa	Not expanded	Expanded
9.	Shape of the Forehead	Sloping	Vertical

10. Frontal Eminences	Small	Large
11. Parietal Eminences	Small	Large
12. Position of Nasion	Moderately to markedly depressed	Rarely depressed
13. Supra Mastoid Crest	Marked development and prominent deep supramastoid groove	Slight groove, faint or absent
14. Cheek Bones	Heavier, more laterally arched	Lighter, more compressed
15. Orbits	Squared, lower, relatively smaller with rounded margins	Rounded higher, relatively larger, with sharp margins
16. Palate	Larger, broader, tends more to a V-shape	Small, tends more to a parabola
17. Posterior Root of Zygoma	Well developed	Slight
18. Supramastoid Crest and Supramastoid Groove	Well developed with a deep groove	Slight groove faint or absent
19. Occipital Condyles	Large	Small
20. Glenoid Fossa	Deep	Shallow
21. Post Glenoid Tubercle	Well developed and prominant	Moderate size
22. Shape of Chin	Square contour	Rounded contour
23 Zygomatic Arch	Phaenozygous	Cryptozygous

24. Intercondylar distance	+108mm	+102mm
26. Tympanic Plate of Temporal Bone	Well developed	Delicate
26. Mandible	Larger, higher symphysis, broader ascending ramus	Small, with less corpal and ramal dimensions

The determination of sex in the skull is not reliable until well after puberty when the secondary sexual characteristics emerge.

Even then no single trait is characteristic. Instead, the initial general impression of a constellation of traits tends to be more accurate.[4] Assessment of race or population group of the cranium and mandible can be determined by employing a biometrical technique.

BIOMETRIC DEFINITIONS OF CRANIAL LANDMARKS, STANDARD PLANES AND MEASUREMENTS[10]

1. Definition of biometric points on the cranium

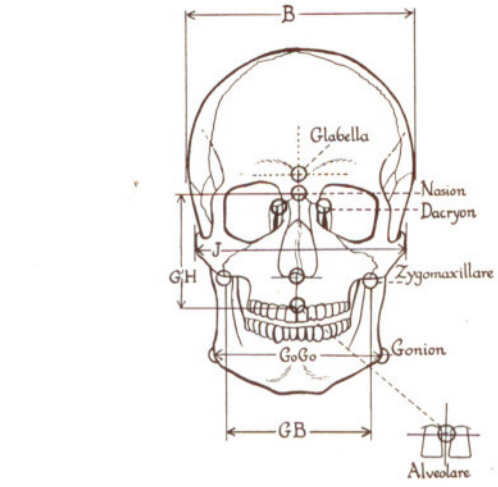
a. **Alveolare** (Figs. 1 and 2)

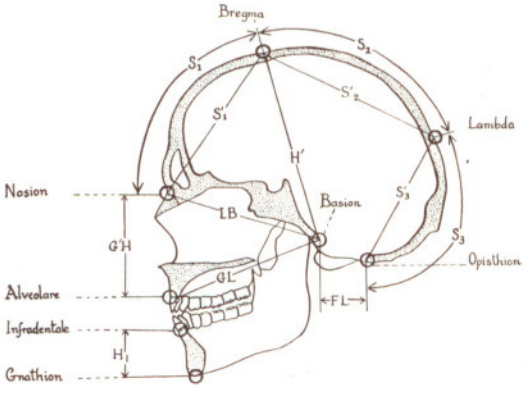
This is the lowest point on the process between the sockets of the two upper central incisor teeth. This definition is not sufficiently precise for all crania and further conventions are followed where necessary.

Usually, the process has the form of a blunt spine but it may terminate in a flat or irregular surface, in which case there may not be a distinct lowest point.

When this difficulty arises the point selected is the median one on the anterior/inferior border of the interdental process, this border being the lowest edge of the process seen when the cranium is viewed in norma frontalis.

Occasionally, the process has two more or less symmetrically placed tips, due to the incomplete fusion of the two maxillae. In this event, we may follow the same convention as when the tip is single but has no distinct lowest point: the alveolar point is taken to be the one


B
Glabella
Nasion
Dacryon
J
G'H
Zygomaxillare
GoGo
Gonion
GB
Alveolare


Bregma
S1
S2
S'1
S'2
Lambda
H'
Nasion
LB
Basion
S3
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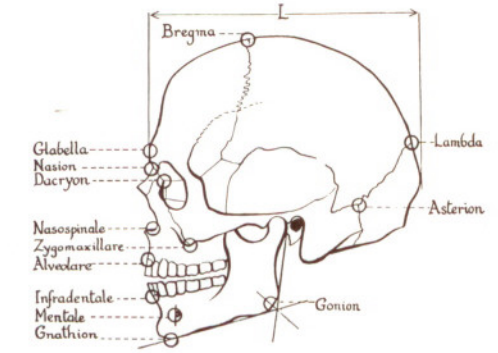
G'H
Opisthion
GL
Alveolare
FL
Infradentale
H'1
Gnathion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Alveolare
Infradentale
Mentale
Gnathion
Gonion

midway between the two lateral points. If the socket of either central incisor has been lost owing to the loss of a tooth before death, it may not be possible to reach a sufficiently precise approximation to the alveolar point. The alveolar point should therefore be considered indeterminate unless on the basis of past experience the accepted point does not differ by more than one millimeter from the alveolar point which would have been located on a complete cranium.

b. Alveolon

The point at which the interpalatine suture meets a line drawn tangential to the posterior alveolar margin.

c. Basion (Fig. 2)

The lowest point in the median plane on the external surface of the anterior margin of the foramen magnum. This point is the same as endobasion as defined by Trevor.[11]

d. Bregma (Fig. 2)

The point at which the coronal and sagittal sutures meet is termed bregma and in most crania, can be determined with precision. If, however, the sutures are so complex that the point of union cannot be found, the point of intersection of pencil lines drawn through the sutures to indicate their direction is accepted as bregma. This method is also used in cases where the sutures have been partially obliterated. Where a bregmatic ossicle is encountered, bregma is determined by continuing the directions of the coronal and sagittal sutures as pencil lines to their point of intersection.[12]

e. Dacryon (Figs. 1 and 2)

This is the point at which the sutures between the frontal, maxillary and lacrimal bones meet.

f. Ectomolare

A point on the outer margin of the socket of the maxillary second molar tooth lying midway between the medial and distal margins of the socket.

g. Endomolare

A point on the inner margin of the socket of the maxillary second molar tooth lying midway between the mesial and distal margins of the socket.

h. Euryon

A point on the side of the cranium which is furthest from the corresponding point on the opposite side in the same coronal plane. This point is not determined by anatomical relations but by trial measurements of the maximum cranial breadth.

i. Frontomalare orbitale

The most medial point on the frontozygomatic suture.

j. Frontomalare temporale

The most lateral point on the frontozygomatic suture.

k. Glabella (Figs. 1 and 2)

The most anterior point in the median sagittal plane of the bony prominence joining the superciliary ridges, the cranium being orientated in the standard horizontal plane.

l. Lambda (Fig. 2)

The point at which the sagittal and lambdoid sutures meet is termed lambda.

Sutural bones are often present in the line of the lambdoid suture and it is frequently not possible to locate lambda with precision. In such cases the procedure described by Buxton and Morant[12] is followed. This is: when a sutural bone is present between the occipital and the two parietal bones, the general directions of the sagittal and lambdoid sutures are continued by pencil lines to the point of intersection of these three lines. This intersection is then accepted as lambda.

If these three lines fail to meet at a single point, lambda is taken as the point on the sagittal line equidistant from the two points of

intersection between the sagittal line and the lines of the two lambdoid sutures. Where there is an interparietal bone, the accepted lambda is then located on this bone. Where the sutures are partially obliterated or very complex and the point of union cannot be found, the point of intersection of pencil lines drawn through the sutures to indicate their direction is accepted as lambda.

m. Maxillofrontale

The point at which a line marking the upward continuation of the anterior lacrimal crest meets the suture between the maxillary and frontal bones.

n. Nariale

Is the lowest point on the inferior margin of the nasal aperture on each side of the nasal spine. On some crania, however, the inferior margins of the pyriform aperture are not well defined by ridges which usually mark the boundary between the floor of the nasal cavity and the anterior surface of the maxilla.

In doubtful cases the inferior margin is marked by a curved pencil line from the edge of the nasal spine to the lateral margin of the pyriform aperture and nariale is taken as the lowest point on this pencil line.[13]

o. Nasion (Figs. 1 and 2)

This is the midpoint of the suture between the frontal and the two nasal bones. It often fails to coincide with the junction between the frontonasal and internasal sutures since the nasal bones are often asymmetrical.

p. Opisthion (Fig. 2)

The point at which the external and internal surfaces of the occipital bone meet on the posterior margin of the foramen magnum, in the median plane of the foramen is known an opisthion. Thus, in an asymmetrical cranium opisthion need not lie in the median sagittal plane of the cranium.

q. Opisthocranion

This is a point on the posterior aspect of the cranium furthest from glabella, in the median sagittal plane of the cranium.

r. Orale

Orale is the midpoint, usually in "the air", of a line tangential to the posterior margins of the sockets of the upper central incisor teeth.

s. Orbitale

The lowest point on the inferior margins of the orbits is known as orbitale

t. Porion

This has been defined as the highest point on the superior margin of the external auditory meatus. The precise determination of porion is, however, difficult owing to the fact that the superior margin of the meatus is often ill-defined, or even indeterminate. In many crania the roof of the meatus is a smooth curved surface which extends upwards and outwards to blend with the root of the zygoma and there is no bony landmark separating the two regions. Buxton and Morant[12] have therefore suggested that the superior margin of the meatus be defined by a pencil line drawn from the anterior point of the suprameatal triangle parallel to the upper border of the zygomatic arch which is continued above the auricular passage as the temporal ridge. The anterior point of the suprameatal triangle, in turn, lies on the suprameatal spine and is generally easy to locate. This pencil line is accepted by convention as the superior margin of the auditory meatus. To determine the exact position of the poria, the cranium is adjusted in the standard horizontal position in the craniophore, in such a way that the horizontal bars are in contact with points on the pencil lines. These points of contact are accepted as the poria. A short vertical pencil line is drawn above the horizontal bar of the craniophore on each side. The point of intersection of this line with the line marking the superior margin of the auditory meatus indicates the position of porion.

u. Prosthion

The most anterior point on the process between the sockets of the upper central incisor teeth is known as prosthion.

v. **Rhinion**

Rhinion is the lowest point on the internasal suture.

w. **Staphylion**

This is the point at which a line tangential to the curves in the posterior border of the palate crosses the interpalatine suture.

x. **Temporal Crest**

This is the point of greatest incurvature of the anterior bony crest formed by the attachment of the temporalis muscle. It is a point situated above and lateral to the orbital margin.

y. **Zygomaxillare** (Figs. 1 and 2)

The lowest point on the suture between the zygomatic and maxillary bones is zygomaxillare.

z **Zygion**

The point on the zygomatic arch furthest from a corresponding point on the opposite zygomatic arch in the same coronal plane is known as zygion. This point is determined not by anatomical relations, but by trial measurements of the maximum bizygomatic breadth.[10]

Superb but very expensive instrumentation is available to determine the necessary measurements for the indices listed below. A less expensive outfit which can be purchased from any hardware store, and serves the purpose, consists of the following:

1. Ruler - in centimetres
2. Tape measure - in centimetres
3. Dividers
4. Vernier Caliper
5. Large outside caliper - capable of measuring points on the skull

ASSESSMENT OF POPULATION OR RACE GROUP[10]

1. CRANIAL INDEX 100 X B/L

B = maximum cranial breadth from euryon to euryon
L = maximum cranial length from glabella to opisthocranion
Less than 74,9 (dolichocranial) negroid - long skull
75,0 - 79,9 (mesocranial) khoisanoid - mid-skull
80,0 and over (brachycranial) caucasoid, mongoloid - broad, short skull

2. CRANIAL HEIGHT INDEX 100 X H'/L

H' = basibregmatic height from basion to bregma
L = maximum cranial length from glabella to opisthocranion
Less than 69,9 (chamaecranial) khoisanoid - long skull
70,0 - 74,9 (orthocranial) negroid - mid-skull
75,0 and over (hypsicranial) caucasoid, mongoloid-High skull

3. VERTICAL INDEX 100 X H'/B

H' = basion to bregma
B = euryon to euryon
x - 91,9 tapeinocranial - low, broad skull
92,0-97,9 metriocranial-caucasoid, khoisanoid, negroid (females) - mid-skull
98,0 acrocranial-caucasoid, negroid (males) - high, narrow skull

4. TRANSVERSE FRONTO-PARIETAL INDEX 100 x B'/B

B' = temporal crest to temporal crest
B = euryon to euryon
less than - 6519 stenometopic - narrow
66,0 - 68,9 metriometopic, khoisanoid - mid more than - 69,0 eurymetopic - negroid, caucasoid, mongoloid - broad

5. OCCIPITAL SAGITTAL CHORD ARC INDEX 100 x S' 3/S3

S'3 = occipital sagittal chord from lambda to opisthion
S 3 = occipital sagittal arc from lambda to opisthion
Up to 81,9 (strong occipital curvature) khoisanoid
82,0 - 83,5 (marked occipital curvature) khoisanoid

83,5 - 85,0 (moderate occipital curvature) negroid
85,0 and above (slight occipital curvature) caucasoid

6. FORAMEN MAGNUM INDEX 100 X fmb/fml

fmb = breadth of foramen magnum measured at right angles to length
fml = length of foramen magnum from basion to opisthion
81,9 (Dolichotrematous) negroid, caucasoid (northern) - long
82,0 - 85,9 (mesotrematous) - mid
86,0 and above (brachytrematous) khoisanoid, caucasoid (central) - broad

7. UPPER FACIAL INDEX 100 x G'H/J

G'H = nasion to alveolare
J = zygion to zygion
Up to 44,9 (euryene) khoisanoid - broad upper face
45 - 54,9 (mesene) negroid - mid-upper face
55,0 = and above (leptene) caucasoid - narrow upper face

8. GNATHIC INDEX 100 x GL/LB

GL = alveolare to basion
LB = nasion to basion
Up to 97,9 (orthognathic) khoisanoid, caucasoid - straight profile
98,0 - 102,9 (mesognathic) negroid - mid-profile
103,0 and above (prognathic) negroid - protrusive profile

9. ORBITAL INDEX 100 x 02/01

02 = Maximum height taken at right angles to 01
01 = dacryon to lateral margin of orbit, parallel with the upper and lower orbital margins
less than 75,0 chamaeconch. khoisanoid - low orbit
76,0 - 84,9 mesoconch - mid-orbit
85,0 and above hypsiconch-caucasoid, negroid, mongoloid - high orbit

10. NASAL INDEX 100 x NB/NH

NB = greatest breadth of nasal aperture
NH = nasion to nariale

Up to 46,9 (leptorrhine) caucasoid - narrow
47,0 - 50,9 (megorrhine) caucasoid - mid
51,0 and above (platyrrhine) khoisanoid, negroid wide

11. PALATAL INDEX 100 x G' 2/G' 1

G'2 = palatal breadth between two endomolaria
G'1 = palatal length. Orale to Staphylion
Up to 79,9 (leptostaphyline) negroid, caucasoid long narrow palate
80,0 - 84,9 (mesostaphyline) caucasoid - midpalate
85,0 and above (brachystaphyline) khoisanoid short, broad palate[10]

Usually the indices are predominantly either caucasoid, negroid, mongoloid or khoisanoid in character.

CONCLUSION

Biggerstaff[4] states that the bones and teeth of the human skull can reveal numerous morphological traits useful in human identification. Skilled data acquisition and interpretation are mandatory to avoid obvious pitfalls and one cannot interpret the morphology of a trait without understanding origin and mode of growth.[4]

With the criteria as set out for **age** determination even dental traits must be interpreted with caution.[4] The non-materical techniques for **sex** assessment and the metrical techniques outlined for **race** determination enable the forensic odontologist to complete the investigation of skeletal remains of the cranium and mandible in an orderly and methodical manner.

The services of recognised experts in physical anthropology are not always readily available in all centres and the forensic odontologist is frequently called upon to give an opinion.

This simple hands-on guide will serve as a useful starting point for the forensic odontologist confronted with skeletal skull remains. Standard and more voluminous texts and reference works on archaelogy and anthropology should be consulted.

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SOME LEGAL ASPECTS OF MASS DISASTERS

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All states have absolute sovereignty over their territories, including their sea and airspace. Thus they have the legal right to act whenever the law is broken within their jurisdiction. There are situations, however, when national interest may be superceded by international interests, such as environmental problems, commerce, trade, international finance, sea navigation and flight. Circumstances like these are usually covered by international law and may be negotiated within bodies such as the United Nations and the European Community. At the other end of the scale two countries may negotiate bilateral agreements.

In most cases, although conventions lay down rules for cooperation between the signatories, they do not stop problems of enforcement from arising, nor do they suggest ways in which conflicts shall be resolved. Usually recourse is made to diplomatic negotiation, or mediation by an international body. In aviation this task is often performed by the council of the International Civil Aviation Organisation and appeals against their decisions may be heard by an arbitration tribunal (commission "ad hoc") or the International Court of Justice. Theoretically, if both parties have ratified a convention, then the only problem which ought to arise should be one of interpretation and this is quite different from the situation between non-contracting States.

It has to be remembered, however, that states cannot be forced to join or adopt an existing agreement and even where these do exist enforcement of their tenets is not absolutely certain. There is no international tribunal in existance which enjoys power over all states. Even the International Court of Justice can only act if the conflicting states agree to accept its jurisdiction, and only states can bring a case before the Court. Therefore, whenever a legal problem arises, the basis of the national law involved and the requirements of existing international agreements have to be considered. In

aviation there are other problems to contend with, such as the question of civil or military flight, domestic or international flight and involvement of civil or criminal law.

Civil aviation is less than 70 years old, but during this relatively short period technological advances have proceeded with considerable pace. Passenger carrying airliners can travel at Mach 2 with an international complement to every country of the world. Air accidents and aeronautical law are not thus a purely domestic national matter and they are governed by international regulations, conventions and protocols.

The forensic pathologist and odontologist may have an important role to play in litigation following mass disasters involving aircraft and they would be well advised to recognise this fact when they are called upon to carry out investigations into these accidents. During the last 25 years more than 30000 people have been killed in accidents throughout the world, and many others have been injured. Each year there are an average of 60 accidents of which 35 are non-survivable. However about 30% of those involved in a fatal accident will survive.

PART 1

GENERAL PRINCIPLE OF CIVIL AVIATION AND INTERNATIONAL LAW

1. The Operational Sphere of the International Civil Aviation organisation (ICAO) and the International Air Transport Association (IATA).

a. ICAO

This was established in 1947 to promote the safety and efficiency of civil aviation and is empowered to make binding rules covering flights over the high seas. Most of its functions are accomplished by the council as the general assembly meets only once every 3 years. Since its inception ICAO has made a considerable contribution to air safety, particularly insofar as the provision of navigational aids is concerned. ICAO headquarters is situated in Montreal.

b. IATA

At the end of the second world war this non-governmental association was established at a meeting in Havana. It too is based in Montreal. Much of IATA's activity is concerned with resolving problems related to tariffs, the commercial cooperation between companies and other similar activities. Conferences are organised by the various sections at which relevant topics are discussed.

c. Institut du Transport Aérien

This was established in Paris in 1954, its objectives being to study and promote research into the economic, political and technological aspects of aviation.

d. The International Technical Committee of Legal Experts (CITEJA)

This subdivision of the International Chamber of Commerce meets regularly to look at the problems concerning the liabilities of air-carriers .

e. The Air Law Committee of the International Law Association

Codification of international air law is this body's principle concern and because it is an independent, apolitical body, it enjoys great respect and influence.

f. The International Federation of Airline Pilots' Associations (IFALPA) represents the majority of pilots and is a very powerful body able to influence international opinion at will.

2. Freedom of the Air
(Article 1 Section 1 - The International Air Transport Agreement Chicago / Dec 1944)

Signatories to this agreement have a duty to tolerate the peaceful passage of aircraft on scheduled or unscheduled flights over their territories and to permit them to land for technical reasons. They must also allow them to carry passengers, mail and cargo from one state to another, and to return to their own country. They are regulated by bilateral regulations covering landing rights, landing sites, the authorisation of airlines and the scope of the service.

3. International versus National Flights
(Article 1, Section 2 Warsaw convention, Hague Protocol)

A flight is considered to be international if the place of departure and the place of destination, whether or not there be a break in the carriage or a trans-shipment, are situated either within the territories of two contracting parties or within the territory of another state, even if that state is not a contracting party. In any other case/event the flight is only domestic (or national).

4. National Regulations

Every state remains responsible for the good functioning of air transport at and over its territory. National regulations are enacted according to internationally required standards and are enforced by organisations established for that purpose and which can be independent bodies (e.g. the Civil Aviation Board (USA), the British Aviation Authority) or departments of the Ministry of Transport (France, Belgium and others).

These national regulations deal mainly with the administrative organisation of air transport and thus differ from one country to another. For strictly national (domestic) flights the national law and also the general rules of Law are the ones that have to be applied. This therefore influences the field of liability . In common Law countries delictual liability (tort) is applied, where in civil Law countries contractual liability prevails. States can by Law or decree limit liability by adopting the limits of the Warsaw Convention or the Hague Protocol or by fixing their own limit (UK). Other states do not establish any limitation of claims on domestic flights (USA,CANADA).

5. The Chicago Convention, 7 December 1944

It was very early realised that civil aviation had to be regulated internationally. The first air convention was conducted in 1919 in Paris and it served as a basis for the Chicago Convention after World War 2. The Chicago Convention lays down some very important aeronautical principles concerning the safety and organization of civil aviation with the purpose of establishing international air transport services between countries on a basis of equality, opportunity, sound operation and economic viability (preamble of the convention).

The Convention consists of 4 parts : the air navigator, the ICAO, International Air Transport and Final Provisions. In part 1 the general principles and applications of the convention are laid down, such as the recognition of state

sovereignty, the limitation of the convention to civil aviation, the right of overflight for non-scheduled flights, prohibited areas, the rules of the air, the right of search of an aircraft, the registration and nationality of the aircraft and measures to facilitate air navigation.

Art.26 deals with the investigation of accidents and is of interest to the forensic pathologist and odontologist, namely, " In the event of an accident to an aircraft of a contracted state, and involving death or serious injury ..., the State in which the accident occurs will institute an inquiry into *the circumstances of the accident,* in accordance, so far as its laws permit, with the procedure which may be recommended by the ICAO."

"The state in which the aircraft is registered shall be given the opportunity to appoint OBSERVERS to be present at the inquiry and the state holding the inquiry shall communicate the report and the findings in the matter to that state."

This article deals with the INVESTIGATION INTO THE CIRCUMSTANCES OF THE ACCIDENT but it does not literally include a reference to the identification procedure as such.

The council of the ICAO RECOMMENDS in Annex 13 the "standards and recommended practices for an aircraft accident inquiry" and the procedure to be followed by the contracting states in that event.

States may, however, in accordance with article 38, deviate from any provision of Annex 13 if they notify the council of the ICAO of differences between their own practice and that established by the international standard.

An ACCIDENT is defined therein as "an occurrence associated with the operation of an aircraft which takes place between the time of boarding the aircraft with the intention to flight, until the time of disembarking in which :

a. a person is fatally or seriously injured as a result of being in or upon the aircraft or by direct contact with the aircraft or any thing attached thereto,

b. the aircraft incurs damage or structural failure which adversely affects the structural strength, performance or flight characteristics of the aircraft and which would normally require major repair or replacement of the affected component.

Excluded from a. are

- death from *natural causes*
- death or injury *self-inflicted or inflicted by another person*
- *ground personnel* before or after flight
- death or injury *not directly a result of the operation of the aircraft*
- stowaways

The Chicago Convention is ratified by a large number of countries and the contracting states are more or less bound by it. *Annex 13 is only a recommendation.*

Part 2 deals with ICAO, its organisation, competencies, powers and duties.

In part 4 the Convention provides for the resolution of disputes and disagreements over the interpretation or application of the Convention. The resolution of disputes shall be settled through bilateral negotiations in the first place. If a disagreement cannot be settled by negotiation then it shall be decided by the ICAO council. Any state may appeal from there to an "ad hoc" arbitration tribunal agreed upon with the other parties to the dispute or to the International Court of Justice. The decisions of the appeal are final and binding.

PART 2

THE AIR-CARRIER'S LIABILITY

The Warsaw Convention was adopted on October 12, 1929. Because of dissatisfaction and changing circumstances it was amended by the Hague protocol in 1955, but it is only binding upon its signatories. Subsequently the Guadalajara Convention of 1961 was added (it resulted from political and technical reasons, namely the status of the contracting and the actual carrier, lessor/lessee relations, and is a supplementary feature only).

Essentially, the Warsaw Convention is concerned with the aircarrier's liability and the regulation of claims. It is limited to commercial aviation, both private and international.

The Warsaw Convention covers and is limited to all *international and civil* flights from one contracting state to another even if the different stages are completed by different companies (state companies as well as private companies). NOT COVERED are domestic, military, police or custom flights.

The employees of the carrier (pilot, agent, hostess) are not covered by the Convention but rather by their contracts of employment (unless they are travelling and not on duty).

Liability is based upon presumed fault, the burden of proof being the carrier's responsibility. All that a passenger has to prove is that the injury or damage occurred during the flight.

Articles 17 and 18 deal with the liability of the carrier for death and injury and damage to goods and baggage. Damage sustained in consequence of delay is also charged to the carrier's account unless he can prove "force majeure" (art.19). There is reduced or no liability of the carrier if the injury or harm was self-inflicted by the victim.

Liability is limited to certain maxima. Initially the limit was set at 125000 gold francs for death and injury (Warsaw Convention) but later raised to 250000 gold francs (Hague protocol) (1 gold franc = 65.5 mg of 90 % pure gold). These gold francs are converted into national currencies on the day of the verdict.

The USA denounced the Warsaw convention in 1965 because it considered the limits to be unsatisfactory and it adopted a regulation for its own carriers. This Montreal Inter-Carrier Agreement (CAB 18900) which is not a convention between governments but an agreement between air carriers was signed on 4 May 1966. It increased the limit of liability to 58000 US $ (or 75000 US $ legal fees included) if there was a start, departure or a stopping place in the USA. ICAO tried to coordinate and reunify international regulations with the Guatemala Protocol in 1971, and the 4 Montreal Protocols of 1975, but so far without success.

Limitation can be avoided if the plaintiff can prove that the accident was caused by wilful misconduct of the carrier or his representative or if the board documents (ticket or baggage ticket) do not mention that Warsaw or another convention is applicable. There is some doubt as to what constitutes wilful misconduct but it indicates a deliberate act, with intent to cause

damage, or reckless act without regard to the consequences. If the Guatemala Convention is adopted, the carrier will not be liable if the death or injuries are the result of a pre-existing pathological condition of the victim (modification of the WC/HP). This matter will mostly be dealt with by the national legislation of the state that has to handle the case.

The carrier cannot in any way exonerate, exclude or reduce beforehand its liability in this matter, which, in practical terms means that in virtually all carriage conducted by major international scheduled or chartered airlines the victims of an accident and their dependents can recover compensation from the carrier merely on proof that the victim was on the aircraft.

The maximum that can be recovered will vary according to the journey but will not be less than 125000 gold francs (10000 US $) and in some cases might even be as high as 75000 US $.

PRESENT LIABILITY OF AIRCARRIERS FOR DEATH AND INJURY

Warsaw Convention	10000 US $
Hague Protocol	20000 US $
CAB 18900	75000 US $ - legal fee included or 58000 US $ - legal fee not included
MALTA agreement	58000 US $ - agreement between most European companies whether or not their routes touch the USA
Guatemala Protocol	120000 US $
Montreal Protocols	100000 SDR (special drawing rights) - special basket composed of the most important currencies of the IMF

Liability limits under the different conventions for damages or loss of property (goods).

Warsaw Convention Hague Protocol	Checked baggage 250 gold francs / kg or 5000 gold francs / passenger
Guatemala Protocol Montreal Protocol	Checked baggage 15000 gold francs / passenger or 1000 SDR

DEPENDENCY CLAIMS

These prove to be unfair to some people, as a plaintiff's claim against the carrier in a case of international carriage to which the Warsaw Convention applies, is limited to 10000 or 20000 US $.

A widow whose husband is killed in a flight abroad under the CAB18900 agreement with a dependency claim of 50000 US $ will be paid in full. However a widow with a husband on the same flight but with a dependency claim of 200000 US $ will receive only 58000 US $.

To increase the claim the plaintiff must prove under article 25 of the Warsaw Convention that : "The damage resulted from an act or omission of the carrier, his servants or agents - done with the intent to cause damage or recklessly and with knowledge that damage would probably result."

This is a formidable task and even if settlements over the limit have been achieved there is little likelihood of persuading the insurers to pay over the limit unless the carrier has been previously criticised in the report of the official enquiry.

Before recovering even the lowest figure the plaintiff must overcome the defence available to the carrier under article 20 of the Warsaw Convention. That is to say, the carrier is not liable if he can prove that he has taken all necessary measures to avoid the damage, or it was impossible for him to take such measures.

If the plaintiff recovers, having beaten article 20 he will now have some funds with which to proceed further, perhaps against defendants other than the carrier. It is only the carrier who is protected by the Convention but claims have been made against aircraft designers, manufacturers and others.

LIABILITY INSURANCE

To be able to pay those claims for damages under the different conventions in case of an accident, the air-carriers have concluded insurance policies which cover claims up to 500 or 600 million US $ per accident, per aircraft.

There are no exact international rules for the quantification of damage to or loss of property nor for the extent of physical injuries because they differ from one country to another. In fact the aftermath of recent airline crashes has been characterised in some instances by unprecedented claims for damage, reflecting in some ways the lack of guidelines and a tendency to ignore earlier agreements.

This has created an emotional and legal jungle for plaintiffs who may be approached by representatives of lawyers in the early post-crash period with offers of assistance in pursuing claims. That is to say the contingency fee system which has become accepted practice among American lawyers when representing plaintiffs who would be unable to pay the fees unless they were successful.

This situation has arisen because of dissatisfaction with the Warsaw Convention and in some cases a desire to seek a positive award. All over the world plaintiffs try to set aside the limited liability of the conventions and are therefore looking to other parties, such as the aircraft designers, the manufacturers of precision navigation instruments (on a basis of "product liability"), the airport authorities, traffic controllers ("professional liability") or others, which they can hold responsible for the accident. None of them has the possibility of hiding behind any of the international conventions.

That the sums paid out to the relatives of victims of mass disasters are not always limited to those provided by the conventions is shown in the following table :

TURKISH AIRLINES	DC 10	March 1974	Paris	$US200000 / passenger paid by Turkish Airlines, Mc Donald Douglas General Electric.
PANAM	747	27 March 1977	Tenerife	
KLM	747			112000 US $ / passenger

American AIRLINES DC 10 25 May 1979 Chicago
450000 US $
none of the conventions was applicable because it was a DOMESTIC flight

IMEX ADRA Co DC 9 10 Sept 1976 Zagreb
BRITISH AIRWAYS Trident
IAC - 3.7 million D-mark between 108 passengers
= ± 20000 US $/passenger
BA - 1.8 million £ between 54 passengers
= ± 58000 US $/passenger

This is an example of different sums paid out in the same accident. Attempts to obtain more by implicating the aircontrol system and the Yugoslav government have so far failed.

"Which court = competency ratione loci" - before which court and country ~hall a claim be introduced

Normally the victims (or their relatives) can choose the court before which to bring their claim for damages. The only limitation is that it has to be done before a period of 2 years has elapsed since the day of the accident and, if the Guatemala Convention is applicable, that the courts of a contracting state will be competent only if the carrier has an establishment in that state.

Which company will be liable if there is only one contract and several carriers ?

In this case the carrier that has effectively performed the transfer will be held liable for injuries to a passenger and in the case of loss or damage to baggage, all the carriers will be held liable in solidum

THE ABSENTEE OR THE MISSING PERSON - Legal consequences

An absentee is a person who has left home without notice and it is uncertain whether he is dead or alive.

A missing person is a person who has died but his body has not been found. His death is presumed because of the circumstances which include war, calamities or mass disasters.

Most governments have created a legal statute covering the absentee, but surprisingly this has not been done for missing persons. There is a difference in the legal statutes of both categories which influences the legal consequences, especially those which are related to marriage, the goods of the disappeared and the legal position of the children.

In the case of the absentee a declaration of absence will usually be made by court decision or sometimes through an administrative procedure. The delays before such a declaration can be obtained differ from one state to another. The declaration of absence does not mean that the marriage is dissolved and remarriage impossible. Sometimes a curator will be appointed to manage the goods of the absentee or the court will permit the surviving partner to take over.

A declaration of death can be obtained through a court decision in some countries and is much more decisive and final. From that moment the marriage is dissolved and the partner can conclude a new marriage.

Special national laws exist in most states to regulate the status of those who disappeared during the great World Wars but these regulations where mostly limited to soldiers or prisoners of war and not civilians. For example, the convention of Lake Success 6 April 1950 - about missing persons from World War 2 was primarily meant for Jewish people.

The International Commission for Registration Services *("La Commission Internationale de l'Etat Civil")* headquarted in Geneva, proposed a convention in Athens on 14 September 1966 which was concluded between European states only and as yet only ratified by a small number of countries - Netherlands, Turkey, Greece. According to article 1 each jurisdiction or administrative authority can deliver a declaration of death every time that a body of a missing person cannot be found whilst the circumstances are such that his death is certain beyond all reasonable doubt.

Such a declaration of death is delivered in the following cases:

1. The disappearance takes place in the territory of the contracting state or during a journey by ship or aircraft of that state.
2. If the disappeared person is a citizen of that state or has his residence in the territory of that state.

According to article 2 of this convention a declaration of death can also be delivered in the same conditions as mentioned in article 1 if the accident

occurs outside the territory of the contracting state when no such act is delivered by the state in which the accident took place.

A comparative legal review of some European legislations with regard to the delivery of a declaration of death

Germany and Austria:

1 year after the conclusion of peace/end of the war
6 months after a disaster at sea
3 months after a disaster involving an aircraft

Netherlands :

1 year in case of disaster at sea or aircraft accident
3 years after war or calamity
5 years after any other disappearance

Belgium and France:

no specific regulation the courts can deliver a special act of decease but the procedure is expensive and long and there is no legal basis for it.

Italy:

2 years after disaster at sea or aircraft accident or end of war / conclusion of peace

Sweden :

usually not before 10 years have elapsed
(3 years if the disappeared is more than 75 years old)
1 year if the missing person was in apparent danger of death at the moment of disappearance

It is worth mentioning that private international law of individual countries in matters of absence and declaration of death raises problems of choice of law, of jurisdiction and of the recognition of foreign declarations of death.

THE COMMORIENTES LEGISLATION IN DIFFERENT STATES

Ever since Roman times, it has been a problem to solve the question of survivorship when 2 related persons die in the same accident at the same time. In practice this is only of importance where questions of succession and insurance are involved and it is sometimes possible for the forensic odontologist or pathologist to find evidence that proves that one person definitely survived the other; often it is impossible.

The legal consequences in most westeuropean countries are that if two people of the same family die in the same accident, they are presumed to have died together at the same time, unless it can be proven that one survived the other.

U.K. - Australia

The younger survives the older, unless proved to the contrary.

France:

If both are < 15 years the older survives the younger > 60 years the younger survives the older

If one is < 15 and the other > 60 the 15 year-old survives the 60 year-old person

From 15 - 60 years and in the same age or with a difference of less than one year the man survives the woman.

while if from the same gender the younger survives the older

Scotland:

Spouses are presumed to have died at the same time and in all other situations , younger survives the older

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INTRAORAL MICRO-IDENTIFICATION DISCS

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Abstract

Intraoral micro-identification discs have recently been utilized to provide a more permanent method of personal identification. A wafer of plastic or metal with a surface area of 2.5 to 5 mm^2 and carrying identifying numbers and/or letters (indicia) is bonded to the buccal enamel surface of the posterior teeth. Personal identification can occur after the I.D. disc is identified and the indicia is read. Reading of photoreduced indicia requires the aid of a microscope subsequent to the removal of the microdisc. *In situ* reading of disc indicia is possible using low power handheld magnifiers if the size of the indicia approximates 0. 3mm.

Computerization is an integral part of non-custom alpha/numeric type designs, but a custom disc carries a name, address, and other specific information unique to the manufacturer. The use of a computer improves access to the database and it decreases the amount of data placed on the disc. Microdisc bases may be fabricated using a mylar type plastic or they may be manufactured from a stainless steel blank. Plastic discs are constructed with an internal sandwich containing the photo-reduced indicia. Metal discs are marked with a photochemical etch or engraved with a computer driven YAG laser. Attachment of the disc to the enamel surface is accomplished by conventional etching and bonding techniques and are typically bonded to the buccal surface of the maxillary first permanent molar or the second primary

molar. Clear composite bonding material covers the disc so that salivary contamination does not result in degradation of the indicia. Orthodontic style discs with a mesh back carry laser written information that may be cemented with conventional orthodontic bonding cement. Standardization of the indicia and overall design is considered to be an important aspect of patient and professional acceptance.

Key Words

Intraoral, Microdisc, Bonding,

Introduction

Personal identification in various forms has interested mankind for centuries. Early man dressed in a distinctive fashion which was a primitive form of identification and now documents to confirm identity are often requested in daily activity and take the form of licences, credit cards, membership cards or specific legal documents. The business activity of many citizens is also monitored by both state and federal governments under statutes which direct the acquisition of various identification numbers so that employers may conduct business in conformity with the law. Identification is accepted as an important social requirement by most citizens of our country.

The use of an enamel bonded intraoral microdisc as a method of person identification was suggested in 1983 as an improvement over more conventional identification systems.[1] Previous to that date intraoral identification was achieved by embedding information under a dental restoration[2,4] or by placement in a prosthetic device.[3] When enamel etching and bonding became commonplace, the permanent fixation of an identification device became a logical development of identification technology. The application of information to the microdisc can be achieved with the use of optical photo-reduction systems or by computer-driven lasers. Photographic image reduction or chemical engraving is a relatively old technique and the industrial use of these techniques is widespread. Laser application of characters with a dimension less than 0.1 mm is a recent improvement brought about by combining laser and microcomputer. This lack of uniformity has created a need to standardize the technical and clinical details before acceptance by the profession and public can be achieved. The social implications of permanently fixed micro-identification discs has received little attention and this should be a concern in the related disciplines.

An intraoral system of identification is an addition to existing identification procedures. It involves a technique of miniaturization which complicates indicia retrieval, but allows the disc to be placed in a secure location with favourable aesthetics. This new technology must also provide practicability, safety and near universal acceptance by the profession and the public before the bonded intraoral microdisc is routinely utilized.

The need for a permanently fixed type of personal identification has been expressed by professionals who deal with the recovery of lost, abducted or runaway children and adults. Numerous agencies have attempted to quantify the number of individuals in each of these categories, but the reporting methods lack uniformity and this often results in inaccuracies.

Intraoral micro-identification is also applicable in the recovery of the mentally ill or elderly persons who stray from their homes. Permanent identification is perceived by many health care workers as essential and some believe that large numbers of "at risk" individuals will bear some kind of identification tag that cannot easily be lost or set aside. Many young and old alike wear their name, address and phone number engraved on a plate of stainless steel attached to a wrist chain. Although even a removable ID system has value, a fixed system has obvious benefits.

Recent Development

When enamel etching and bonding became prevalent, the possibility of applying this technology to fixing the carrier in a non-invasive manner directly to the enamel surface was considered. This resulted in the trial of several designs and developments in this field over the past three years indicate that intraoral identification is a viable alternative to many other methods of identification such as fingerprinting, photographs, dental charts, dental radiographs, I.D. cards, driver's licence, wrist I.D., wax bites, plaster models, videotapes and military "dog tags".

Patent Awards

Several patents have been awarded since the early 1980's and others are pending, which limits the availability of information. There has also been at least one patent infringement suit which has also delayed introduction of the intraorally cemented microidentification disc.

One of the earliest identification systems placed in a single tooth was developed by Samis in 1977.[2] His device consisted of an identification wafer under a dental restoration with a a vertical post inserted with it to assist in locating the disc. The lack of an external marker meant that a radiograph had to establish the presence of the marker pin and identification depended on the removal of the overlying restoration. The purpose of the device was chiefly forensic, and it was manufactured of a ceramic material designed to withstand the severe heat and trauma occurring in certain mass disasters. The procedure is invasive and this fact plays an important role in current patent litigation since recent patent awards recognize the major difference between invasive and non-invasive disc placement.

In 1984, Mayclin[3] patented an identification system for use with a removable dental prosthesis. The carrier is clear plastic with typewritten or hand lettered indicia. Heating the carrier will cause it to shrink thus reducing the total size of the carrier and the indicia. The carrier may then be inserted into a slot prepared in a denture. This identification system is available from dental laboratories upon request or as mandated by legislation in some states. The Exact-I-Dent carries the first patent for a microdisc that is noninvasive in nature.[1] This disc incorporates a thin stainless steel base material with ten photo engraved characters which is embedded in clear composite bonding material at the time of insertion.

Review of the literature

The Swiss identification system was reported by Muhlemann, Steiner and Brandestini.[4] This system consists of an encoded information chip sealed within the enamel of the tooth with a fire-resistant filling of coloured composite material. The characters are engraved as a series of dots on a gold disk that has a diameter of 2.0 mm. The need to improve the speed and reliability of forensic procedures by using dental evidence was emphasized by Scholle[5] who noted that 40,000 unsolved cases of missing persons and 2,000 to 10,000 unidentified dead bodies requires that "we computerize dental evidence for expeditious retrieval". His editorial addressed the need for precise identification methods by outlining the size of the problem and the nature of the identification process as currently managed by various federal and state authorities. He concludes that the "potential public and professional benefits of the American Dental Information Registry (ADIR) would act as the rallying point for American dentists and those seeking to identify or locate thousands of persons into a working unit". The extent of our nation's missing persons is discussed and a case is included by

Bernstein[6] in a report of the procedure used in the identification of a decomposed body found 1,400 miles from its last known location. Subtle dental and anthropologic peculiarities identified on antemortem radiographs made three years earlier are reported. The use of the computer to store and retrieve dental information in the military services has also been considered as a reliable method to identify field casualties.[7] In this instance the precise location of each oral restoration is computerized for subsequent retrieval using relational database software.

The durability of a plastic carrier has not been studied and a lack of resistance to the heat generated by many mass disasters could lead to the microdisc being destroyed by incineration or the reliability of the inscribed characters compromised.[8] In the case of ceramic devices however, the heat resistance would be assured. The analysis of dental materials found at crash sites can aid in the identification of military personnel subsequent to aircraft accidents.[9] The severe violence and trauma found in aircraft disasters often makes the identification of passengers and crew difficult and the forensic dental team has a substantial role to play. In such cases Morlang[10] suggests that "time can be saved...if the dental section provides a name discovered on a dental microdot". The technology could furthermore be useful in tracking the estimated 1.5 million children who have been reported missing by the National Center for Missing and Exploited Children. The continuing large number of deceased in the United States is typified in a survey which estimates 1,450 to 2,000 bodies could not be identified during 1979.[11] Microdisc systems are reviewed by Wilson[12], who concludes that computerized disc technology has the potential of resolving the identification of thousands of anonymous bodies.

Identification by microdisc is believed by some to have social value in addition to its forensic usefulness and the suggestion that it is just another gimmick is rejected by Sperber[13] who believes that the microdisc has valuable forensic application with appropriate cost effectiveness. He also notes that variation in disc design potentially complicates identification procedures and this may militate against universal acceptance. Another method of identification is the wax bite wafer.[14] In this procedure the contoured laminate wax bite wafer is used to register tooth size, tooth position and jaw relationships as an aid to identification. The "Toothprint" system has limitations insofar as there needs to be an existing record of dental characteristics of a missing person for comparison using validated forensic techniques. This "indirect" identification technique obviously has disadvantages when compared to a more "direct" one, namely, micro-identification.

A micro-identification disc inscribed with the name of the person (or his identifying alpha-numeric characters) and attached to a posterior tooth would be considered "direct" evidence of identity, since the name of the bearer or his registered number can be read directly. An identification made on the spot is clearly more desirable and should not be overlooked when comparing systems that in other respects seem to be identical.

The large number of children who are caries free and who possess an intact dentition attests to the need for a system that is not based on dental restorations or missing teeth. Primary dentitions are often remarkably alike and some system other than direct comparison of plaster casts will be required to establish a positive identification. Microidentification systems assist in establishing positive identification indirectly when a number is matched to number held in a central repository or when the name is read and further examination is required only for indicia corroboration.

The American Dental Association Identification Project

After the first accounts of a proposed ADA identification project appeared in the ADA NEWS, the Association received several hundred inquiries requesting further information.[15] The subsequent interest of the dental profession in the ADA project to promote identification was reported to be ''overwhelming''.[16] The Association proposed that the system be named the "American Dental Identification Registry (ADIR) and suggested that the ADA would develop a standardized specification and processing method for the microdisc. Their proposal requested that the microdisc contain a unique patient identification number that would be assigned to the treating dentist and that the ADA would install a telephone hotline in their Chicago office. They further added that "as the dental health of the nation continues to improve, people are becoming less likely to have fillings and other distinguishing marks which serve as a basis for identification through dental records".[16]

In a later edition of the ADA News, criticism of "the potential profiteering" was expressed by members in its Letters to the Editor. The Secretary of the Council of Dental Practice however wrote that the ADA "is responding to the high level of concern expressed by the membership (and it) presents a unique opportunity for the ADA to meet its overall responsibility to encourage the improvement of the health of the public''[17]

After months of work the ADA News reported in March of 1986 that because of possible patent and licensing problems the microdisc project had been cancelled, but ADA Executive Director Thomas Ginley said that "the Association continues its strong support for the concept of microdisc identification". The Exact-I-Dent corporation was reported by the ADA News as unwilling to grant a nonexclusive long-term licence to the ADA or any other group, owing to unrevealed business plans and projections.[17]

Standardization

From the outset the ADA sought standardization of the indicia on microdiscs. The various numbering systems did not lend themselves to a universal method of identification and the ADA believed that a universal system was desirable. At the present time two systems of marking are utilized. They consist of either a "custom" disc enscribed with personal data (Figs.2,3,4) or a "non-custom" disk with alpha-numerics and/or numerics (Figs. 1,5,6). The ADA disk was conceived as a numeric disc (Fig. 3) but others utilize a custom unit with the personal data as selected by the patient. Some disc designs incorporate a telephone number for access to additional information stored in a computer, but some disc manufacturers omit this feature (Figs. 3,5,6). Standardization has proved an elusive target and there is no active effort on the part of manufacturers or the profession to standardize the indicia or the base material. Some characteristics are shared by all discs, but every wafer has a unique design. The difference of the base materials, the general shapes, indicia types, overall sizes, numbers of characters, and base thicknesses of several microdiscs may be compared in Table 1.

The Role of Computerization

The development of the microdisc has been rapid, spurred on by the concern of special interest groups, the success of enamel bonding and the low cost of computer memory. The computer plays a major role in this triad since large numbers of patients may be recorded for retrieval by software that has a relational capability. If database fields are independently programmed, the patient can be identified using any one of perhaps fifteen fields. The computer can also play a primary role engraving the disc if the indicia is not "custom" written for each patient and can generate the alpha-numeric indicia automatically reducing the unit cost substantially. Some forensic authorities are convinced that the indicia must contain an imbedded check digit to minimize the possibility of fraudulent duplication of the codes. Computers will function admirably since they can generate random check digits that defy counterfeiting.

Indicia Management

The use of a social security number as the only indicia necessitates customizing the disc and access to the number from the Social Security Administration (Fig. 3). The placement of less than fifteen characters on the disc allows a reduction in the size of the disc or alternatively, the indicia may be applied in a larger size format. When sixty or more characters are placed on a 2 to 3 mm diameter disk, the characters will be unreadable unless high magnification facilities are available (Figs. 2,4). It will be possible to read the same sized disc with fewer digits at lower magnification.
The pure numeric system as advocated by one manufacturer includes a numeric redundancy, so that loss of one or more characters does not render the disk useless (Fig. 1). This system and others can include complex numbers which contain codes to identify medical and other conditions, so much so that some investigators regard the primary purpose of identification as being overshadowed. If this were to happen the disc will require more extensive development and require the input of a variety of disciplines.

Mathematics of Indicia Management

One of the positive aspects of a combined letters/digits code is the vast number of possible configurations. If certain elements are discarded to minimize reading error approximately thirty characters remain. If the microdisc were to contain only eight spaces where either a digit or a letter could be used, the total possible combinations could be 30^8 or 6.56×10^{11}, sufficient to codify every person on earth. Additional digits could be included to serve other functions as required from time to time or the eight spaces could be reduced to six, resulting in 729 million possible combinations.

Base Material

The base material in current use is either stainless steel or plastic. Plastic or mylar bases carry photo-reduced indicia for embedding into clear resin which is then hardened by light or chemical polymerization. Since the marking system relies on silver sensitive salts and a photo-reduction technique to create the characters, the mylar material must be sealed within the resin capsule to prevent the ingress of oral fluids. When moisture contamination of the indicia occurs the photographic image will quickly become unreadable. Moisture contamination of the etched enamel prior to

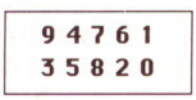

Figure 1

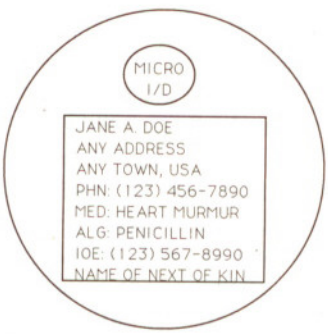

Figure 2

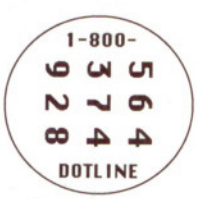

Figure 3

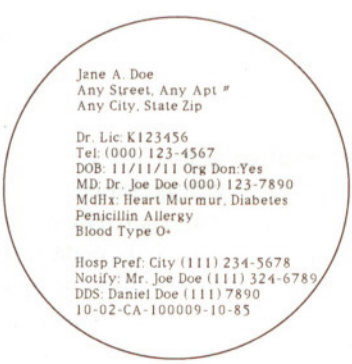

Figure 4

Figure 5

Figure 6

Figure 1. The indicia format of the Exact-I-Dent microdisc. The base material is soft stainless steel with chemically etched numeric data. Disc dimension = 2 x 3 mm.

Figure 2. The format of the custom fabricated plastic Micro I/D microdisc. Disc dimension = 2.6 mm.

Figure 3. The VD dot plastic disc with a social security number placed in a "three by three" format. The 1-800 DOTLINE is the telephone number that is used to access the firm. Disc diameter= 3.2 mm.

Figure 4. The Ident microdisc fabricated in blue plastic. Disc dimension = 2.3 mm.

Figure 5. The Codent microdisc fabricated on an orthodontic stainless pad with a mesh back. The access telephone number and an alpha/numeric code is engraved on the surface. Disc dimension = 2.4 x 3.8 mm.

Figure 6. The Codent Weld microdisc. The "ears" can be utilized to weld the microdot to orthodontic bands or to stainless steel crowns. Disc dimension = 2.4 x 6.5 mm.

Table 1

A Comparison of the Characteristics of Six Intraoral Bonded Microdiscs

	Exact-I-Dent*	Micro I/D#	I/D Dot •	Indent ø	Codent ¶	Codent Weld ¶
Base Material	Stainless Steel	Clear Plastic	Clear Plastic	Blue Plastic	Stainless Steel	Stainless Steel
Shape	Rectangular	Round	Round	Round	Pentagonal	Pentagonal
Indicia	Photo Engraved	Photo Reduced	Photo Reduced	Photo Reduced	Laser Engraved	Laser Engraved
Size	2x3mm	2.6mm	3.2mm	2.3mm	3.8x2.4mm	6.5x2.4mm
Characters	10	150	30	250	20	20
Base Thickness	< 0.1 mm	0.3 mm	0.3 mm	0.2 mm	0.4 mm	0.4 mm

* Exact-I-Dent, 9662 S. State, Sandy, UT 84070.
\# Micro I/D, 216 NE Perry Avenue, Peoria, IL 61651*.
• I/D Dot, Post Office Box #404, Hinsdale, IL 60522.*
ø Ident, 11709 Old Dallas Road, Suite 203, Creve Coeur, MO 63141
¶ Codent, U.C.L.A. School of Dentistry, Dept. of Pediatric Dentistry, Center for the Health Sciences, Los Angeles 90024.
* last known address

bonding may also cause the microdisc to fail. The extreme sensitivity to contamination from oral fluids during the enamel bonding processs is critical to success and many failures may be attributed to poor cementation technique. Early mylar discs were apparently more prone to this problem but recently the failure rate has been lower.

Stainless steel is used by two firms who employ different methods to inscribe the indicia. A modified photoengraving process has been reported by one manufacturer (Fig. 1) and the other uses a computer driven YAG laser to engrave the stainless steel surface (Fig. 5,6), which, with appropriate programming, engraves 12 to 14 characters on the disk in seconds. This

speed results in lower cost per unit, a major factor if large numbers of discs must be produced in the shortest period of time. There are different types of lasers to drill holes in metal and if the laser is programmed appropriately the indicia can be reproduced as dot matrix characters cut through the base metal.

Cementation

A stainless steel disc may also be combined with a mesh back that is similar to orthodontic bracket pads (Fig. 5). This disc is acid-etch bonded on the tooth surface with orthodontic type composite resin. The method is identical to the orthodontic bracket cementation technique which enjoys universal clinical acceptability. Embedded cementation is the alternative technique and may require the preparation of a shallow cavity in the tooth. The discs may again be stainless or plastic and although thickness of each disc system is slightly different there is no protrusion and consequent discomfort.

Mesh backed discs can be manufactured for use on orthodontic bands or stainless steel crowns with spot welding tabs so that direct application to metal is possible, obviating the necessity for an enamel interface (Fig. 6).

Intraoral Optical Detection of the Indicia

The ability to read a microdisc *in situ* is definitely an advantage because removal is not required. When the size of the characters is less than 0.5mm, magnification in excess of 10x is necessary, requiring special optical instrumentation or removal of the disc for inspection. In addition, if compound microscopes are utilized the characters will be viewed inverted but magnifiers delivering an upright image of 10x power should be sufficient when discs in the range of 2.5 mm to 3 mm contain 10 to 14 characters. Discs with 30 to 40 characters on 1.5 to 2 mm wafers will certainly defy intraoral legibility (Figs. 2,3). The *in situ* legibility requirement may be the standard for all discs in the future since removal may deface the disc, compromise legibility and require replacement at an additional cost. The Ident corporation has developed an intraoral reading device that can allow detection of the indicia without removing the disc (Fig.4). Intraoral readability is improved when the cementation site is easily accessible and is located at the most anterior site which does not compromise aesthetics. The suggestion that the most universally accepted site for disc placement should be the maxillary first permanent molar overlooks the issue of intraoral readability. The accessibility of the maxillary first permanent molar in very

young patients is often limited which makes intraoral reading of the indicia very difficult. The very young patient who has an unerupted first permanent molar may require placement on the primary second molar. The positioning of a disc on the buccal surface of the maxillary molars is considered better than the buccal surfaces of mandibular molars since the encapsulated disc may interfere with occlusion.

Intraoral X-Ray Detection of the Indicia

The YAG laser produces its inscription by penetrating the steel base and producing a mark containing alpha and/or numerics which on magnification of a radiograph allows the indicia to be read. This procedure may have substantial benefits in the future.

Information Storage-Computer Retneval

The use of a computer for retrieval of stored information is essential if alpha and/or numeric indicia are placed on a microdisc. Access to the computer files could occur by direct telephone contact to an operator or by automated retrieval via a modem. The accessibility to the computer files must be controlled to maintain confidentiality and it may be necessary to create a hierarchical system to allow certain institutional users direct on-line access while other public users would be required to identify the nature of their need to access. The on-line feature would enable public agencies to recover data from the computer bank with high reliability and rapidity. Law enforcement agencies would be authorized to bypass the public's normal telephone access. The relatively low cost of computer storage and the speed with which relational database software managers operate suggest that this system of storage will provide ready retrieval of data if the appropriate external and internal security measures are addressed. The software must include several levels of security before access to the database can be achieved. Passwords with additional coding that is modified with some regularity will ensure that the information in the database can only be retrieved by authorized individuals.

Durability

Any identification system including a disc must be resistant to incineration, direct defacement, oro-facial trauma, alteration of indicia (fraud) and yet be clinically practical. None of the currently available discs has been in use for long enough to prove itself. Some abrasion and loss of indicia is likely and

replacement will be required after several years. Formal clinical trials and laboratory testing will be essential to the development of the most clinically acceptable microdisc.

Radiopacity

A metal disc that is radiopaque presents an image on a radiograph which identifies it as an object that requires further examination. Plastic discs are not radiopaque and may not be noticed upon casual examination of the teeth. On the other hand, if a metal disc is aspirated or displaced into the surrounding soft tissue, it can be easily detected. Aspirated foreign objects which cannot be detected represent a serious medical complication and radiopacity should therefore be considered to be of paramount importance when any small object is manipulated in the oral cavity.

Fraud Protection

Forensic consultants believe that purposeful defacement of the indicia is always possible, which makes their design and application particularly important. Some current designs do not incorporate check digits or other types of integral fraud protection. Disc design that utilizes computer driven indicia generation presents the best opportunity for fraud protection. Use of the appropriate algorithms can create an unlimited number of alpha-numeric combinations with imbedded check digits and computer software can be written to change periodically each series of discs according to a preset plan of multiple digit modification for absolute fraud protection.

Conclusion

Identification in various forms has become commonplace in our society. While external devices have enjoyed wide acceptance, the intraoral microdisc has often been beset with indifferent social attitudes coupled with design and fabrication difficulties. As the interest of the dental profession has grown, the availability of discs has waned after patent litigation suits impacted on marketing incentives. A pattern of rising and falling interest has characterized the initial introduction of the microdisc and its future is unknown. If acceptance is achieved in the future standardization will have to emerge. Several characteristics have been suggested as essential to any microdisc. They are 1) standardized format and coding, 2) resistance to incineration, 3) resistance to corrosion, 4) resistance to extraoral trauma and occlusal attrition, 5) low cost, 6) non-invasive application to the tooth,

7) fraud protection, 8) computerized indicia management and 9) radiopacity. The development of a system wherein the indicia can be read by radiography is also considered to be an achievable objective.

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