ISSN 2219-6749

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The Journal of Forensic Odonto-Stomatology

Volume 17, n. 2 - Dec 1999

OFFICIAL PUBLICATION OF THE
INTERNATIONAL ORGANIZATION FOR
FORENSIC ODONTO-STOMATOLOGY

CONTENTS

GENDER DETERMINATION BY ODONTOMETRICS IN A SWEDISH POPULATION

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ABSTRACT

Gender determination of skeletal remains is fraught with uncertainty, especially in subadults. Many anatomical structures have been studied, but the teeth and their measurements seem to be the most reliable method in individuals whose secondary sexual characteristics have not yet developed. The purpose of this study was to investigate the accuracy with which gender can be differentiated by odontometric analyses in the Swedish population. The material consisted of 58 dental casts, 29 male and 29 female, ranging in age from 14 to 38 (mean 19) years. Measurements were made on the *mesio-distal*, *bucco-lingual*, *mesiobuccal-distolingual* and *distobuccal-mesiolingual* diameters. The mean diameters for males were larger than those for females in all variables and 27 out of the 56 differences were statistically significant ($p<0.05$). The upper canine had significant mean differences in all measurements. Lower canines, second upper and lower premolars, upper second molars and the lower first molars all had significant mean values in three of four variables. These findings support the usefulness of especially the canines in gender determination by odontometric analyses. It also shows high significant dimorphic values for some of the other variables investigated **(J Forensic Odontostomatol 1999;17:30-4)**

Keywords: sex determination, odontometrics, tooth size, forensic odontology

INTRODUCTION

Gender determination of skeletal remains is part of archaeological and many medicolegal examinations. The methods vary and depend on the available bones and their condition. The only method which can give a totally accurate result is the DNA technique, but in many cases for some reason or another it cannot be used. Anthropological measurements of the skeleton, and the comparison with existing standard data must then be applied and may help to differentiate between male and female remains. On an individual basis however gender differences are not always distinctive, but taken collectively they can give a good indication in the majority of cases.[1,2] When jaws are at hand, teeth may be used for sexing with the aid of odontometric analysis and this is of special importance in young individuals where the skeletal secondary sexual characteristics have not yet developed.

Sexual dimorphism of the teeth has been extensively studied by means of odontometric analyses, and most studies have shown statistically significant differences with *t*-test as well as with discriminant analysis based on data of the crown diameters in the permanent dentition.[3,4] In general male teeth have been found to be larger than those of the females and an excellent review has been published by Kieser.[5] Studies performed on the lower canines by using the ratio between the maximum crown width and canine arc width, resulting in a Mandibular Canine Index (MCI), have shown the ability to determine gender with an accuracy of 84.3% in males and 87.5% in females by comparing the observed MCI with a standard MCI value.[6] Combinations of root lengths and crown diameters have also shown a high discriminatory ability.[7]

Although most studies have resulted in a high degree of accuracy of gender determination, a later

study on the other hand has focused on the complexity and unreliability of accurate determination based on odontometric data. In spite of high levels of confidence and high percentages of correct classification by gender (Caucasoid 81.8-91.3%) the high levels were unmatched in the allocatoly procedures; only 30.4% of male and 18.2% of female Caucasians could be allocated correctly.[8]

The purpose of this study was to investigate further the accuracy with which gender can be differentiated by using odontometric measurements on the permanent dentition in a Swedish population, to verify existing measurements and find new parameters to differentiate male from female teeth.

MATERIALS AND METHODS

Subjects

The material used in the investigation consisted of 58 dental casts from the Department of Orthodontics, School of Dentistry, Huddinge, Sweden. The casts where chosen sequentially (alternate males and females) from the archive, and assumed from their names to be individuals of Swedish descent. Twenty-nine were males and 29 females, ranging in age from 14 to 38 ($\bar{x} = 19$) years, all teeth were fully erupted, and none of the individuals wore orthodontic appliances or had any anomalies which could influence the measurements. The actual number of teeth investigated is shown in Table 1. With the exception of the first premolars, most teeth were present in the casts.

The data used for the investigation on gender dimorphism came from measurements of the right side of the maxilla and the mandible. In half of the casts (15 males, 14 females) both sides were measured to investigate contralaterality in the material.

Instrument

A digital vernier caliper* giving two decimal points was used for the measurements

Measurement methods

Each tooth (third molars excluded) was measured in four different dimensions: mesio-distal (m-d), bucco-lingual (b-l), mesiobuccal-distolingual (mb-dl) and distobuccal-mesiolingual (db-ml). Measurements of mesio-distal and bucco-lingual crown diameters were performed according to the techniques by Seipel[9] and Moorrees.[10]

Mesio-distal crown diameter - the greatest distance between the approximal surfaces of the crown measured with a vernier caliper held parallel to the occlusal and vestibular surfaces of the crown. If a tooth was malpositioned or rotated in relation to the dental arch, mesio-distal measurement was taken between the contact points of the crown.

Bucco-lingual crown diameter - the greatest distance between the buccal surface and lingual surfaces of the crown measured with a vernier caliper held at right angles to the mesio-distal crown diameter of the tooth.

Mesiobuccal-distolingual crown diameter - the greatest distance between the mesio-buccal and disto-lingual surfaces of the crown, creating a diagonal in relation to the tooth and with the vernier caliper held parallel to the occlusal surface of the crown.

Distobuccal-mesiolingual crown diameter - the greatest distance between the disto-buccal and mesio-lingual surfaces of the crown, creating a diagonal in relation to the tooth and with the vernier caliper held parallel to the occlusal surface of the crown.

Statistical method

The Student's *t*-test was used in the statistical evaluation of the data.

RESULTS

The mean values of all recorded dimensions were larger in males than in females (Table 1). Twenty-seven of the 56 recorded dimensions (48%) had mean dimorphic differences that were statistically significant at the $p<0.05$ level. The upper canines showed significant mean differences in all investigated variables. Lower canines, upper and lower second premolars, upper second molars and lower first molars all had mean differences that were significantly dimorphic in three of the four variables.

Of the investigated variables, the mesiobuccal-distolingual dimension showed the highest lack

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percentage of statistically significant mean differences. While the lower central incisors and the upper first premolars had no significant dimorphic mean values. There were no statistically significant differences between any of the measurements of the left and right sides of either the maxilla, or the mandible.

DISCUSSION

The present findings that there are significant, genetically determined, dimorphic differences between male and female tooth dimensions corroborate earlier studies on odontometric measurements of the permanent dentition.

Tooth	Number of teeth		m-d				b-l			
	Males	*Females*	*Males* Mean±SD	Diff	P	*Females* Mean±SD	*Males* Mean±SD	Diff	P	*Females* Mean±SD
11	29	29	8.88±.680	0.40	<0.05	8.48±.604	7.13±.614	0.11		7.02±.613
12	29	29	6.98±.502	0.33	<0.05	6.65±.557	6.47±.729	0.24		6.23±.579
13	29	29	8.26±.498	0.66	<0.001	7.61±.488	8.37±.646	0.50	<0.01	7.88±.614
14	14	11	6.87±.315	0.11		6.76±.390	9.32±.492	0.38		8.93±.680
15	29	28	6.73±.525	0.08		6.65±.536	9.82±.536	0.53	<0.001	9.29±.565
16	29	29	11.00±.635	0.42	<0.05	10.58±.726	11.03±.600	0.16		10.87±.776
17	29	29	10.40±.657	0.46	<0.01	9.94±.615	11.01±.771	0.33		10.68±.602
41	28	28	5.48±.435	0.16		5.32±.481	6.19±.483	0.13		6.06±.470
42	29	29	6.09±.393	0.19		5.90±.412	6.53±.497	0.07		6.46±.453
43	29	28	7.19±.529	0.63	<0.001	6.56±.394	7.55±.609	0.18		7.38±.518
44	18	22	7.12±.388	0.15		6.98±.472	7.88±.459	0.27		7.61±.527
45	29	27	7.36±.531	0.44	<0.001	6.92±.386	8.62±.579	0.38	<0.05	8.23±.661
46	29	29	11.13±.633	0.33	<0.05	10.80±.604	10.42±.563	0.25		10.17±.680
47	29	29	10.52±.760	0.29		10.22±.575	10.25±.764	0.32		9.92±.621

Tooth	Number of teeth		mb-dl				db-ml			
	Males	*Females*	*Males* Mean±SD	Diff	P	*Females* Mean±SD	*Males* Mean±SD	Diff	P	*Females* Mean±SD
11	29	29	8.41±.677	0.40	<0.05	8.00±.538	7.67±.806	0.21		7.47±.532
12	29	29	6.96±.795	0.43	<0.05	6.53±.611	6.52±.614	0.19		6.33±.540
13	29	29	8.16±.587	0.57	<0.001	7.60±.580	7.54±.562	0.32	<0.05	7.22±.471
14	14	11	8.38±.443	0.25		8.13±.529	8.50±.395	0.28		8.22±.493
15	29	28	9.02±.513	0.51	<0.01	8.51±.544	8.56±.572	0.29	<0.05	8.27±.501
16	29	29	12.68±.532	0.40	<0.05	12.28±.656	11.11±.581	0.23		10.88±.740
17	29	29	11.83±1.022	0.62	<0.01	11.21±.716	10.87±.751	0.40	<0.05	10.47±.634
41	28	28	5.85±.491	0.03		5.82±.542	5.89±.466	0.09		5.81±.556
42	29	29	6.31±.574	0.05		6.26±.601	6.02±.390	0.04		5.99±.470
43	29	28	7.58±.660	0.38	<0.05	7.21±.446	6.88±.477	0.38	0.01	6.49±.438
44	18	22	7.75±.511	0.42	<0.05	7.33±.473	7.04±.433	0.24		6.80±.503
45	29	27	8.36±.544	0.48	<0.01	7.88±.653	8.03±.620	0.31		7.72±.726
46	29	29	11.83±.577	0.35	<0.05	11.48±.520	11.61±.631	0.40	<0.05	11.21±.560
47	29	29	11.58±.798	0.36		11.22±.582	11.36±.828	0.42	<0.05	10.92±.502

TABLE 1: *Difference in tooth diameters between male and female teeth. Teeth are designated according to the FDI system. Values are given in mm with ± one standard deviation. Diff = difference between male and female values. The number of teeth available for measurements is shown in the second column*

There are a few earlier studies[9,11] on a Swedish population as regards the mesiodistal dimension and our results are in full agreement with those. A comparison[4] with the genetically close populations of Iceland and Britain demonstrates that the teeth of the Swedish population in general terms (sum of diameters of all teeth) are somewhat smaller than those of the Icelanders in both the mesiodistal and buccolingual dimensions, but somewhat larger than those of the British population, with the exception of the lower teeth of females which are larger in the British population.

The size differences between male and female teeth of the Swedish population are considerably larger than in the Icelandic and British populations using the index of percentage sexual difference ($100((x_m/x_f)-1)$ showing an almost doubling of the difference in the mesiodistal diameter in the Swedish population[4] (8.54% of upper canines and 9.60% of lower canines compared with 4.49% and 4.85% in the Icelandic and 2.45% and 0.73% in the British populations, respectively).

The statistically significantly high level of dimorphic differences of the canines in the mesiodistal and mesiobuccal-distolingual crown diameters ($p<0,001$) suggests a high level of reliability in this dimorphic trait.

There were only three teeth which did not have any significant dimorphic mean values: the first upper premolar and the lower first and second incisors. The lack of significant mean values in the upper first premolars may be due to the few cases investigated (14 male, 11 female), because of orthodontic reatment and resulting extraction of this tooth. Another reason could be the experience that accurate diagonal measurements are difficult to carry out on the lower incisors.

In general the difference in size between male and female teeth has been explained as part of the genetic expression of the male which is larger than the female. The reason for the high level of dimorphic difference between male and female canines is uncertain, and consequently a large number of theories has been proposed. A popular theory has been to ascribe this to their function, which on an evolutionary basis differs from other teeth. Eimerl and DeVore[12] postulated that in the evolution of the primates there was a transfer of aggressive function from the canines in apes to the fingers in man, and that until this transfer was complete survival was dependent on the canines, especially those of the males.

The usefulness of the canines as an aid in gender determination by odontometric analyses in, for example, forensic dentistry is supported by their high level of survival in the dentition.

The present study thus supports the usefulness of the canine crown diameters in gender determination by odontometric analyses, and introduces some new diagonal variables, which may be useful as complements.

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THE EFFECT OF TEMPERATURE ON SEX DETERMINATION USING DNA-PCR ANALYSIS OF DENTAL PULP

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ABSTRACT

Forensic applications often necessitate the identification of human remains. This is made more difficult when the tissues have been exposed to high temperatures. Previously, metrical and non-metrical assessments of skeletal remains have been used to assess gender. Recent advances in molecular biology allow amplification of DNA from human blood, dental pulp and other tissues using the polymerase chain reaction (PCR), thus facilitating gender identification. The aim of this study was to investigate the efficacy of utilising DNA retrieved from the pulp of human teeth that had been exposed to different temperatures for different lengths of time, in order to assess gender. DNA was obtained from 94 teeth, 88 of which were isolated (44 male and 44 female), and six male teeth embedded in bone and soft tissue. A 106 base pair fragment from the X chromosome and a 112 base pair fragment from the Y chromosome was amplified from the amelogenin gene. PCR was shown to be 100% reliable when used to assess the gender of teeth which had been heated at 100°C for 15 minutes but less reliable when the teeth were heated at higher temperatures for longer periods of time. Teeth encased in bone and soft tissue yielded better results when subjected to higher temperatures than did the isolated teeth. **(J Forensic Odontostomatol 1999;17:35-9)**

Key words: Sex identification, temperature, dental pulp, amelogenin gene, PCR.

INTRODUCTION

Disastrous events such as explosions, high impact collisions, crimes and fires complicate the process of human identification, thereby annually increasing the number of unidentified deceased persons. The demand for accurate methods of gender identification is thus on the increase. It is generally easier to establish the identity of an individual from an intact corpse while the degree of difficulty increases in deteriorated, fragmented or mutilated remains.[1]

Identification of the gender of an individual includes both non-dental and dental parameters[1],and utilises both metrical and non-metrical procedures. The size and shape of the skull and the pelvic girdle along with the length and girth of the long bones are the most common skeletal determinants used.[2] However, the age of the subject, the degree of fragmentation of the bones and biological variability may influence the accuracy of these methods. The accuracy of gender determination using an intact pelvis is 95%, followed by 85% when using an intact skull and 70 - 75% when using the length of the humerus.[3]

Skeletal elements subjected to physical trauma such as explosions or fire, require more sophisticated measures for gender determination. Analysis of DNA provides this sophistication, particularly in forensic studies where trace amounts of DNA could yield the necessary information. A rich and reliable source of DNA is the pulp of the tooth. The pulp is cloistered in a hard tissue casing and is well protected from the effects of heat.[2] Teeth are able to withstand temperatures of between 150°C – 450°C,[4] they are tough, due to their high inorganic content [5] and are easily removed for examination purposes. As teeth are small, it is highly unlikely that all the teeth would be destroyed if a body was crushed or fragmented.

The established effectiveness and refinement of the polymerase chain reaction (PCR) has allowed amplification of degraded samples yielding information about gender[6] amongst other things. PCR is an *in vitro* method for the synthesis and amplification of specific DNA sequences of interest. In a series of cyclic reactions the number of PCR sequence products increases exponentially.[7] It is an extremely fast and sensitive technique and can be tolerant of

poor quality DNA. Further, it has a high probability of success and a low assay time[7] and has been applied in the diagnosis of genetic disorders, the detection of pathogenic organisms, the genetic identification of forensic samples and the analysis of mutations.[8]

Pillay and Kramer[9], amplified a region of the ZFX and ZFY gene in human pulp by PCR, followed by a restriction digest, to show that the method was an accurate alternative to metrical and non-metrical assessments of skeletal remains for gender determination. A 100% accuracy in determining the gender of human teeth, which were kept at room temperature, was demonstrated.

The amplification of the portion of the X - Y homologous amelogenin gene offers a gender typing system that requires only a short DNA sequence, and which is useful when forensic samples contain highly degraded DNA or DNA damaged by fire and explosions.[10] Large portions of this DNA sequence are highly conserved and the amplification of the X-Y amelogenin gene yields a 106 base pair (bp) fragment from the X chromosome and a 112 bp fragment from the Y chromosome. The use of the amelogenin gene may provide a better result than the primers used by Pillay and Kramer[9] in the likely event of the DNA being degraded by heat. Use of the amelogenin gene has the added advantage of not requiring additional enzyme restriction. The amelogenin gene has previously been used to sex teeth exposed to high temperatures, but exposure times were relatively short (between 1 and l0mins)[11] The aim of the present study was therefore to identify gender from DNA extracted from dental pulp subjected to high temperatures for increased periods of time.

MATERIAL AND METHODS

Eighty-eight extracted carious and non-carious teeth of known gender, consisting largely of impacted third molars, were obtained from the Department of MaxilloFacial Surgery, School of Dentistry, University of the Witwatersrand and from private maxillo-facial surgeons. Six teeth embedded in their bony sockets and surrounding soft tissue were obtained from a male cadaver in the Department of Anatomical Sciences, University of the Witwatersrand.

Preparation of specimens

A calibrated furnace was used to heat the isolated teeth at varying temperatures and for different lengths of time. In each group of isolated teeth, 50% were male and 50% female. The sex of the tooth was not known to the investigators until after the experiment was completed. Teeth were exposed to the following temperatures: 100°C for 15 min (n=14), 100°C for 30 min (n=14), 200°C for 15 min (n=16), 200°C for 30 min (n=16), 300°C for 15 min (n=14) and 300°C for 30 min(n=14). Based on the results obtained with the isolated teeth, six male cadaver teeth, embedded in bone and surrounded by soft tissue, were exposed to slightly higher temperatures of 150°C (n = 2), 250°C (n = 2) and 350°C (n = 2), each for 15min.

Following heating, the teeth were split open and the dental pulp was retrieved using sterile fine forceps. DNA was extracted from the dental pulp by a NaOH and phenol /chloroform method and PCR was applied to determine the gender of the individual.

Extraction of DNA

Blood from normal male and female individuals was used with every run as a reliable, standardised source of control DNA. Amplified control DNA would provide the expected 106 and 112 bp bands for comparison with the male and female pulp samples in every reaction.

DNA was extracted from the buffy layer from 5ml of blood. Three millilitres of a 0.17M NH_4C1 solution was added to the buffy layer, mixed and placed on ice for 20min. The remaining white blood cells were pelleted for 5min at 15 000 rpm, mixed with 8ml of phosphate buffered saline and pelleted at 15 000 rpm for l0min. The pellet was washed three times in a 0.9% NaCl solution. The sample was resuspended in 500µl of NaOH, boiled at 98°C for 15 min and neutralised by adding 62.5µl of Tris-HC1 (pH 8.0) before being allowed to precipitate at –70°C overnight.

Dental pulp

The teeth obtained were all not of the same size or condition. Some of the isolated teeth showed evidence of caries while others were impacted and showed no evidence of wear. DNA extraction from the pulp was performed by using the above method and further purification of the DNA was carried out using a phenol / chloroform extraction method.[8] This

method of extraction was chosen as it gave an OD 260:OD 280 ratio of approximately 1.8 indicating the high purity of the DNA preparation.

Primers were synthesised to homologous regions of the human amelogenin gene, spanning the area of the difference between the X and Y chromosomes. The sequences of these primers were:

SULI 5' CCC Tgg gCT CTg TAA AgA ATA gTg 3'

SULII 5' ATC AgA gCT TAA ACT ggg AAg CTg 3'

These were used to amplify the DNA extracted from the heated teeth. PCR was carried out using a PCR Core Kit* following the manufacturer's instructions. A 1.5µM final concentration of $MgCl_2$, 0.25µg of sample DNA and 2.5µl of a 10µM solution of each primer was added per 50µl reaction.

DNA samples extracted from male and female blood were used as standardised controls, while reagent blanks, which contained no DNA controlled for potential contamination.

The samples were amplified for 30 cycles in a Perkin Elmer thermocycler (2400). Each cycle consisted of three phases namely: denaturation at 94°C for 45 sec, annealing at 60°C for 45 sec and extension at 73°C for 1min. The first cycle was preceded by a denaturation step at 97°C for 2min.

Twenty microlitres of the PCR product from each tooth was analysed by electrophoresis on a 4% agarose gel.

RESULTS

All control samples gave satisfactory results. Blood and pulp from male subjects were identified as having two base pair bands of 106 and 112, while blood and pulp from female individuals were identified as having a single band of 106 bp. The reagent blanks showed no product as expected (Fig.1).

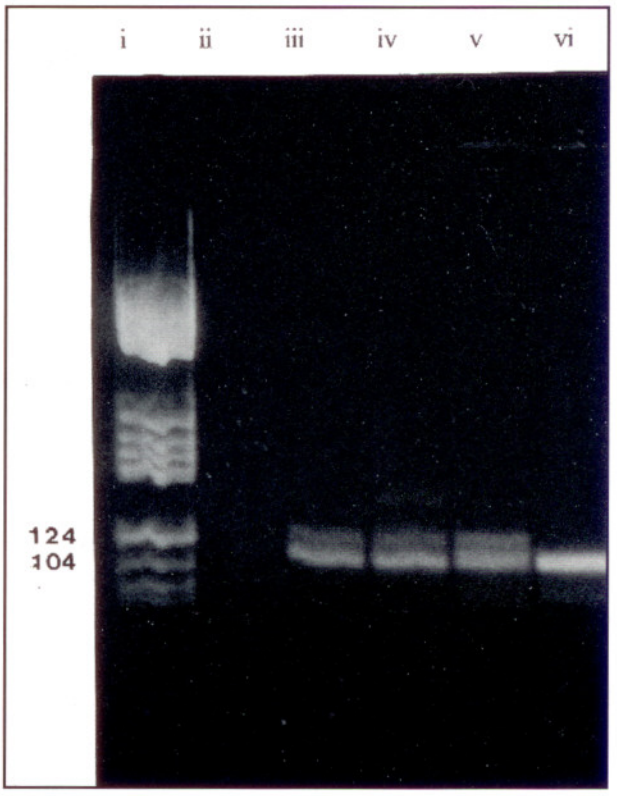

Fig.1: *A 4% agarose gel depicting the amelogenin PCR products from male DNA [lanes iii-v] and female DNA [lane vi]. Lane i - molecular weight marker v (Boehringer Mannheim) and lane ii - reagent blank*

Temperature and time	Male (n)	Percentage correctly sexed	Female (n)	Percentage correctly sexed
100°C for 15 min	7	100%	7	100%
100°C for 30 min	7	86%	7	71.4%
200°C for 15 min	8	62.5%	8	37.5%
200°C for 30 min	8	50%	8	25%
300°C for 15 min	7	14.3%	7	14.3%
300°C for 30 min	7	0%	7	0%

Table 1: *Isolated teeth. The percentage of teeth correctly sexed with increasing temperatures and times.*

*Boehringer, Mannheim

At 100°C and with an exposure of 15min, all the isolated teeth were correctly sexed (Table 1). However, with increasing temperature and length of exposure the ability to sex a sample diminished. The accuracy of sexing varied between the male and female samples. At 300°C and an exposure of 15mins, only 14.3% of both the male and female samples were correctly sexed (Table 1).

The ability to sex a sample following heating improved when the teeth were encased in bone and protected by soft tissue (Table 2). At 250°C both teeth were correctly sexed. However at 350°C, neither tooth was sexed.

Temperature	Male (n)	Percentage correctly sexed
150°C	2	100%
250°C	2	100%
350°C	2	0%

Table 2: *Teeth embedded in bone and soft tissue. The percentage of teeth correctly sexed following increased temperatures. Incineration time was 15 minutes for all specimens*

DISCUSSION

The term "sexed correctly" simply implies that the gender of the tooth was identified following PCR. No teeth were sexed incorrectly, that is, no male specimens were classified as female and *vice versa*.

Teeth remained unsexed if the PCR failed to produce a result.

In this study, the success of the PCR in sexing individuals decreased as the temperature and exposure time increased. When the teeth were heated for a longer period, that is 30min as compared to 15min, the percentage of sexed teeth decreased even further. Of the 14 teeth heated at 300°C for 30min, no DNA was amplified. Alvarez Garcia *et al.* [11] obtained an 87% positive identification of sex at 100°C for 10 min (compared with 100% at 15min in this study). When they increased the temperature to 200°C for l0mins, their result was significantly poorer (33% positive). It is of interest that at 200 °C (15mins), we obtained 62.5% accuracy in the identification of males and 37.5% for females. At 30mins (200°C), we obtained 50% accuracy for males and 25% for females. Alvarez Garcia *et al.* [11] were able to obtain positive gender identification at 500°C, but incineration time was for only 2 mins.

The discrepancies between the percentage of males and females correctly sexed at 100°C (30min exposure) and 200°C (both 15 and 30min exposure) in this study, may be due to the male teeth being larger and more protective of the pulp during incineration. In addition, the condition of the teeth from different patients varied as some patients had healthy teeth without caries (impacted third molars), while others had carious teeth. Although the number of carious to non-carious teeth was not quantitated, more female than male teeth were carious. The impact of caries on the quality of the DNA extracted from the pulp could not be determined in this study. It is however possible that exposed dentine would develop cracks at lower temperatures than when protected by enamel (dentine shows multidirectional cracks at temperatures of 400°C [12]). The fact that more female teeth had caries could account for the higher success in identification of male specimens.

All of the embedded teeth were correctly sexed at both 150°C and 250°C for 15min (Table 2), but no results were obtained for the embedded teeth at 350°C. While Alvarez Garcia *et al.*[11] obtained positive sexual identification on isolated teeth above temperatures of 300° C, their exposure time did not exceed 2 mins. It is possible that longer exposure times at high temperatures leads to incineration of the DNA.

There was a two-fold increase in the success rate of embedded teeth exposed to 250°C (15 min) compared to extracted teeth exposed to 200°C (15 min). This could imply that the mandible and soft tissue have the capacity of absorbing the heat and in so doing, protect the teeth and the pulp.

In summary, using primers designed to amplify 106 and 112 bp from the amelogenin gene of the X and Y chromosome respectively, we were able to accurately sex 100% of isolated teeth exposed to 100°C for up to 15min. Beyond this temperature and length of time, the ability to sex the individuals diminished, but was still possible at 250°C for teeth embedded in bone.

ACKNOWLEDGEMENTS

The technical assistance of Mrs L. York is gratefully acknowledged. Our gratitude is expressed to Elida-Ponds and the Dental Association of South Africa for financial assistance. This study was cleared by the Human Ethics Committee of the University of the Witwatersrand (HEC No. M960418)

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EVALUATION OF A BITEMARK USING CLEAR ACRYLIC REPLICAS OF THE SUSPECT'S DENTITION - A CASE REPORT

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ABSTRACT

An assault occurred during which a bite was inflicted on the left ear of the victim, producing a laceration and severing a portion of tissue from the ear. During the course of their investigation police recovered a lacerated fragment of tissue thought to be of a person's left ear. Impressions of a suspect's dentition were made and cast in dental stone. Positive replicas of the occlusal surfaces of the suspect's dentition were subsequently made using acrylic resin. The ear fragment displayed a lacerated border and a surface which exhibited indentations. When compared with the details of the suspect's lower anterior teeth, correspondence was visible between the shape of the indentations and characteristics of the suspect's dentition. The use of transparent acrylic replicas of the suspect's dentition facilitated the interpretation and comparison between the marks retained in the ear fragment and the features of the suspect's dentition. **(J Forensic Odontostomatol 1999;17:40-43)**

Keywords: Bitemark, fragment of ear, acrylic replicas

INTRODUCTION

According to Levine[1] the presentation and interpretation of a bitemark wound in human skin requires at least four major factors to be considered, as follows: the dentition of the person who inflicted the bite; the influence of the forces applied by the tongue, lips and cheeks; the mental state of the biter at the time; and the portion of the body which received the bite. For the examination of a bitemark, Levine[1] recommended that both the size and shape of the arch need to be addressed in addition to the position of the body when the bite was inflicted. Following an epidemiological study of human bites, Marr *et al.*[2] noted that out of 892 bites recorded in one year, 14.9% were sustained in the region of the head and neck. Brandt[3] commented that the protruding pinna seemed to be a frequent target for human bites that typically occurred during bar fights, gang attacks and similar circumstances. Brandt[3] reported five cases where segments of ears were lost, resulting commonly in sharp incised wound margins or sharply demarcated borders following avulsions.

Other reports include an incident where a bitemark was sustained on the nose of the victim.[4] It was determined in this case that the configuration of marks evident on the dorsal and inferior surfaces of the nose demonstrated profile contours and incisal edge characteristics of the suspect's maxillary and mandibular incisors. Govindiah and Bahskar[5] reported a case which involved traumatic amputation of a finger as a result of a bite by an assailant. In this case (evidence of) marks generated by human teeth were visible in the soft tissue of the avulsed piece of finger. Previous case reports[4,5] indicate that evidence of bitemarks can be revealed and interpreted even when tissue has been distorted, displaced and avulsed. The following case report involves examination of a fragment of ear which had been forcibly torn from the ear of an assault victim.

CASE

In April 1996 a fight between two adult males took place in a car park at the rear of a foundary in Edwardstown, South Australia at approximately 1430 hours. There were a number of blows exchanged and in a single bite one of them severed a piece of tissue from the left ear of the other, spat it out and left the scene. The victim of the assault was

transported to Flinders Medical Centre and within 30 minutes of the attack a uniformed police patrol recovered the piece of ear from the scene and placed it in a saline solution. Although it was apparent that the avulsed piece of tissue had originated from the left ear of the victim, it was decided by the medical officer who treated the victim that an attempt to reattach the fragment of ear would probably be unsuccessful due to the large surface area involved and relatively avascular nature of ear tissue.

On the same day the offender was arrested, charged and subsequently taken to Adelaide City Watchouse. Impressions of the suspect's dentition were obtained using GC Examix# at the request of the Police under Section 81, subsection 4 of the Summary Offences Act. The following day the fragment of ear, which had been stored in saline was transferred to alcohol after being delivered to the Forensic Odontology Unit, University of Adelaide.

METHOD

The fragment of tissue was pale in colour with hairs present on the surface. The tissue was convoluted in shape and it was necessary to secure it to a surface in order to measure the dimensions and inspect the surfaces. The approximate length and maximum breadth were around 44mm and 33mm respectively.

One border of the tissue appeared to be intact, whilst the other border displayed an irregular lacerated margin (Fig. 1).

The entire fragment of tissue appeared to be part of the posterior helix above the lobe of a human left ear. The margins were irregular in outline with an area of fatty tissue toward one end. In the fossa of the helix there was a pattern of five depressions which displayed the characteristic appearance of marks made by human teeth. It appeared that with his head in a rotated position relative to the victim, the assailant had applied the lower anterior teeth to the fossa of the helix, and had bitten applying the upper anterior teeth to the outer border of the helix. Sufficient force had been applied during this action to allow tearing and avulsion of the tissue surrounding the area, the lacerated margin was approximately 3.0mm from the area where the teeth had been positioned.

#GC Examix™ GC Corporation 76-1 Hasunuma-Cho-Itabashi-Ku, Tokyo Japan

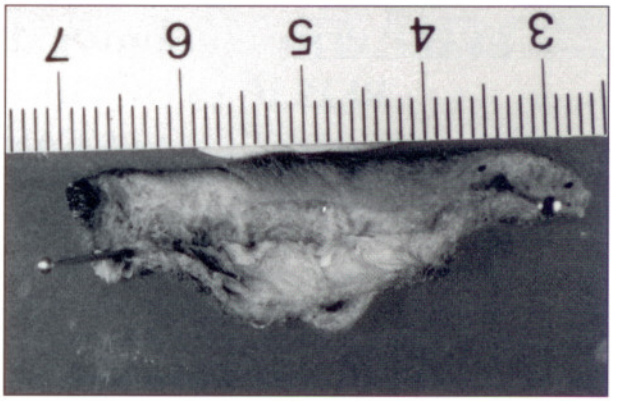

***Fig.1**: Fragment of ear displaying a lacerated margin and a pattern of depressions*

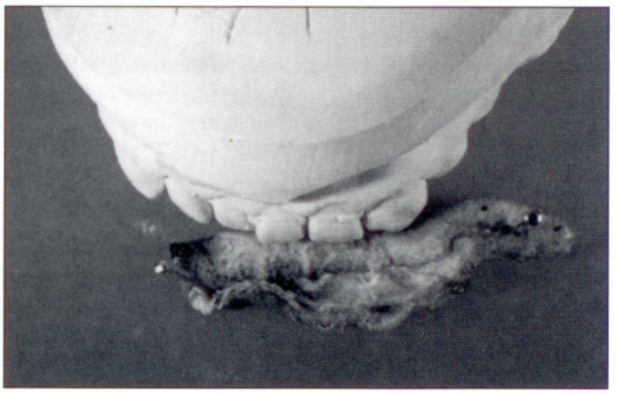

***Fig.2:** Fragment of ear with stone cast of the suspect's dentition*

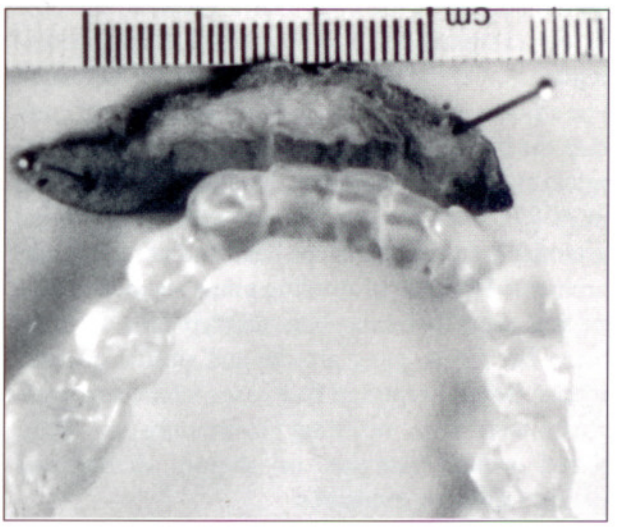

***Fig.3:** Fragment of ear with a clear acrylic replica of the suspect's dentition*

The impressions of the suspect's dentition were used to provide positive replicas of the dentition using 'Leocryl'* acrylic resin.

This method of reproducing the suspect's dentition in a transparent form permitted direct alignment and simultaneous viewing of both the incisal and labial surfaces of the suspect's dentition with the pattern of marks present in the tissue surface.

The dimensions and arrangement of these marks were analogous with features of the lower anterior teeth of the suspect and it was possible to orientate the depressed marks with respect to the incisal surfaces of three teeth (Figs. 2 and 3).

There was correspondence between the outline of the labial surfaces of the lower right canine, lateral and central incisor teeth and the border of the marks closest to the lacerated margin (Fig, 3). Each of the marks was distinct, separated by raised areas which were orientated in alignment with the spaces and distances inbetween the corresponding anterior teeth. The most notable single feature which was revealed by this method of comparison involved an imprint within the tissue which was outlined by three borders. The contour of these borders was similar in orientation and dimensions to the incisal edge of the lower right lateral incisor including the labial margin and mesial and distal incisal angles.

The opposing surface of the ear fragment demonstrated other depressions which were ill-defined but also appeared to be generated by human teeth and would have been made at the time that the portion of ear was torn from the victim.

DISCUSSION

As previously stated, Levine[1] observed that the interpretation of a bitemark in human skin requires that several factors are considered and these factors may vary between different cases. In this instance the bitemark was sustained in a piece of tissue which became removed from the victim and as a result there were no inflammatory changes because of loss of blood supply and also because of the avascular nature of ear tissue. That part of the ear has relatively little subcutaneous tissue, containing mostly fibroelastic cartilage. Despite the lack of subcutaneous tissue the skin of the ear had retained some characteristic features, the most notable of these being a distinct outline which corresponded to the incisal surface and incisal angles of the lower right lateral incisor. In addition the labial profile contours of the adjacent canine and central incisor were evident, interrupted at intervals by raised areas which represented the distances between these three teeth.

The ability to make meaningful interpretations of bitemark evidence relies heavily on both the nature of the tissue involved and the reproduction of unique characteristics displayed in the dentition of the perpetrator. The validity of bitemark evidence requires that each individual dentition has a combination of features relating to the size, shape, occlusion and arrangement of teeth which is unique to that individual. The range of morphological variation of both maxillary incisors and canines was studied by Taylor [6,7] and it was concluded that the range of variation negates the concept of a 'typical tooth'. Sognnaes et al. [8] compared the bitemark pattern of monozygotic twin pairs and despite similar developmental morphology of individual teeth, significant variation was evident between twins in each pair with respect to individual tooth position and arrangement in the anterior segment. Rawson et al. [9] studied precise registrations of dentitions from 397 individuals and concluded that the human dentition is unique beyond reasonable doubt. It seems therefore that while the uniqueness of a person's dentition can be demonstrated objectively, the physical nature of a bite in human skin varies according to location on the body and age of the individual and the response of skin to bite pressure.

Various methods have been suggested for the analysis of bitemark evidence. Dorion[10] recommended the use of transillumination for poorly defined marks, Bang[11] made analyses using visual description, stereo-photography, scanning electron-microscopy and stereometric graphic plotting, but also observed that no one particular method has proved to be applicable to every case.

The marks which were observed on the surface of the avulsed tissue in this case were distinct in outline and it was determined that the method of

*Leone Orthodontics, Gunz Dental Supplies, Locked Bag 690, Beaconsfield, NSW 2014, Australia

interpretation and comparison to be applied must easily demonstrate those features of the outlines which were analogous with the features of the suspect's dentition. The translucent nature of the acrylic replicas permitted direct visual comparison of the incisal edges and labial surfaces of the anterior teeth with the depressions in the tissue without obscuring the area and thus the relationship between the dentition and the tissue at the time the bite occurred could be better appreciated.

The suspect was on bail at the time that this assault occurred. He was subsequently charged with assault occasioning grevious bodily harm and after pleading guilty received a two year prison sentence

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ODONTOLOGICAL IDENTIFICATION IN TWO HIGH-IMPACT, HIGH-TEMPERATURE ACCIDENTS

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ABSTRACT

Here we report on two high-impact accidents both of which were complicated by fire. The first accident involved a light aircraft which crashed in a gorge while performing a low, slow flight. Both victims were found to have experienced extensive dental fracturing. The second accident was a high speed motor vehicle crash followed by incineration which left the two victims without dental fracturing. In the absence of comparative data on the effect of burning on teeth the cause of the foregoing remains unanswered. **(J Forensic Odontostomatol 1999;17:44-46)**

Keywords: identification, aircraft crash, incineration

INTRODUCTION

Identification of the victims of high impact aircraft and motor vehicle accidents may be difficult if the bodies are severely charred or dismembered. In these cases routine identification relies mainly on dental records which may be supplemented by more sophisticated techniques such as DNA fingerprinting or mitochondrial DNA analysis.[1-4] However, teeth that are subjected to high temperatures carbonise and become highly brittle[5] and can thus easily be fractured or lost during recovery and post-mortem procedures. Additionally, radiography of a resected maxilla and mandible presents two major problems: the lack of soft tissue which often leads to over-exposure of the radiograph, and difficulty in aligning the resected jaws without the cranium.[6] In what follows, we describe two recent identifications which involved high velocity accidents complicated by incineration.

Case I - Taieri Gorge Plane Crash

On Saturday afternoon, 27 September 1997, a Tiger Moth bi-plane carrying two persons crashed into the rugged Taieri Gorge south-west of Dunedin, New Zealand. Because the accident occurred whilst the plane was performing aerobatics above a loaded sight-seeing train, police and rescue personnel were immediately called in. However, the crash site proved

Fig. 1: *Site of impact of the Taieri air crash*

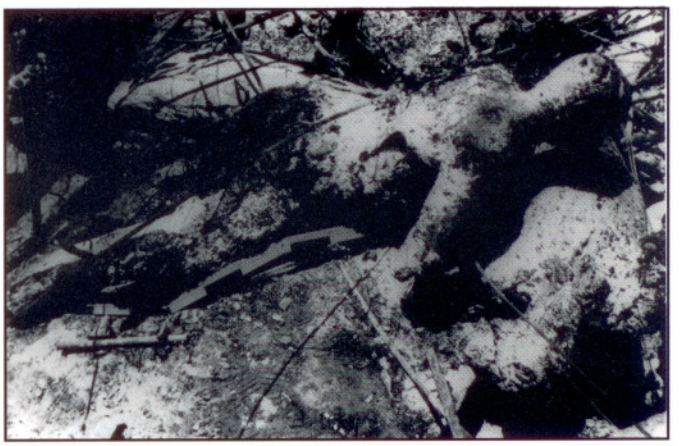

Fig.2: *Highly carbonised body of the passenger in the Taieri air crash*

to be highly inaccessible, and the bodies were not recovered until the following day. Figure 1 shows the site of impact in the rugged Taieri Gorge and Figure 2 the highly carbonised body of the passenger which was located two meters away from the wreckage. From the intact frame of the plane, it can be deduced that the accident was not a particularly high impact one.

Upon initial examination, both corpses were found to have suffered multiple fractures and severe incineration to their entire bodies. As is the case with many victims of incineration initial inspection revealed charred, tightly locked jaws which had to be resected by submandibular incision, with care taken not to damage the roots of the maxillary teeth or any possible impacted wisdom teeth. The jaws were then labelled and transferred to the University of Otago School of Dentistry for investigation. Following debridement and a full series of periapical radiography, a dental charting was recorded on Interpol postmortem DVI forms (F1 and F2) which was found to match those obtained from the victim's dental practitioner.

Case II - Wanaka Car Crash

A couple heading north towards the Haast pass during a New Zealand holiday on 3 March 1998 died instantly when their utility van was involved in a head-on collision with a campervan near the township of Makarora in the Wanaka district of the South Island. The force of impact embedded the utility van into the front of the campervan, the former bursting into flames upon impact.

When we examined the two corpses these were found to have been extensively incinerated with severe trauma to both crania. As intra-oral examination could not be performed directly, the upper and lower jaws of both victims were resected, labelled and transferred to the University of Otago School of Dentistry for investigation. Antemortem dental records were obtained for both victims which made their identification straightforward.

DISCUSSION

What made these two cases noteworthy was the combination of high impact with extensive carbonisation common to both incidents. Radiological investigation of the teeth however, showed that the two victims of the light aircraft crash had suffered severe dental fracturing, which was not noted in the victims of the motor vehicle accident (Figs.3,4). Yet the latter appeared to involve the greater impact.

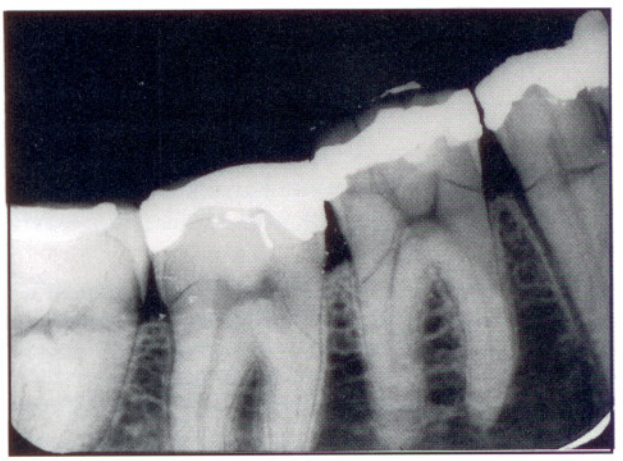

Fig.3: *Postmortem periapical radiograph of the lower right segment of aircraft victim*

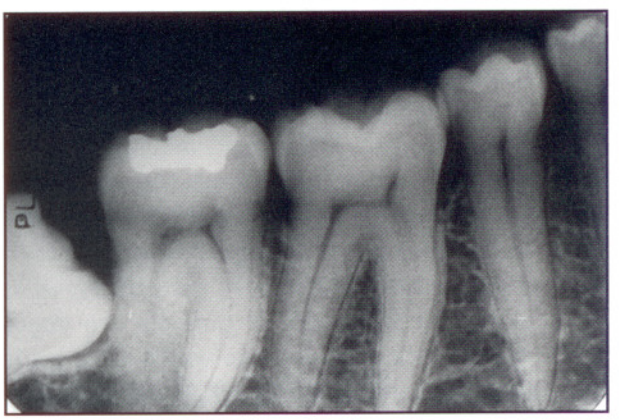

Fig.4: *Postmortem periapical radiograph of the lower right segment of motor vehicle crash victim*

The effects of burning temperature on teeth has attracted little attention from research workers. Recently Muller and her co-workers[7] have studied extracted premolars which were incinerated in a furnace at temperatures rangeing from 150° to 1150°C.

Enamel was found to show cracks at 150°C with dentinal cracking being evident at 450°C. Interestingly, dentine retained its tubular structure up to 1150°C. To understand why two of the four victims of the high impact incinerations discussed here showed enamel and dentine fracture, one would need to know more about the behaviour of teeth under impact and at different temperatures. We hypothesise that it is probably a combination of temperature and force of impact which led to the fractured teeth in the aircraft crash victims. We cannot, however, account for the absence of fracturing in the victims of the motor vehicle accident.

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RADIOGRAPHY IN FORENSIC DENTAL IDENTIFICATION - A REVIEW

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ABSTRACT

It is recognised that reliable objective evidence is provided by medical and dental radiographs in forensic identification. This depends on the observation and comparison of anatomical and artificial structures recorded in both ante-mortem and post-mortem radiographs, and which can be regarded as unequivocal evidence. The introduction of new technology into the area of radiographic imaging provides both clear advantages and also some cause for concern where image enhancement can be carried out which may give rise to dispute if this technology is to be applied to forensic dental identification. To date there have been no published forensic case reports involving the use of directly acquired digital radiographs but it is anticipated that this will change. The technical advantages and known limitations need to be considered if this method of radiography is to be applied in forensic dental identification. **(J Forensic Odontostomatol 1999; 17:47-53)**

Keywords : forensic dental identification, radiography, direct digital radiography.

INTRODUCTION

The scientific methods employed to compare the results of post-mortem examination with ante-mortem data are required to be accurate, objective and reproducible. The use of medical radiographs initially suggested by Beclere in 1918[1] was supported by Schuller in 1921[2] who proposed that the bony structure of the cranium including air sinuses visible on radiographs may be used for identification procedures. This method of comparing the structures of the cranium visible on postmortem and ante-mortem radiographs was applied and published in 1927.[3] Subsequently there have been many reports involving the use of medical radiographs in the process of forensic identification.[4-16] Visible features which were used for comparison typically included anatomy, fractures, evidence of pathology and post-surgical features. In addition to providing proof for positive identification, radiographs have revealed structures which may exclude a presumed identification.[8]

The first application of radiography in clinical dentistry began as early as 1896,[17] with a report of its use in forensic dental identification in the case of a bitemark wound in 1932.[18] The routine diagnostic imaging of dental structures in the form of intra-oral, extra-oral and panoramic radiographs provides a per manent and objective record of the dental hard tissues in the course of dental diagnosis and treatment.

When included as ante-mortem data, dental radiographs provide a valuable tool in identification which will also include details of any restorative treatment.

As stated by Maclean *et al.* [19] *'dental identification relies heavily on the disclosure of ante-mortem treatment in the comparison process'*. When this is done radiographically, metallic restorative materials provide ideal artefacts for the comparison process including other details such as retentive pins, endodontic posts, cements and obturation materials.[19,20] Historically, artefacts have provided the principal points used during the identification process and there have been many reports of the application of dental radiographs and subsequent establishment of identification[21-26] or exclusion of a presumed identification. [27]

Validation studies have indicated that there may be problems encountered with the use of dental radiographs which limit the accuracy of establishing an identification, for example:

- therapy performed between ante-mortem and post-mortem radiographs may limit accuracy in establishing identity,[28]
- unrestored dentitions,[28]
- extensive time intervals between ante-mortem and post-mortem radiographs,[29] and

- time lapse between radiographs displaying primary and permanent dentitions.[30]

Another fundamental problem which is known to influence the information included in dental radiographs relates to the differences in projection geometry of the x-ray source between ante-mortem and post-mortem exposures. Alteration of the path of the radiation beam through an object or change in position of the object relative to the beam between successive exposures will alter the image intensity values recorded and therefore the radiographic information.[31]

Within the last two decades there has been an increase in the use of dental restorative materials which are less obviously radiopaque than metallic materials.[32] In addition there has been a decrease in the rate of dental caries in most industrialised nations[33-35] which suggests that there will be a reduction in the number of artificial features visible on dental radiographs. Both these trends may significantly restrict traditional forensic dental identification methods.

In spite of evidence indicating that the rate of dental caries may be in decline, there has been no evidence to date suggesting that a reduction in the application of dental radiography in clinical dental practice has taken place. It may therefore be assumed that dental radiographs will continue to be included in ante-mortem dental records.

Recent Advances in Dental Radiographic Technology

The traditional method of establishing a radiographic record involves the use of radiographic film. Recent years have seen the introduction of Direct Digital Radiography (DDR) into dentalpractice[36] where the direct digital method of acquiring a radiograph replaces the film with an image receptor which may be either a Charge-Coupled Device (CCD) or a Storage Phosphor Plate (SPP) sensor. Analogue information is any information that is represented in continuous form whereas digital information is represented in discrete units.[37] Traditional radiographic film is considered to be an analogue image because it has nearly continuous spatial and grey scale resolution while a digital image is a numerical representation of an image in discrete units.

Radiographic information in digital form is described in binary digits positioned in rows and columns known as a matrix and each single unit in the matrix is referred to as a picture element or pixel.[38] Individual pixels assume a digital value corresponding to a level or shade of grey, the value of which is based upon the information received and recorded by the image receptor. The bit depth or pixel depth refers to the number of grey levels per unit of image amplitude and determines how accurately a digital radiograph represents correct brightness or density at each pixel position.[39] A pixel with a bit depth of 1 has only two possible values, black and white, a pixel with a value of 8 has 2^8 or 256 possible values and a bit depth of 24 has 2^{24} or approximately 16 million values. Hence a larger pixel depth allows for more bits of information which represent the levels of image intensity.[40,41]

The matrix size and number of pixels in a digital imaging system determines the spatial resolution and so dictates the size of detail that an image can display. Contrast resolution is the ability to distinguish a feature from its background and is determined by the number of grey scales in the system. To accurately locate or represent a boundary a large number of pixels and distinguishable grey levels are required[42] and studies of digital radiographs have led to the conclusion that a smaller pixel size or higher resolution leads to greater levels of diagnostic accuracy.[43-46]

Historically, analogue radiographic images have been converted into digital form for the purpose of evaluation and research. The most commonly used spatial resolution for this process was a matrix of 512 rows and 512 columns with a pixel depth of 8 bits. At present the different direct digital radiography systems have varying pixel sizes, number of pixels and sensitive areas included in the receptors and none of them matches the resolution of film radiographs.[36] Ohki *et al.*[44] stated that conventional intra-oral films have a high spatial resolution, in the order of 20 micrometres and observed that digitised images with a pixel size greater than 100 micrometres had significantly lower diagnostic accuracy.[44] An evaluation of the Digora® storage phosphor system revealed that a pixel size of 71x71 micrometres was sufficient to detect periapical lesions.[47]

Densitometric evaluation of radiographs is performed in order to detect any increase or decrease in bone density, and involves measurements derived from pixel grey scale values. The main methods of establishing densitometric data are the digital subtraction technique,[48,49] ^{125}I absorptiometry,[50] use of an aluminium step wedge[51,52] and evaluation of the distribution of the pixel grey scale values within regions of interest.[53],[54] These methods of evaluation require that the imaging device used provide highly accurate representation of the object. Hildebolt *et al.* [55] observed that for capturing the information content of alveolar bone a spatial resolution of 50 micrometres was adequate, but for densitometric evaluation it was recommended that a pixel depth of 12 bits which provides 4096 grey levels should be used for this purpose as it would provide more precise definition of each grey scale.

One of the chief advantages of DDR is that in comparison with intraoral films, images can be obtained at considerably lower radiation doses without any significant loss in diagnostic information.[36,56] There is a clear advantage in reducing the radiation dose, but not to the point where the statistical fluctuation of their distribution results in increased granularity and limits the resolution.[56] This effect has been observed with both SPPs[57] and CCDs[58] although Borg *et al.* [58] reported that the effect was less visible with SPPs when compared with CCDs and radiographic film.

To date most studies evaluating the diagnostic sensitivity of direct digital radiographs have been performed under laboratory conditions.[59-62] With respect to caries detection, Wenzel *et al.*[59] observed that quantitative measurements of caries depth on digitised radiographs were strongly correlated to the histological measurements. In the report of another study however the DDR systems evaluated were not accurate in diagnosing initial caries when compared with conventional film.[63]

Clearly, it can be appreciated that the spatial resolution at specific contrast settings in conjunction with the display of any direct digital imaging system are major factors in determining the diagnostic sensitivity of such systems. The technical constraints of these systems have important implications if directly acquired digital images generated by such systems are to be used in dental identification.

The information contained in a digital radiographic image is stored as a set of numeric data points and as such, image processing algorithms can be applied to present an image to the observer that is better adapted to the viewer's perceptive ability.[64] It has been observed that the choice of image treatment algorithms in digital radiographs seems to be task-dependent,[65] however to date there is only sparse evidence concerning the application of enhancement facilities for clinical interpretation.[66]

Forensic Applications of Digital images

The advantages and possible applications of digital images for clinical and forensic purposes have been recognised.[67-75] The storage and retrieval of dental radiographic images on laser optical disc for archiving and transmission via fibre optic telephone lines has been proposed[68-69] while Fitzpatrick *et al.*[71] reported seven cases of radiographic identification where digitised images were used. Image treatment algorithms were used to enhance skeletal details and the radiographic outline of a preformed endodontic post visible on an ante-mortem radiograph for comparison with a preformed post found with some human remains.[71]

The interpretation of dental radiographs for clinical purposes requires the discrimination between the presence or absence of a physical signal i.e. the presence or absence of an abnormality. The processes involved in the interpretation and comparison of ante-mortem and post-mortem dental radiographs require that features of similarity or points of agreement are recognised in order to establish a match or non-match. The potential for the application of image treatment filters to assist the identification process has been recognised and use of video-images of panoramic radiographs and intra-oral radiographs under test conditions has been suggested.[73] Image processing under test conditions has also been applied[74-76] and the participants in Eisenberg and Haller's[75] study reported that in their opinion the image treatments were beneficial. It was claimed in one of the studies[76] that the processing was 100% specific and 100% sensitive in all test cases, but there was no statistical evaluation included in this report.

The use of digital image processing in a forensic case has been reported[77] in which imaging software

allowed the visual alignment of the dentition evident on ante-mortem and post-mortem video-images. In other studies[71,75] the use of image inversion to assist the comparison process has been suggested while a clinical evaluation of digital radiographs showed that inversion of the grey scale had no diagnostic advantage[78] and so it would have limited value in the identification process.

It is anticipated that filmless radiography will replace the use of analogue dental film partly because *'the digital form of information has acquired a mobility, a pervasiveness, an ability to be transformed into new shapes and sizes'*.[79] The integrity of stored data however is of particular relevance for both clinical and forensic purposes and whereas a manual file cannot be altered readily without some detectable trace the electrical pulses in which digital information is stored can be modified without evidence. These potential medico-legal implications of computed radiography have been addressed[80,81] in a study where a group of dentists was requested to try to detect an altered digital image in a series of originals with the result that the detection rate was found to be close to random.[82]

Conventional radiographic film generates a permanent record at the exposure stage, and equally, digital radiography is considered to provide a radiographic document at exposure. However, if image processing is applied in order to enhance details in the image it has yet to be determined whether the result may also be considered a radiographic document.

Questions remain with respect to the degree of image processing which can be considered enhancement for visual interpretation or which may result in accidental or deliberate misrepresentation of the original radiographic information.

The application of radiographic records in forensic identification has long been recognised and it is now anticipated that filmless radiography will replace conventional medical and dental film radiographs. To date there have been no reports documenting the integration of directly acquired digital radiographs into the forensic identification process but it may be expected that with widespread use of these systems in clinical practice, this will not remain the case.

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BOOK REVIEW

Dental Anthropology; Fundamentals, Limits and Prospects

K.A. Alt, F.W. Rösing & M Teschler-Nicola (Eds)

Springer, Wien. 1998. ISBN.3-211-829741 pp564

The past decade has seen an avalanche of data on dental anthropology in the broad sense. We have seen the expansion of the fields of tooth size and morphology, tooth structure and mineralisation, ontogeny and phylogeny of teeth, bioarchaeology and clinical anthropology, dental wear and surface loss, and age and gender estimation. Kurt Alt's book serves the reader a generous sampling of these important developments. This is reflected in the major subdivisions of the book which are; Teeth in History, Dental Morphology, Structure and Evolution, Dental Pathology and Epidemiology, Nutrition and Human Behaviour, Age and Sex Determination, and finally, Geographical and Familial Tooth Variation.

The book is edited by Kurt Alt of Freiburg University, Friedrich Rösing of the Institute of Anthropology at Ulm and Maria Teschler-Nicola of the Natural History Museum in Vienna. This continental flavour is enhanced by the spread of its contributors, more than half of whom were from continental Europe. Other contributions originated from Japan, England and the USA.

Let me state at the outset that this book can be read profitably and most enjoyably by forensic dentists or those with an interest in forensic odontology. We are all aware that dental anthropology encompasses disciplines ranging from physics and biochemistry to archaeology and nutrition. No one treatment of the entire field could be definitive. Yet this book skilfully samples the field to reflect its subject richness and subtleties.

Teeth in History consists of four chapters with the chapter on the history of dental anthropology as its centre-piece. Alt and his co-authors review the early theories of odontology and the subsequent birth of the field of dental anthropology in the early 60's. The chapter ends with an exposition of the current standing of research in this area. Forensic dentists will be intrigued by the chapter on the evolution of dental nomenclature.

Dental morphology, structure and evolution are addressed in six chapters of which two would be of interest to forensic experts: Anatomy and Morphology of Human Teeth and Hereditary Dental Anomalies. While the first of these is a rather sketchy affair, the second is more than adequate. The latter chapter is well written and informative and also introduces the reader to a vast number of publications in German which one would not normally have read.

Dental pathology and epidemiology is possibly the least apposite to those interested in forensics. Yet, as a practicing dentist one enjoyed excellent sections on caries - the ancient plaque of humankind, periapical lesions and enamel hypoplasias. The chapter on enamel hypoplasias deserves particular mention; it is beautifully illustrated and well referenced. I was surprised, however, to find a table (p256) giving the criteria for radiographic differentiation of periapical granulomas and radicular cysts; are these not microscopic rather than radiological diagnoses?

Nutrition and human behaviour was, though well written, possibly less informative from a forensic point of view. Of the four chapters in this section I was most impressed by the one on dental wear by Jerome Rose and Peter Ungar. Those of us working in the field of tooth surface loss know and value the contribution that Peter Ungar's research has made to it. As expected, their review is informative and addresses most of the issues that are currently being debated.

Age and sex determination, is concerned with allocation, with considerable emphasis on dental metrics. Helen Liveridge and her co-authors present an excellent review of the subject with reference to non-adults. The focus of Rösing and Kvaal's chapter is age estimation in adults. It concludes with the statement that modern ageing techniques are no longer insufficient, particularly if one considers the processes of cementum annulation and racemisation. Another most valuable chapter for the forensic dentist is the one on sex determination using tooth size by Maria Teschler-Nicola and Hermann Prossinger. The final chapter is on the reconstruction of missing tooth dimensions by Prossinger. Again a most interesting article for the forensic expert. Inevitably one can find areas of weakness when one deals with this breadth of material. One would, for instance, have liked to have seen a discussion on allocation versus discrimination (**vide** *Am J Phys Anthropol* 79:331-337, 1989).

Geographical and familiar tooth variation focuses on global trends in tooth size and also on kinship studies.

In conclusion, one would have to say that a book of this size could usefully have taken a more detailed approach, at the expense of an eclectic coverage of the broad field of dental anthropology. Nevertheless, with this beautifully presented book Kurt Alt and his co-workers have made a unique and important contribution to this field.

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12 July 1999