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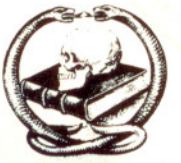

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Contents

Multivariate Sexing of the Human Viscerocranium

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Abstract

One hundred human crania were subjected to canonical and stepwise discriminant analyses utilizing four viscerocranial measurements and two indices to determine specific characteristics useful in sexual distinction of skeletal material. The maximum projective length of the mandible alone accounted for correct classification of 72% of males and 84% of females. Addition of the bimaxillary breadth enables 80% of males and 88% of females to be correctly assigned. From the observed contrast between univariate and multivariate analyses of the data set, it is concluded that both methods should routinely be combined in the evaluation of skeletal material.

Introduction

Accurate sexing of fragmented skeletal material is of undoubted importance to forensic scientists, archaeologists and physical anthropologists. The high differential survival of cranial structures during natural decomposition[1] underlines the usefulness of cranial measurements in the classification of such remains. Traditional craniometric analyses have however, been hampered by the impractically large numbers of anatomical distances that had to be considered, often with little regard for their relative importance.[2,3] Von Török for instance, is quoted as having advocated the use of 5000 measurements on a single skull.[2] Ideally, what is required is a reliable method of sex discrimination which rests on a small number of easily determined measurements. The present report applies both univariate and multivariate procedures to a sample of crania in order to evaluate the reliability of four such measurements and their indices.

Materials and Methods

The sample of 100 contemporary Negro crania (50 male, 50 female) was chosen from a large collection of dissecting room skeletons of known age, sex and ethnic derivation, which forms part of the Raymond Dart Collection of the Department of Anatomy, Faculty of Medicine, University of the Witwatersrand. Four viscerocranial measurements were taken using a sliding caliper with a varnier scale (0,05 mm). The reliability of this method is documented elsewhere.[4] The bimaxillary breadth (GB or

M46) was defined as the maximum distance from one zygomaxillare to the other[5,6] (Figure 1). The second measurements was the maxillo-alveolar length, defined as the distance from prostheon to alveolon (M60). A maxillary index was calculated by dividing GB by M60. The maximum projective length of the mandible (ML), was read on the horizontal scale of the mandible board with both condyles in contact with the vertical rameal wing.[6] The distance between the gonia was taken as the bigonial breadth (GoGo or M66), and the mandibular index was calculated by dividing ML by GoGo.

In addition to standard univariate statistics, the multivariate nature of our data matrix was explored by the application of discriminant analysis.[7]

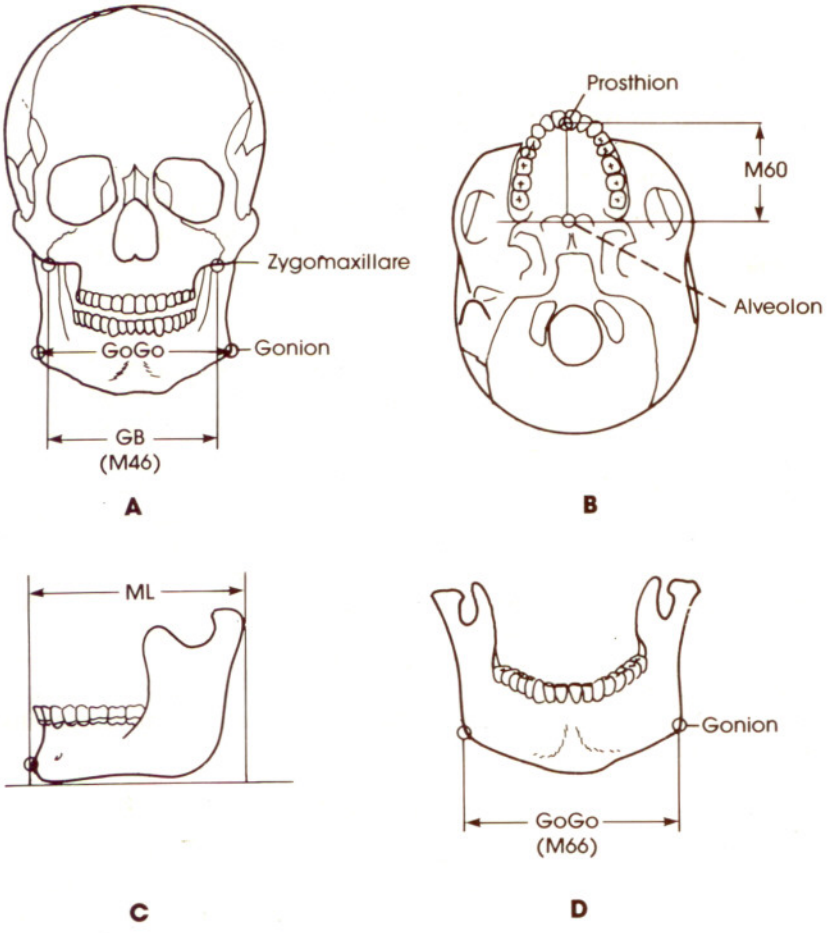

Fig. 1. The viscerocranial landmarks and distances considered (A = anterior view, B = base of the skull, C = lateral view of the mandible, D = anterior view of the mandible). Distances are as follows: GB is bimaxillary breadth; M60 is maxillo-alveolar length; GoGo is bigonial breadth and ML is maximum projective length of the mandible.

Results and Discussion

Table 1 presents summary univariate statistics of the viscerocranial measurements and their indices. Inspection reveals that statistically significant sexual dimorphism is limited to the linear measurements, with mandibular length (ML) being the most dimorphic. Student-t tests failed to demonstrate significant sex differences between the two indices.

Statistically significant multivariate differences were confirmed by canonical discriminant analysis: Mahalanobis' distance between canonical centroids $D^2 = 2{,}272$, Wilks' Lambda $= 0{,}431$ and $p < 0{,}001$. These results are graphically illustrated in Figure 2. While Mahalanobis' generalized distance (D^2) indicates the absolute separation between the two canonical centroids, this information may in fact be slightly misleading. More informative would be a consideration of the relative contribution of the respective variables to the overall separation of the sexes. This may be done by examination of the magnitude of the standardized canonical coefficients — the larger their absolute magnitude, the greater the contribution.[8] Inspection of Table 2 reveals that the mandibular length (ML) contributes most to the overall discrimination, followed by the bimaxillary breadth (GB) and by the maxillary index (GB/M60). To determine the similarity between each variable and the overall discriminant function, one has to consider the structure coefficient, which is simply the product-moment correlation between each variable and the discriminant function. These correlations are taken as the cosiness of the angles between the variables and the discriminant function and may be interpreted as follows: when the absolute magnitude is near +1 or -1, then the function carries nearly the same information of the variable. From Table 2 it should be clear that ML and GB have the largest structure coefficients. In other words, they have the largest bivariate correlation to the discriminant function.

Klecka[8] has noted that the situation is often encountered where the investigator has several potential discriminating variables but they are of uncertain reliability. Unreliable or unnecessary variables may be eliminated by using a stepwise discriminant analysis. The results of such a procedure applied to our data are summarized in Table 3, from which it appears that the optimal set of discriminating variables consists of two linear measurements and two indices. Together, these will account for the correct classification of 88% of males and 94% of females. The variable which generates the greatest separation of the two groups is the maximum projective length of the mandible (ML) which allows 72% of males and 84% of females to be correctly sexed.

If one wishes to take into consideration both the difference between the two sexes and the cohesiveness within the two groups, then one needs to measure the degree of clustering of variables around the canonical centroids. One such measure is Wilks' Lambda which will select a variable that increases cohesiveness without contributing much to the separation between centroids. Because Wilks' Lambda is an inverse statistic,[8] the smallest significant value is selected (Table 3) which is the Maxillary Index (GB/M60).

Table 1. Descriptive univariate statistics for the differences between males and females

		Males					Females			
Variable	*n*	*x*	*S.D.*	*Range*	*C.V.*	*t*	*x*	*S.D.*	*Range*	*C.V.*
GB	50	95,38	4,48	82,32 - 106,86	7,00	6,90**	89,75	3,63	82,20 - 97,81	5,09
M60	50	57,73	4,40	48,88 - 69,44	4,70	6,36**	53,35	2,72	42,26 - 59,00	4,05
GoGo	50	91,80	5,81	78,88 - 110,00	4,10	6,63**	84,62	4,99	75,00 - 98,10	4,17
ML	50	110,95	4,55	101,62 - 122,20	6,33	7,69**	104,10	4,34	91,60 - 117,23	5,89
GB/M60	50	165,84	7,76	135,69 - 190,26	7,10	-1,24	168,60	10,41	150,38 - 194,08	6,18
ML/GoGo	50	121,22	7,60	104,30 - 139,97	6,26	-1,37	123,37	8,09	106,47 - 154,36	6,56

x = mean; S.D. = standard deviation; ** = $p < 0,001$; n = sample size for each sex; c.v. = coefficient of variation; t = Student's t-test.

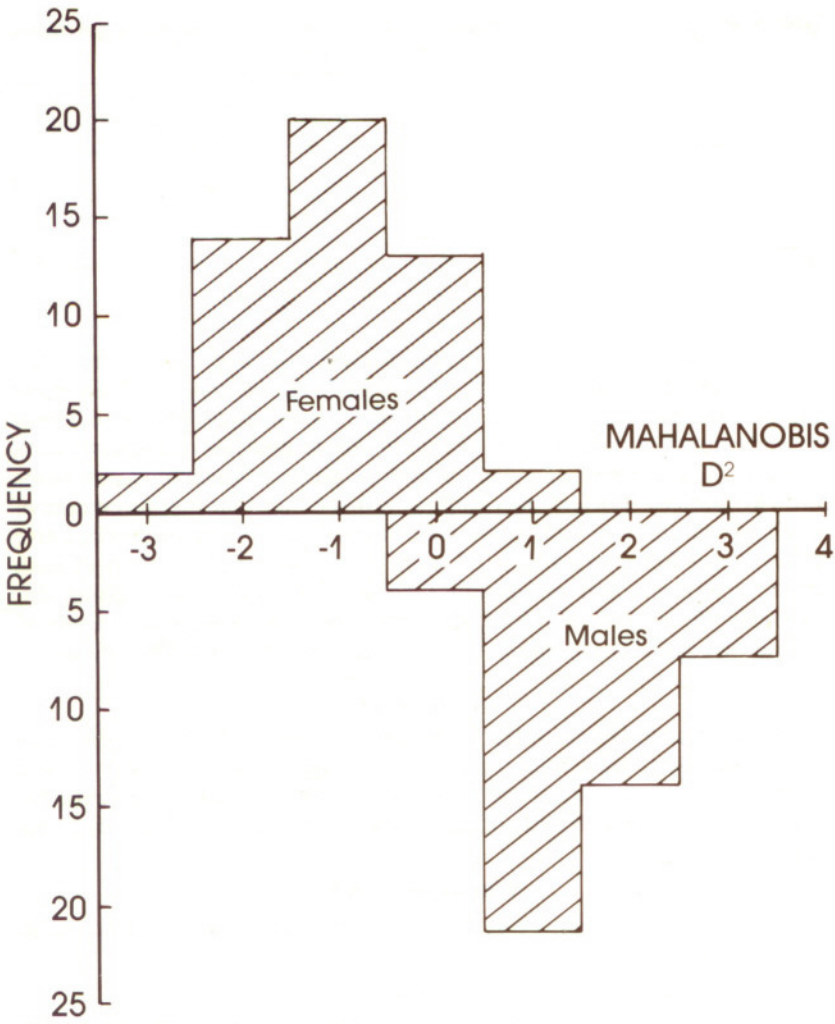

Fig. 2. Distribution of Mahalanobis' D values for the male and female viscerocranial measurements and their indices.

Table 2. Standardized canonical coefficients and structure coefficients for the cranial measurements considered

Variable	*Standardized canonical coefficient*	*Structure coefficient*
GB	1,586	0,758
M60	–1,024	0,716
GoGo	–0,061	0,737
ML	1,925	0,814
GB/M60	–1,438	–0,165
ML/GoGo	–0,549	–0,182

Table 3. Results of a stepwise discriminant analysis for viscerocraniometric differences between males and females

Step	*Variable entered*	*Partial R^2*	*F*	*Wilks' Lambda*	*Hierarchical percentage correct classification*	
					Males	*Females*
1	ML	0,376	59,23**	0,623**	72%	84%
2	GB	0,170	19,94**	0,516**	80%	88%
3	ML/GoGo	0,077	8,11*	0,476**	82%	92%
4	GB/M60	0,089	9,28*	0,434**	88%	94%

* = $p < 0,05$; ** = $p < 0,001$.

That univariate and multivariate analyses for sex differences often yield different results has been repeatedly emphasized.[4,9,10] Univariate analysis of our data isolated significant sexual dimorphism to linear measurements only (Table 1). Yet multivariate analysis of the same data suggests that the best sex discriminators are two linear measurements and two indices. Potter[10] has emphasized the fact that measurements of orofacial characters are correlated according to common causative factors, and hence treatment of such variables as independent of each other in analysis will not produce accurate information of group differences. We suggest therefore, that univariate and multivariate analyses should be routinely combined in the exploration of dentofacial data.

Conclusion

It may be concluded from the foregoing analysis that effective discrimination between male and female crania can be achieved by using a number of measurements and their indices. Of these measurements, the maximum projected length of the mandible provides optimal discrimination.

Acknowledgements

The authors thank Prof. P. V. Tobias for allowing them access to the R. A. Dart Collection.

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The Importance of Radiology in a Case of Soft Tissue Laceration: Beneath the Tip of the Iceberg

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Introduction

The value of radiology as a screening procedure in maxillo-facial assault cases should never be underestimated. The American Dental Association[1] recommends that the use of radiographs in dentistry should be based on previous clinical examination. This case presentation emphasizes the need to document all assault cases radiologically however trivial the injury is considered to be and even if injury appears to be confined to soft tissues. In addition this case illustrates the problems encountered with patients who are unable to remember details of events leading to their injury and the importance of careful handling of the assaulted patient.

Case Report

A thirty-four year old Cape Coloured female presented to the Faculty of Dentistry, University of Stellenbosch with a complaint of a stiff neck. Upon questioning the patient revealed that she had difficulty extending her neck and opening her mouth fully. Further questioning revealed that she had been assaulted by her husband ten days previously but was unaware of the precise details of this assault.

Physical examination revealed an otherwise healthy female in no acute distress and with no sign of fracture of the maxillo-facial complex. Neck extension was limited as was oral opening which was judged to be moderately reduced. The remains of a soft tissue laceration were evident in the region of the left zygomatic prominence (Fig. 1). A working diagnosis of whiplash injury was made and a panoramic radiograph was ordered. The panoramic radiograph revealed a band of radiopacity overlying the right and left maxilla. Initially this opacity was considered to be artifactual (Fig. 2). Further plain films were taken including a Waters view, lateral skull and PA skull (Figs 3 and 4). The patient was unable to extend her neck sufficiently for a basal view. Plain films revealed the same band of radiopacity which was then identified as a knife blade. The knife had penetrated the left aspect of the maxillary sinus and the left lateral pharyngeal space and had come to rest within the cervical vertebrae, but had not penetrated the spinal cord or its coverings.

Fig. 1. Photograph of patient at time of presentation. Note linear scar in region of left cheek (arrow).

The patient was questioned again. This time she stated that she thought there was a knife involved in the assault. Both she and her husband had been consuming alcohol at the time of the assault and the following day a knife handle was found without the blade. This did not seem to concern her.

The patient was taken to the operating theatre and the knife blade was removed surgically without incident. During surgery the tissue immediately surrounding the knife wound was seen to be necrotic. Pus was noted escaping from the wound. This necrosis of the surrounding tissues facilitated removal of the blade which normally would have been more firmly wedged in bone.[2] The soft tissue lesion was closed, and recovery was uneventful.

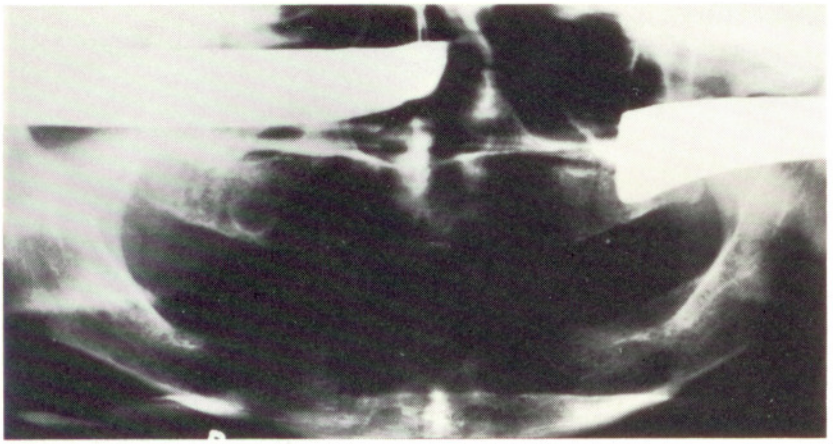

Fig. 2. Panoramic view of patient showing wide band of radiopacity bilaterally. This was originally thought to be artifactual.

Discussion

This case illustrates several important medicolegal considerations in the handling of assault cases. This patient is a prime example of a poor historian as she could not remember the details of the assault without prodding. Radiographs are invaluable in providing a permanent record of happenings which could later save the practitioner from embarrassment[3] and litigation.[4] The nature of the linear scar on the patients cheek and the history of an assault should have provided information as to the nature of the wound. Knife wounds and knife patterns in flesh have provided valuable forensic information in previous murder investigations.[5] The patient's background should also have provided a clue as to the nature of the assault. A significant number of assaults in the Cape Coloured group involve the use of knives.[6]

Other cases of penetrating facial injuries have been reported in the literature but this represents the first case wherein the patient could not remember being stabbed. Heidelman[7] reported a case of stabbing of the tongue with breakage of the knife blade in a 22-year-old black patient. This patient, unlike ours, presented to the emergency department immediately after assault with the knife handle in hand. Niamtu and Lassiter[8] reported accidental stab wound of the neck with intra-oral communication in a 49-year-old white male which involved an industrial screwdriver which jutted out of the posterior aspect of his neck. There existed a remarkable lack of severe debilitation in this patient as in our case and in fact Rao et al.[9] in their review of 136 cases of penetrating injuries of the neck reported that 52,9% had no major physical signs. In our patient the area of penetration involved the region of the carotid sheath and the knife tip was situated millimetres from the spinal column.

Kreutz and Bear[10] recommended the use of selective emergency arteriography in cases with penetrating stab wounds of the face. Arterio-

Fig. 3. Lateral skull view. This view allowed identification of the linear opacity as a knife blade.

graphy was not performed in the present case. Complications are possible[11] in many cases and it is miraculous that this patient did not suffer greatly. Should this patient have left the clinic without proper radiographs being taken disastrous results may have ensued. Further assault may have driven the knife deeper into tissue or may have caused rupture of major blood vessels in the vicinity of the blade.[12] The site was already infected at the time of operation and there is a good chance that

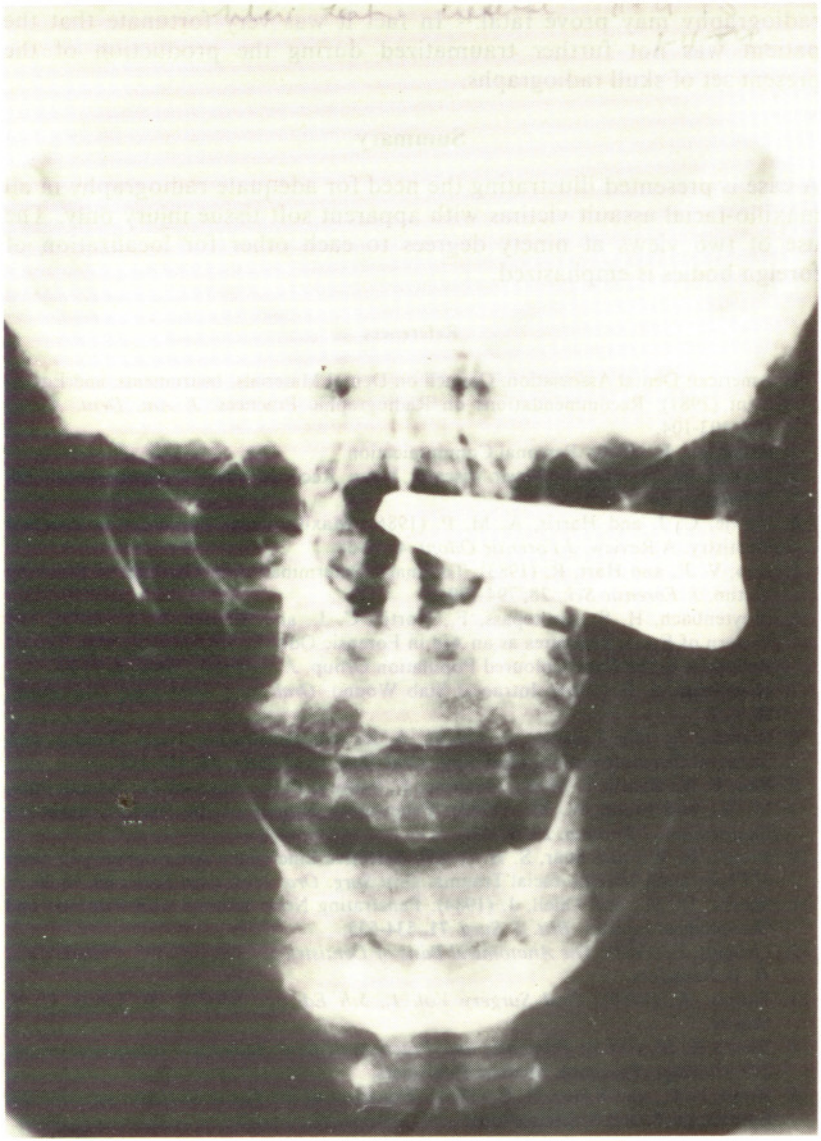

Fig. 4. PA skull view. Note proximity of knife-point to spinal column.

infection may have spread to the mediastinum via the parapharyngeal or retropharyngeal spaces.[13]

The skull view illustrate the necessity of confirming the presence or absence of artifacts seen on the screening panoramic radiograph. Two views at ninety degrees to each other are mandatory when evaluating any foreign body and represent the minimum number of films to be taken in any trauma case.[14] Rough handling of trauma patients during

radiography may prove fatal.[15] In fact it was very fortunate that the patient was not further traumatized during the production of the present set of skull radiographs.

Summary

A case is presented illustrating the need for adequate radiography in all maxillo-facial assault victims with apparent soft tissue injury only. The use of two views at ninety degrees to each other for localization of foreign bodies is emphasized.

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Fort Ancient Mandible: An Unusual Abnormality Associated with Untreated Trauma

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Introduction

Parallels exist between the alterations of oral pathology in living populations as well as those now extinct. Information concerning the course of untreated trauma or disease can be obtained by studying these processes in populations who did not have modern treatment methods available to them. An individual of the Fort Ancient culture of Kentucky, who apparently suffered severe trauma and unusual healing, is the subject of this paper. Comparisons are drawn between similar patterns of trauma in modern populations.

Fort Ancient

The archaeological site, Smithsonian 15Bk200, situated in the town of Augusta has had a history of archaeological investigation that dates to at least 1819. The earliest published reference to the site is that of Clifford.[1,2] He described an "ancient cemetery or burying ground at Augusta" and indicated that two iron bracelets found on the site were "conclusive proof" that the aboriginals in this area knew the use of iron. The next reference to the site is found in Rafinesque's 1824 "Ancient History, or Annals of Kentucky," where the entire description consists of: (a) "great battle-ground, etc., near Augusta, with iron rings and a copper metal with unknown letters." The presence or absence of iron is significant, as iron objects probably resulted from European contact of trade.[3]

Recently, archaeological "salvage" investigations in 1981 for a waste water treatment facility suggested that site 18Bk200 represented two distinct village sites.[4] Archaeological investigations by the University of Kentucky (1984) around Augusta have demonstrated the presence of two additional Madisonville Phase Fort Ancient villages in the Ohio River flood plan within 10 miles of Augusta. The site at Augusta does indeed contain two distinct occupations. Additionally, there have been grooved ceramics recovered in an isolated portion of Augusta that suggest a protohistoric occupation (Christopher Turnbow: personal communication).

What we know about the Fort Ancient people is limited to what is found in the archaeological record It has been suggested that the Fort Ancient culture is the precursor of the historically known Shawnee, but

clear evidence is lacking. Villages were located near streams and supported small populations of generally less than 500 individuals. Some were palisaded and contained rectangular or round houses of wattle and daub or pole and bark construction. We do not know that intensive agriculture of maize, beans and squash was practised by tilling small family garden plots on the fertile floodplains of large streams.[5,6,7]

Agriculture was supplemented by hunting and fishing. The primary species hunted were the white-tailed deer *Odocileus virginianus* and wild turkey *Melegia galopavo.* Additionally, elk *Cervus elaphus,* bison *Bison* and bear *Ursus americanus* bones have been recovered from 12Bk200.[4] The bison and bear must have played a ritual role at this site as several animal bones recovered have been incised with geometric and animistic motifs. Hunting was carried out using the bow and arrow with small, triangular chipped stone projectile points. Tilling the soil was accomplished using shell and flint hoes. The agricultural products were stored in shell-tempered pottery which was made in a multitude of forms having very diverse decorations. Massive storage pits have been recovered, some over 2 meters deep and filled with the remains of maize.[8]

Many of the individuals were ornamented with shell, coal and bone beadwork. It is possible that ornamentation such as feathers, coloured fabrics and skins were used, but materials of this type are rarely recovered.[9] Extended burial was quite common in limestone slab boxes and frequently grave goods consisted of the utilitarian objects of daily life such as ceramic pots, bone needles and fish hooks, weapons and scrapers. Offerings of food such as maize and freshwater mussels were also commonly found with the dead, indicating a belief in an afterlife.[8,10]

Evidence for severe health related problems which remained untreated are common in Fort Ancient burials. Arrow wounds, with projectiles imbedded in bone, have been found, and other specimens have been recovered demonstrating untreated fractures and dislocations. Additionally, the dentition of Fort Ancient populations has been the source of many studies which report poor, or a total lack of, dental care.[8] Osteoarthritic lipping of the lumbar region and lower thoracic region was extremely common. So common, in fact, that the question frequently asked when examining a Fort Ancient burial is not whether the individual was affected, but how extensively.[11]

The mandible that is the subject of this communication was of Fort Ancient origin and recovered at the Augusta site by a young man not associated with any professional investigations. This individual had apparently been overcome with interest in the activities and began digging on his own.

No other portions of the skeleton have been located and it was not possible to relate the mandible to its cranium.

Analysis of Mandible

This mandible (Fig. 1) presents a pronounced mental trigon and flaring gonial angle, and was likely a male individual of middle age at the time

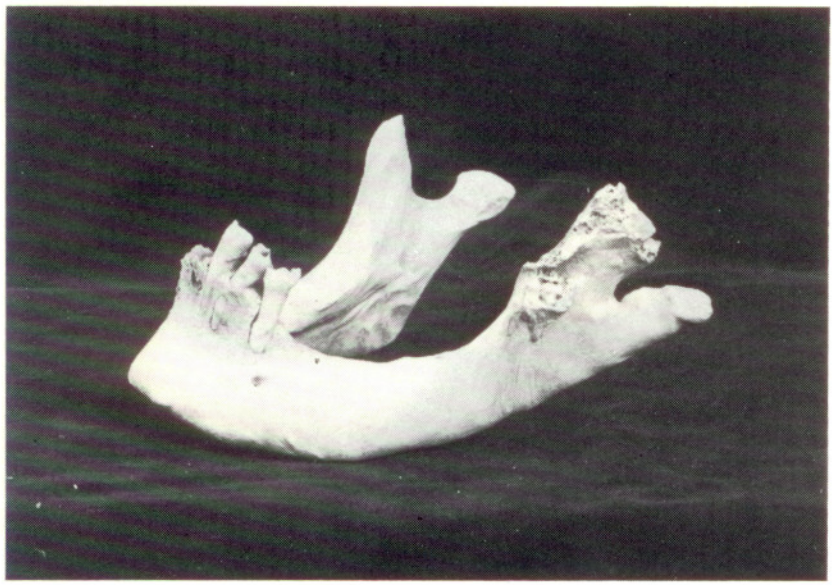

Fig. 1. Lateral view of mandible.

of death. Teeth 33, 34 and 35 are intact in the mandible, but most likely teeth 31, 32, 41, 42 and 43 were present before death and have since been lost. The mandible shows evidence of having been traumatized sometime prior to death, evidencing an unfavourable fracture of the left angle and a fracture of the left condylar neck. Both fractures appear to have been healed for some time prior to death. The left condylar head shows an axial rotation of approximately 80° antero-laterally. There is a well defined articular surface of approximately 1 cm in diameter. This surface is roughly circular and shows some evidence of osteoarthritic deposits (Fig. 2). Surrounding the articular surface is a band of ligamental attachment which most likely represents the inferior compartment of the temporomandibular joint capsule. The condylar neck is shortened by approximately ⅓ and greatly thickened.

The distal aspect of the coronoid process is markedly bulky, more rounded than normal and shows a lack of well defined cortical plate on its distal and anterior aspects. This change in the configuration of the cortical plate implies atypical muscle attachment. Normally the superficial tendon of the temporalis muscle attaches to the anterior aspect of the coronoid process and the deep tendon of the temporalis muscle attaches medially and anteriorly extending inferiorly to the third molar region; however, both attachments relocated lateral to their normal position.[5] This implies a rotation at the time of the jaw fracture of the angle segment of the mandible that was most likely lateral and superior. Moreover, the attachment of the masseter muscle in this same area that could additionally obscure the normal morphology. On the medial aspect of the angle just inferior to the lingula is a bony protruberance that is probably representative of the stylomandibular ligament.

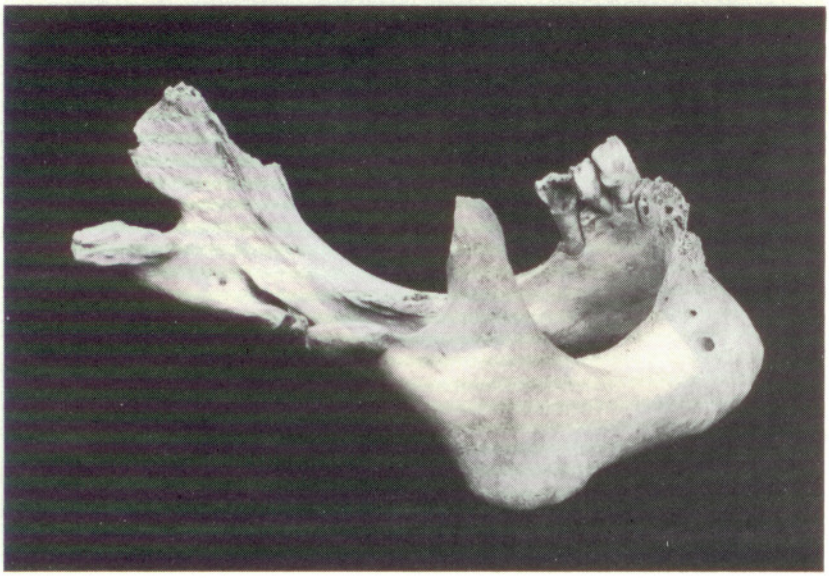

Fig. 2. The left condylar area.

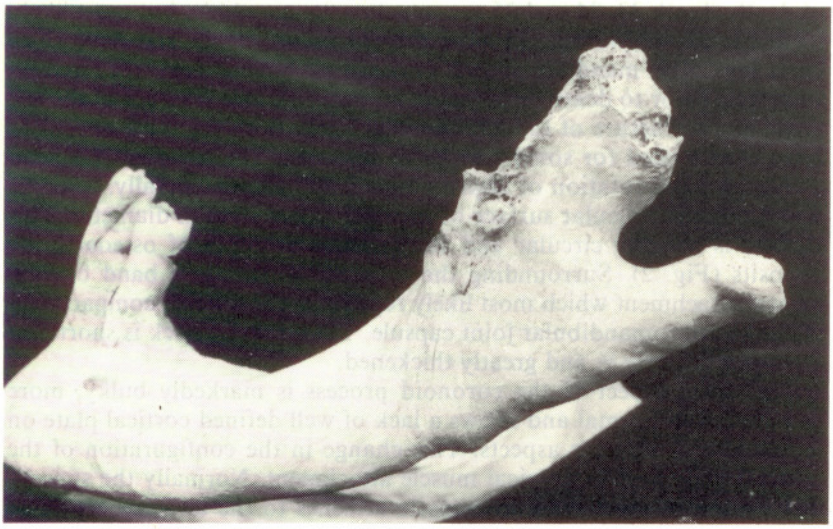

Fig. 3. The left gonial angle shows lines of attachment of masseter.

Close inspection of the lateral surface of the left gonial angle area shows what appears to be directional lines representative of the tendonous muscle attachments of the masseteric sling (Fig. 3). The configuration of the mandible in the left angle area takes on a smooth curve rather than a well demarcated angle. The mylohyoid ridge has a normal morphological character as there was no lack of continuity of the

Fig. 4. A radiograph shows the normal appearance of the mylohyoid ridge and inferior alveolar canal.

inferior alveolar canal (Fig. 4) as confirmed by radiographic and visual analysis. All of the posterior teeth have been lost apparently for some time prior to death, as the socket areas are totally healed with complete osseous remodelling occurring in those segments. Of the three remaining teeth all exhibit dental caries; with 34 and 35 both having exposed pulps. Teeth 33 and 35 show severe occlusal attrition. The socket area of the remaining anterior segment demonstrates marked periodontal disease with multiple periapical pathoses. These teeth show some evidence of hypercementosis that could be a reaction to the occlusal loading in the area secondary to the loss of the other natural dentition. This also would tend to give support to the assumption that at least some function was restored post-trauma.

Based on the analysis of the morphology of the mandible, radiographs, probable directors of muscle attachments, and the appearance of articular surfaces, the following scenario is offered:

During middle age and some years prior to death, this individual suffered a severe crushing blow to the mandible from the left lateral direction which caused fractures of the left condylar neck and mandibular angle. This resulted in a so called "unfavourable fracture" that involved both cortical plates and extended from a point at or near the angle anteriorly and superiorly to just distal to the mylohyoid ridge. Such fractures are classified as unfavourable because the pull of muscles which are attached to the mandible tend to dislodge or displace the fragments, and in this case caused the posterior or ramus segment to be displaced superiorly. The superior pull of the muscles of mastication can

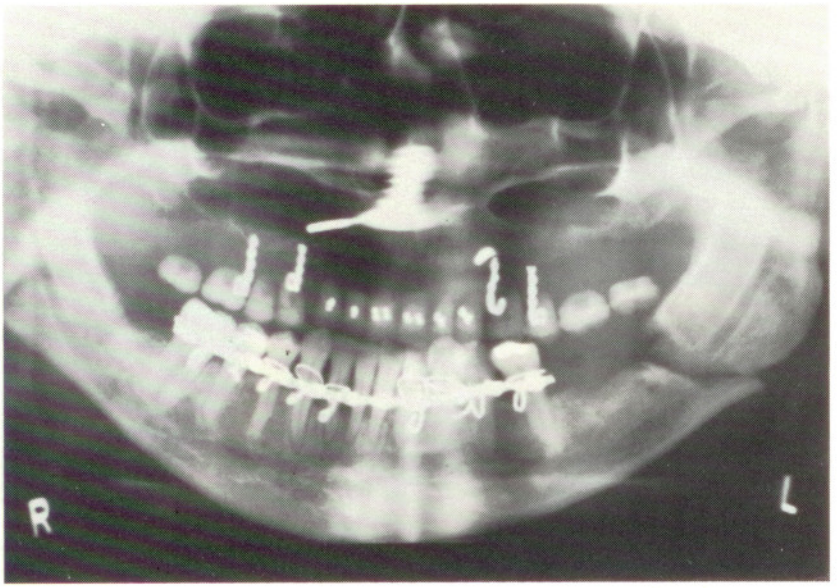

Fig. 5. A modern fracture shows a comparable displacement when not stabilized.

dislodge these type of fractures and presents a challenge to modern day practitioners. An example of a comparable modern fracture is illstrated (Fig. 5). This radiograph reveals how when not stabilized either via an open reduction or other means of fixation, and when not opposed by teeth in the maxillary arch, the posterior segment tends to "ride up" or otherwise be displaced in a superior manner.

In the case of the aboriginal jaw, the angle fracture in conjunction with the condylar fracture would have allowed the ramus segment to displace superiorly and rotate mesially. The muscle attachments have been torn and otherwise heavily damaged. This resulted in the formation of a massive haematoma which likely involved the entire masseteric bundle. The organization of this haematoma obscured the normal attachment sites and caused the formation of the atypical morphological character of the lateral ramus. Loss of the posterior teeth occurred before the trauma could have allowed the rotation of the ramus segment more readily than if teeth were present. It is hypothesised that initially a fibrous union of the fracture sites formed with later ossification occurring resulting in the final morphologic configuration of the bone. Without doubt, the TMJ on the left side was injured — as evidenced by the altered condylar configuration and arthritis changes seen on the articular surface. The wear pattern on the remaining teeth as well as the presence of a fibrous ring surrounding the articular surface would seem to indicate continued function of the joint without ankylosis. Most likely this healing took a considerable amount of time, possibly 8-10 years. During this period the individual would have had a severe limitation in food intake and would have had to exist on a liquid or semi-liquid diet.

This report illustrates how considerable data can be gleaned from an unusual paleopathologic evaluation and applied to improving clinical understanding of the response of extant populations to trauma and disease.

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A Case of Skull Identification by Means of Photographic Superimposition

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Introduction

Photographic superimposition for the identification of a skull has been repeatedly described.[1,2,3] If a photograph, even a passport photograph, of the suspected deceased is available and shows teeth, the matching up of an ante-mortem image with that of the skull is uncomplicated and can even lead to categorical or "unequivocal identification"[3]. However, if the photograph is unsmiling and shows no teeth, or if dentures are involved which were not recovered, the probability of identification can at most reach McKenna's[3] category 3 "highly probable identification" or more probably category 4 "consistent with, but equivocal".

Brown[4] has described a closed circuit television system whereby the images of the skull and photograph can be superimposed in a TV monitor in varying combinations of parts of the images (quadrants are useful fractions) and also recorded for use in later demonstrations such as in a court of law.

This report describes a case in which an edentulous skull (without dentures) was matched to a passport photograph in a simple photographic projection.

Case

A skeleton which included the cranium and mandible was found in a shallow grave partly exposed and accompanied by a pistol and matching cartridges. Suicide was suspected and bullet entry and exit holes were present in the top of the calvaria (Fig. 1). Notable features of the skull were deviated nasal bones (to the left) and a particularly elongated rectangular facial aspect with robust and relatively unresorbed residual alveolar ridges (mental foramina ± 14 mms below crest).

Documents relating to an individual who was suspected of being the deceased included an identity book containing an unsmiling, full-face, passport-size photograph taken slightly from the left. The police request was: could the skeleton be that of the suspected deceased?

Method

1. A life size black-and-white print of the passport photograph was made (Fig. 2).

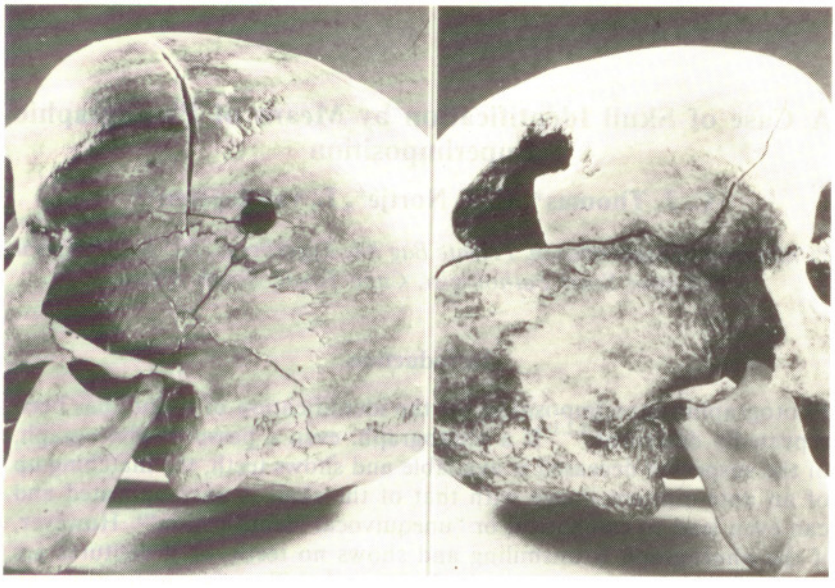

Fig. 1. Left and right sides of skull showing typically small entry and explosive, ragged exit bullet holes.

2. The mandible was fixed to the cranium in a position as close to correct as possible (Fig. 3).
3. The eyes were "whited out" so that shadows would not mask the images of the eyes in the print (Fig. 3).
4. The skull was photographed on colour transparency film from six different angles in accordance with the observed angle of the passport photograph;
   (i) mid-sagitally, in line with, 10° above and 10° below the Frankfort plane,
   (ii) 10° left of mid-sagittal, in line with, 10° above and 10° below the Frankfort plane (Fig. 4).
5. The print was fixed to a vertical surface and a conventional projector with a zoom lens was placed at right angle in front of it at suitable distance to deliver the skull image at more or less life size.
6. Each of the six transparencies was projected in turn onto the print with zoom lens used to vary the magnification so that the closest match of as many features as possible was obtained (Fig. 5).

Results and Discussion

Because the passport photograph was not taken full-face but slightly to the left, it was necessary to photograph the skull from this angle. A variable skull holder has been advocated[3,4] and would contribute to the ease of obtaining corresponding angles in both images. The arbitrary decision to make six views of the skull in this case proved correct as one of them matched satisfactorily.

Fig. 2. The passport photograph.

The features which were useful in this identification were soft-to-hard tissue relationships at the inter-orbital distance, eyes, nasal apertures, malar eminences, gonial angles, chin, lips and curvature of calvaria. The subject was almost bald, and as the latter is one of the most useful outlines to observe because it is not subject to any distortion such as can be found around the eyes and lower face, matching proved to be

Fig. 3. The skull showing mandibular localization and "whited out" eye sockets.

successful. In addition the deviated nasal bones could easily be matched because as in the case of the calvaria the soft tissue layer is thin and the bony profile obvious.

The fact that both the skull and the suspected deceased were edentulous naturally also contributed to the identification by elimination.

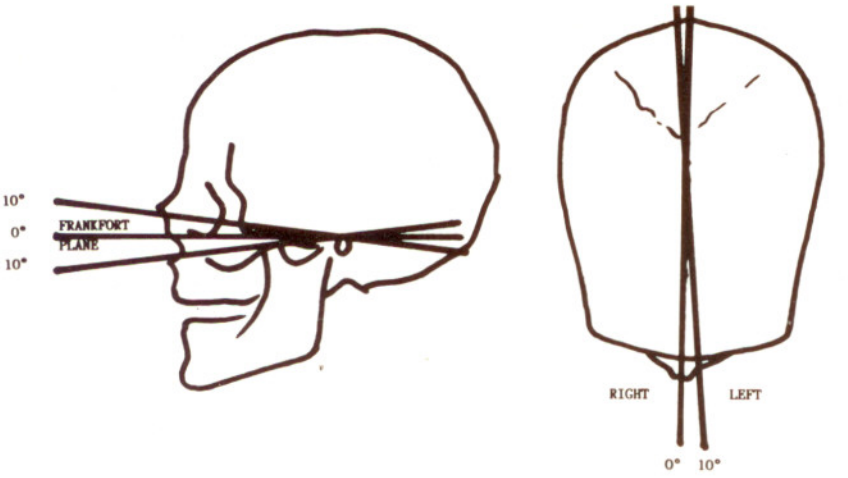

Fig. 4. The various angles from which the skull was photographed.

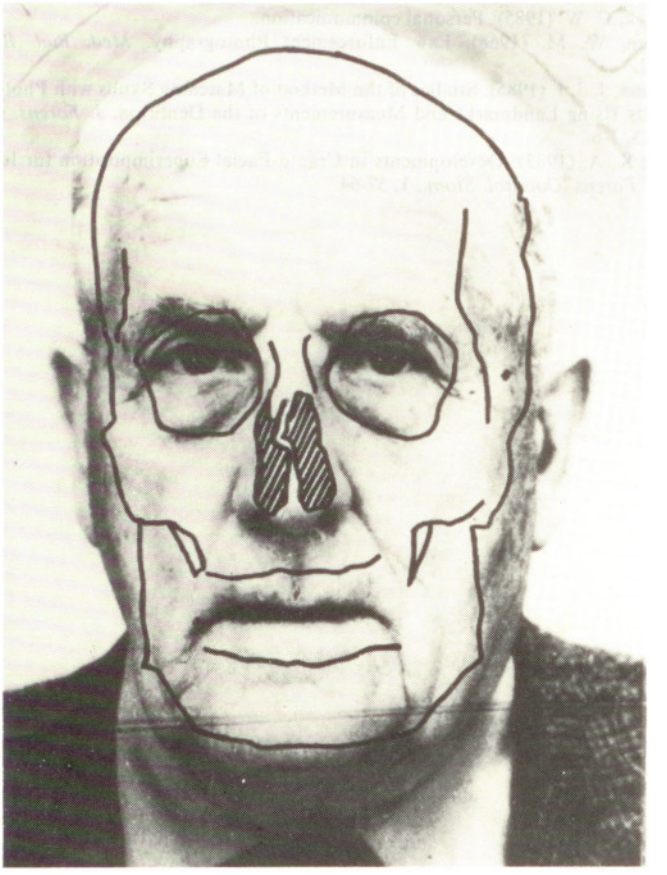

Fig. 5. The final best-fit superimposition.

The success of the technique was dependent on having both photographs containing white backgrounds, the skull photograph being in colour and contrasting dramatically with the black-and-white print. All potential black shadows in the skull should be "whited out", particularly the eye sockets so as to allow the very important eyes in the print to be visible.

Conclusion

The identification was definitely not "unequivocal" but more likely "consistent with, but equivocal".[3] It did however convince the police and relatives that the skeleton found was that of the suspected deceased, and the file has been closed.

The technique described was simple and in spite of the absence of more sophisticated equipment nevertheless proved to be useful and successful.

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The Dental Identification of Fire Victims

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Summary

The forensic odontologist plays a major rôle in the identification of fire victims as he is often the only member of the forensic team able to establish their identity. Good ante-mortem dental records are of paramount importance. The forensic odontologist must be meticulous in recording and comparing post-mortem dental characteristics with the ante-mortem records, always being aware of the effect that fire may have on the various types of dental restorations.

I. Introduction

A fire in the Bazar de la Charité in Paris on the 4th May, 1897 kindled Dr. Oscar Amoëdo's interest in forensic odontology and subsequently he was regarded as the founder of this branch of forensic science. This bazaar had been held in Paris since 1885, and in 1897 it was held for the 13th time. It was a rectangular shed of varnished wood, some 72 metres long and 30 metres wide, with a roof made of tarred cardboard. This shed was a replica of a medieval Parisian street with house façades and shops on each side covered by a canvas ceiling. As a special attraction, a cinematograph had been installed in the long gallery, almost in front of one of the exits. At around 16.10 hours on Tuesday, 4th May 1897, an explosion occurred in the gas lamp of the cinematograph and set fire to the surrounding drapes spreading along the tent ceiling towards both ends of the bazaar and quickly setting the whole interior ablaze. The fire brigades were on the site and in action at 16.23 hours, but the whole building collapsed at around 16.30 hours killing 126 Parisians in the blaze. The reports of investigating dentists involved in this tragedy formed a major part of Oscar Amoëdo's thesis for his doctorate in 1898.[1]

Nearly 100 years later, it is reported that 1985 was the blackest year in aviation history in which more than 2000 people died in aircraft accidents, while 18000 passengers have died in 600 crashes in the last 20 years. Britain's Cranfield Institute of Technology investigated air accidents between 1955 and 1979 and discovered that, in more than 60% of the crashes, half the fatalities were caused by fumes or fire. Fumes produced inside a burning airliner can incapacitate passengers within 30 seconds, and a small blaze can fireball along the plastic internal skin within seconds. Is this so different from the fire in the Paris Charity Bazar? The International Civil Aviation Organization found that fire is

the biggest single killer in survivable accidents. Firotex, a fire retardant cabin material capable of withstanding temperatures of 1 000 C, was developed five years ago but was given the cold shoulder by airlines because of its weight which would have pushed up fuel bills. Fortunately, fire retardant materials are now being installed in aircraft, allowing an evacuation time from a burning aircraft to a greatly improved 2,5 minutes. Engineers at Britain's Imperial Chemical Institute are working on a fireproof fuel which would coagulate when violently shaken during a crash, instead of misting and spraying over the fuselage and runway.[2]

II. Various Aspects of Fire

a. Common causes of fire

The origin of fires can be attributed to chemical (explosives factory, mining industry), electrical (home and factory fires) and natural causes (lightning, volcanic eruptions).

b. The locations of lethal fires can be tabled as follows:[3]

1. **Outdoor locations**

Natural disasters: earthquakes, forest and veld fires, lightning or set fires.

Underground disasters: caves, mines and shelters.

Fire entering crowds: racing car smash, tourist camp, stands.

2. **Indoor locations**

Homes, dwellings, hospitals, nursing homes, dormitories, tenements, jails, nightclubs, hotels, theatres, industrial plants and vehicles of transport.

c. Experimental fires

In an experimental fire at Mimico, Ontario,[4] a two-storey house was left to burn unimpeded. It took 42 minutes to reach a maximum temperature of 1 274° C on the ground floor, during which time the second floor temperature did not rise above 232° C. When the ground floor ceiling collapsed, the second floor temperature peaked at 1 004° C, but dropped to 870° C three minutes later. In another experiment when 1 litre of gasoline was poured on the upholstery in the cab of a car and ignited, a rapid, intense fire developed, attaining a temperature of 822° C at the dome light.

d. Wilson's classification of burns[5]

Type I Epidermal burns
Type II Dermo-epidermal burns
Type III Deep burns

This classification is useful for the purpose of describing morbid anatomical findings in postmortem reports. Burnt bodies often assume the pugilistic pose. This is a typical boxer's posture with the arms drawn up and the fists clenched in a defensive position. It is caused by heat coagulation and shrinkage of muscle bundles of the predominantly stronger flexor muscles.[6]

e. Damages to the human body[7]

The time-destruction phases for an average adult body, after the temperature of 680° C has been reached, are listed below:
Arms badly charred after 10 min.
Legs badly charred after 14 min.
Face and arms bones exposed after 15 min.
Ribs and skull after 20 min.
Shin bones showing after 25 min.
Thighs and shins completely burned after 35 min.

The forensic odontologist can contribute in victim identification if only the face is burnt, which amounts to less than 9% of the body surface.[8]

Fire at the scene of aircraft or motor vehicle accidents, as well as in dwellings and huts, frequently causes loss of life and severe burning of the trapped victims. Occasionally, murder victims are placed in a cab or boot of a motorcar by culprits and set alight to prevent identification.

The so-called necklace murder, where a motorcar tyre is placed around the neck of the victim, filled with petrol and set alight, is now used frequently in South Africa, and is a very effective method to destroy the facial features of the victim and hence the identity (Fig. 1).

Fig. 1. Victim of a necklace murder with tyre steel belt around the neck.

III. Dental Approach to the Identification of Fire Victims

a. Position of the forensic odontologist

Identification is teamwork. As forensic pathologists, police and technicians have their own contribution to make to the identification, it is essential that the forensic odontologist does not work in isolation.

b. Methodology

Sequence of events for identifying a victim of burning:

1. The forensic odontologist should accompany the police and forensic pathologist to the scene of the fire.

2. The body should be examined to establish the dental status and written notes made of all missing tissues. This would help in searching for fragments in the area around a body. These may include parts of jaws, avulsed teeth, enamel shells,[3] inlays, crowns, bridges, orthodontic appliances, complete or partial dentures which may contain an identity mark. The site of the accident should be handled as if it were the scene of a crime.[10] A plastic bag around the victims head can be secured with elastic bands to prevent loss of loose teeth or restorations.

3. The body should be transported in a large vinyl bag to the examination centre. The bag can be identified by means of a tied-on label or with white spray paint.[11] Debris and soil collected from around the victim should be labelled and transported in a separate bag.

4. Photographs taken at the scene should include some or preferably all of the following:

35 mm colour transparencies
Colour prints
Polaroid prints
Black and white (glossy prints)

5. On arrival at the examination centre, the pathologist and odontologist should be present when the bags are opened and the contents examined. Identified articles of clothing and personal belongings should be listed, tagged and bagged for safe keeping. It is advisable to take radiographs of the head, neck and torso. Both antero-posterior and lateral views are necessary to establish and locate fractures, bullets and shrapnel. The examination of the head and neck is best undertaken jointly by the medical and dental examiners. At this stage, it must be established whether lesions of hard and soft tissues were sustained before or after death.[12] A correct diagnosis of fracture type is critical as it may make the difference between a verdict of murder or accident, e.g. a saucer-shaped depressed skull fracture is typical of a blow by a knob kerrie. A victim with such a fracture found in a burnt car would raise suspicion.

The odontologist should examine the mouth with the tongue, oesophagus, trachea and lung block in situ. The heat-coagulated tongue can record valuable information.[12] Then, the pathologist can remove these organs for further investigation. The examination of the oral structures and records are best undertaken by a team consisting of two odontologists, a photographer and radiographer. If the latter two are not available, then the odontologists should also perform these functions.

In severely charred bodies, the upper lip is usually contracted upwards and the lower lip downwards with the tongue protruding between the teeth. In a fire, the gas in the intestines, stomach and lungs may cause protrusion of the tongue resulting in some protection of the teeth. Upon removal of the heat-coagulated tongue, indentations of the teeth are invariably present.[12,13] Photographs are taken to show the position of

the lips and tongue. The tongue is either cut away anteriorly or depressed into the oral cavity. The anterior teeth are carefully cleaned with a toothbrush, cotton wool and hand instruments, and photographed. Charting of brittle anterior teeth is completed at this stage as they may easily crumble with very little handling. The facial bones and mandible are examined for fractures.

The Angle classification of jaw relationship is best recorded with the jaws intact. The jaws are eased apart after making incisions from the labial commissures to the tragi. The mandible can be removed after cutting the vertical rami with a Stryker saw. The cut must be made parallel to the occlusal plane, but well above the crowns in adult victims. In adults, maxillae are removed by making a sawcut parallel to the occlusal plane at the level of the floor of the nose. This prevents the destruction of valuable age-determining features in the developing upper third molar area. In children, it is best to remove the complete mandible and maxillary bones with the floor of orbits so as not to damage the developing upper molars which are situated close to this area. Once the teeth have been cleaned, meticulous charting recorded on internationally recognized forms is completed by the two examining odontologists, each in turn acting as examiner or recorder.

The following photographs should be taken:

1. Full face
2. Anterior teeth in occlusion
3. Right and left buccal views of teeth in occlusion
4. Maxillary and mandibular occlusal views
5. Close-ups of any special features, e.g. crowns, bridges, tori, diastema, malocclusions and supernumerary teeth. The cause number and a scale should be in position in each photograph.

If ante-mortem records of the suspected victims have been obtained, bite-wing and periapical radiographs should be taken at the same angles as those used for the ante-mortem radiographs. If none are available, a complete set of radiographs are taken. The victim's family and medical practitioner should be questioned about previous antero-posterior and lateral skull radiographs that may have been taken for conditions such as sinusitis or fractures sustained in accidents. The frontal sinuses are regarded as an excellent means of identification. A comparison can be made between the teeth on these ante-mortem radiographs and those on postmortem radiographs.

Dentures and parts of dentures can become lodged in the pharynx, larynx, trachea or bronchi. In cases where prostheses have not been found in the mouth of an edentulous or partially edentulous victim, it is essential that the family of the victim be asked to search for the prostheses at home.

In a case investigated by the author, a chrome-cobalt partial denture characterized by two small attached anterior gold inlays was found at the victim's home and not in the victim's mouth. Subsequently when fitting this partial upper denture to the victim's upper jaw it went into place perfectly resulting in a positive identification.

Casts of the jaws can also be of great help in subsequent comparison of ante- and post-mortem records.

With the post-mortem charting, photographs, casts and radiographs, the odontologist can look more closely at the following features and check:

1. Restorations and carious lesions
2. Numbering of teeth
3. Periapical radiographs will give more information about inlays, crowns, bridges, endodontic treatment, implants, retained roots, impacted or unerupted teeth, periodontal disease, fractures or other pathological conditions.

c. The effect of fire on dental restorations and oral hard tissue.

1. **Mandible and maxillae**

The facial portion of the cortical basal and alveolar bone is destroyed long before the more protected deeper palatal or lingual layers.

2. **Enamel**

The damage to the enamel, especially the facial surfaces, can vary from slight scorching to complete carbonization or destruction. The enamel caps may also explode into fragments or separate as a complete shell from the underlying dentine core. This phenomenon could be explained by the presence in the dentinal tubules of 8% to 10% water which, on reaching boiling point, releases steam resulting in the separation or explosion of the enamel caps, depending on the gradual or sudden exposure to intense heat. The underlying dentine core also shrinks by losing its water content.[4] The oral cavity, submitted to gradual hearing, may show intact crowns separated at the gingival margin from the insulated cooler root portion encased within the alveolar process.[14]

3. **Dentine and cementum**

These tissues are usually protected by enamel or bone, but multi-directional cracks, almost to the pulp, can develop at a temperature of 400° C.[13] The colour of the burnt dentine and cementum is usually black-brown.

4. **Amalgam**

Amalgam consists of silver, tin, copper, zinc and mercury which is released at 100° C and boils at 356 ° C. With the loss of mercury, the alloy usually begins to powder into silver-tin and copper-zinc complexes. The silver-tin melts at 500° C but since silver alone melts at 960° C and tin at 231°C, the complex breaks apart and forms silver oxide, a black powder. Between 500° C and 1 000° C the amalgam loses form, colour and integrity.[4] The mercury droplets can also be absorbed onto gold restorations disguising their true identity.

The inclusion of heat-resistant, data-encoded ceramic micro-chips under amalgam restorations has been tested and advocated by many authors.[15]

5. **Composites**

Experimental work has been done by the author on extracted molars restored with P-30* and Occlusin**, and submitted to a temperature of 900°C for 1,5 hours in a crematorium oven. Results show almost complete destruction of the teeth with virtually unaltered restorations. P-30, heated to temperatures between 815° C and 900° C for 1,5 hours, consistently changed from a whitish-yellow to a pale grey colour. Occlusin, tested similarly, changed from a whitish-yellow to a paper white colour. Consequently these restorations can provide an excellent means of identification if the dental records name the type of material used.

6. **Gold restorations and prostheses**

The minimum fusion temperatures for type I to IV gold casting alloys varies between 870° C and 1 070° C, depending upon the percentage of noble metal present.

7. **Base metal alloys**

Base metal alloys, used for partial dentures, melt between 1 275° C and 1 500° C. Experimental work has shown that chrome-cobalt partial dentures submitted to a temperature of 900° C for 1,5 hours resulted in a tarnished appearance of the surface.

8. **Ceramic-metal restorations**

The fusion temperature for noble metal alloys varies between 1 150° C and 1 350°C, and that of base metal alloys between 1 300° C and 1 450° C. Dental porcelains have a fusing range between 870° C and 1 370° C.[16] Experimental work has shown that porcelain denture teeth did not suffer any damage when placed into a crematorium furnace at 900° C for 1,5 hours. Pins remained intact.

9. **Acrylic resin**

Polymethyl methacrylate denture bases and teeth depolymerize to monomer at 450° C.[17] Resin burns at even lower temperatures if it comes into contact with flames.

10. **Root canal fillings**

Gutta percha cones consist of zince oxide (60-75%), pure gutta percha (20-25%) as well as small amounts of wax, resin and metal salts.[18] In an experiment, teeth, root filled with gutta percha and endomethasone-eugenol sealer, were placed in an incinerator at 815° C for 1,5 hours. The filling material boiled out of the apical foramen in teeth with wide open canals. This was not so noticeable in teeth with narrow root canals. A comparison between pre- and post-incineration radiographs revealed radiolucent zones in the root fillings of the heat-treated teeth.

Silver points melt at 960,5° C.[16] The silver content of these points ranges from 99,8% to 99,9% with traces of nickel and copper.[19] The

* Dental Products/3M, St. Paul, Minnesota, U.S.A.
** Imperial Chemical Industries, Macclesfield, Cheshire, England.

silver points in root canals were not affected by heat at 850° C in an experiment designed by the author.

Endomethazone and eugenol were used in an experiment as a sealer or on its own as a root canal filling material. Post-incineration radiographs revealed radiolucencies similar to those found in the gutta percha filled canals submitted to the same treatment.

11. **Steel post in root canal**

A steel post cemented in a root canal showed no change when heated to 815° C for 1,5 hours in an experiment.

Knowledge of the radiopacity or radiolucency of filling and lining materials is essential, especially the new composites and glass-ionomer cements.

d. Factors to be considered when there is no antemortem record.

1. **Dental condition**

Peculiarities of occlusion, presence of diastemata, shape of teeth, missing teeth, dentures, bridgework, intrinsic stain (fluorosis, tetracycline), extrinsic stain (tobacco, betel nut, tea) may be recognized by people who have known the person.

2. **Age, race and sex**

3. **Occupation**

Some clues to the occupation of a person may be gained from his teeth, e.g. wear from holding nails or tacks between the teeth.

4. **Habits**

The habits of a person may be reflected in the dentition and may possibly be a clue to identification, e.g. betel nut chewing, snuff dipping, pipe smoking, clenching of mouthpieces of musical wind instruments, toothbrush abrasion, erosion and attrition.

5. **Socio-economic status**

The quality of the dental treatment and oral hygiene can often give a clue to the social and financial position of an unidentified body.

6. **Country of origin**

The vast volume of international air travel means that identification of aircrash victims may rest upon recognizing certain types of crown design and bridgework typical of certain countries, e.g. in Eastern Europe we are likely to see non-precious metal crowns and bridges. Similar dental treatment in two bodies may indicate that there are husband and wife.[20,21]

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