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CONTENTS

POSSIBILITY OF PATERNITY TESTING USING RFLP ANALYSIS ON A VERY SMALL AMOUNT OF MATERIAL

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ABSTRACT

Paternity testing by DNA analysis was carried out using dental pulpal and chorionic villous tissue from two children respectively, and fresh blood samples obtained from the alleged parents. DNA was extracted spectroscopically from the pulp of an upper wisdom tooth (16μg) and the chorionic villi (53μg). The RFLP method was used for DNA analysis of the parent-child relationships because both of the DNAs extracted had a high molecular weight. Distinct bands were detected with ^{32}P-labelled multi-locus (Myo) and single locus (pYNH24) DNA probes. In the case of the dental specimen all of the bands of the child's DNA were found to be derived from either of the alleged parents, demonstrating a consistent parent-child relationship (the probability of established paternity was 99.86%) whilst in the case of the villous specimen the father-child relationship was denied. This procedure can provide much information using very little material for analysis but where the samples are in a good condition. **(J Forensic Odontostomatol 2001;19:1-4)**

INTRODUCTION

The forensic application of DNA analysis has increased over the past few years[1] and there have been great advances in the identification of individuals using PCR (polymerase chain reaction) analysis which is the most widely used method of DNA analysis in forensic medicine. Identification of DNA polymorphism has also become a popular test in forensic science because of its increased sensitivity. Conversely, DNA fingerprinting[2-6] based on the restriction fragment length polymorphisms (RFLP) analysis is a minor forensic procedure but it may provide more information than PCR.

Conventional paternity testing is based on the detection of as many blood type genetic markers as possible in order to increase the accuracy of the result. If fresh blood samples are not available from the alleged father, mother or child, or if tissues other than blood are the only materials available only limited blood types are detectable and it is difficult to ensure the accuracy of the test result.

We were asked to give an expert opinion of paternity testing by DNA analysis using pulp tissue from a wisdom tooth (case 1), chorionic villous tissue (case2) and fresh blood samples obtained from each of the alleged four parents. The wisdom tooth was from a 22 year-old male extracted as a result of pericoronitis and stored for a period of 2 years. DNA fingerprinting was used because the quantities of both the pulpal and villous tissues were extremely small, and because it may provide more information than PCR. Many laboratories, when presented with these small samples would initially use the PCR procedure.

The main purpose of this study was to confirm the possibility of using the RFLP method with a combination of multi-locus (DNA fingerprinting) and single locus DNA probes for analysis of these extremely small samples.

MATERIALS AND METHODS

Paternity testing by DNA analysis was carried out using three types of tissue sample: pulpal tissue (dry weight 2.4 mg) isolated from the pulp cavity of an undecayed upper wisdom tooth kept at room temperature in a dry environment for 2 years following extraction[7] (case1), chorionic villous tissue (fresh

weight 500 mg) obtained by sampling under ultrasonography at 14 weeks of gestation (case2) and fresh blood samples obtained from each of the four alleged parents.

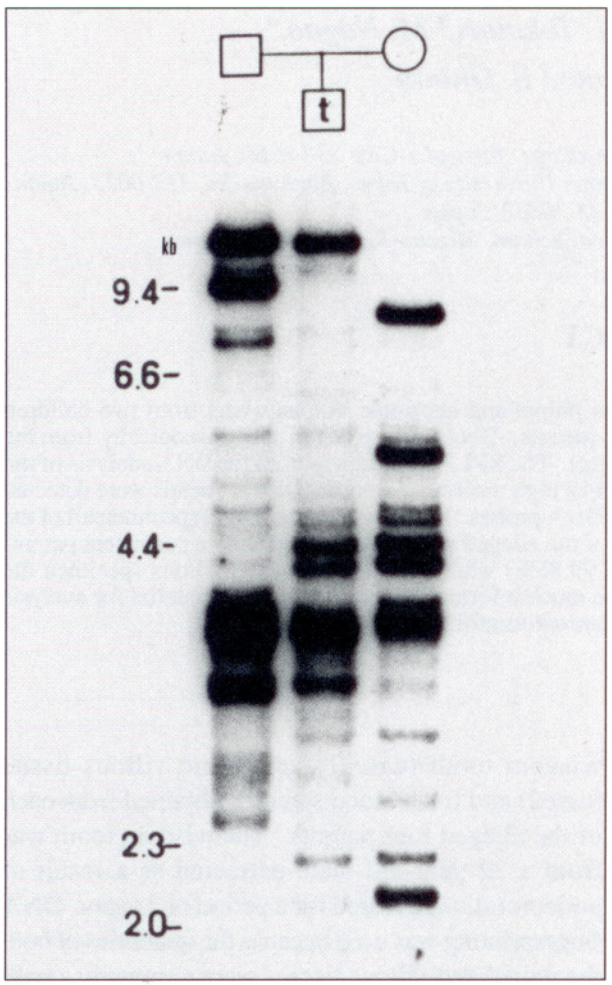

Fig.1: *DNA fingerprints used in paternity testing in an inclusion case (case1). DNA fingerprinting of blood DNA from the father (left) and the mother, and of DNA extracted from the son's tooth (t) is shown. Eliminating maternal bands allowed identification of paternal DNA fragments in the son's DNA. Molecular weight markers are given on the left in kilobases.*

The dental pulp, chorionic villous tissue and leukocytes that were isolated from the blood samples were incubated overnight in 1.5 ml microcentrifuge tubes at 50°C in lysis buffer containing proteinase K (0.1 mg/ml) and 2% SDS. The DNA was then extracted by phenol/chloroform and precipitated in 2 volumes of absolute ethanol. DNA from the alleged parents was extracted from lymphocytes in the fresh blood samples by the usual method. The DNA was pelleted by centrifugation at 3000 rpm for 20 min, air-dried then dissolved in TE (10 mM Tris, 0.1 mM EDTA) to form a DNA solution. To prevent the loss of possibility, DNA yield was determined by comparison to known amounts of intact human DNA after electrophoresis (1.0% agarose, 100V, 30 min.) and ethidium bromide staining. High-molecular-weight DNA extracted from each sample was digested with *Hae* III, electrophoresed on an agarose gel and hybridized with a ^{32}P-labelled multi-locus DNA probe Myo[8] and a single locus (or locus specific) DNA probe pYNH 24 in RFLP analysis, as described previously.[6]

RESULTS AND DISCUSSION

DNA was extracted spectroscopically from the upper wisdom tooth (16µg) and the chorionic villi (53µg). The RFLP method was used for DNA analysis of the parent-child relationships because both of the DNAs extracted had a high molecular weight (data not shown). Distinct bands were detected with ^{32}P-labelled multi-locus and single locus probes and detection of bands with one type of probe was followed by alkaline treatment to remove the probe and secondary detection with the other type of probe on the same filter.[6]

In the case of paternity testing with the dental specimen (case1), all bands obtained from DNA of the

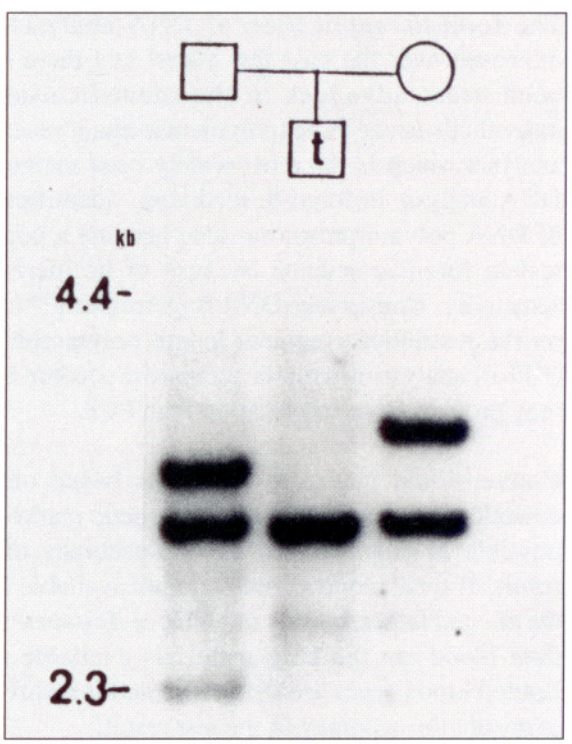

Fig.2: *Paternity testing as shown in Fig. 1. The nylon filter used in Fig. 1 was treated with NaOH, and the Myo probe was removed. The filter was hybridized again with the ^{32}P-labelled single locus DNA probe pYNH24.*

tooth were derived from both of the alleged parents, demonstrating a consistent parent-child relationship. The probability of established paternity was 99.86% using a gene frequency of multiple loci of 0.27[8], and 97.75% using a gene frequency of a single locus of 0.023[9] (Figs.1 and 2). In the case of the villous specimen (case2) the bands were identified with the multi-locus DNA probe in the child's DNA. The father-child relationship of this pair was denied (Figs.3 and 4).

Currently, DNA analysis is used as an auxiliary to blood type analysis in paternity testing and its use by RFLP cannot be accepted as a reliable, stand-alone procedure because of the problems with DNA probes[3] and the lack of sufficient basic data. Although multi-locus DNA probes can detect many bands and provide a large amount of information, the number of loci and alleles is not known, leading to inconclusive results. Conversely, single locus DNA probes can be used to calculate allele frequencies but can detect only 2 bands at most and therefore provide limited information.

Accurate blood type analysis for paternity testing was not feasible in these cases because unusual specimens were used. On the other hand almost all current DNA testing uses PCR[10] because sufficient high-molecular-weight DNA is usually available to allow for any type of DNA analysis. We therefore used the most fundamental technique of DNA analysis, RFLP (in a supporting capacity for PCR analysis), with a combination of multi-locus and single locus DNA probes for analysis of each sample. In this way the drawbacks of each type of probe (ambiguous loci and limited information) were compensated for by the other's benefits, and useful information was obtained. Although we used a radioisotope in terms of DNA marker detection,

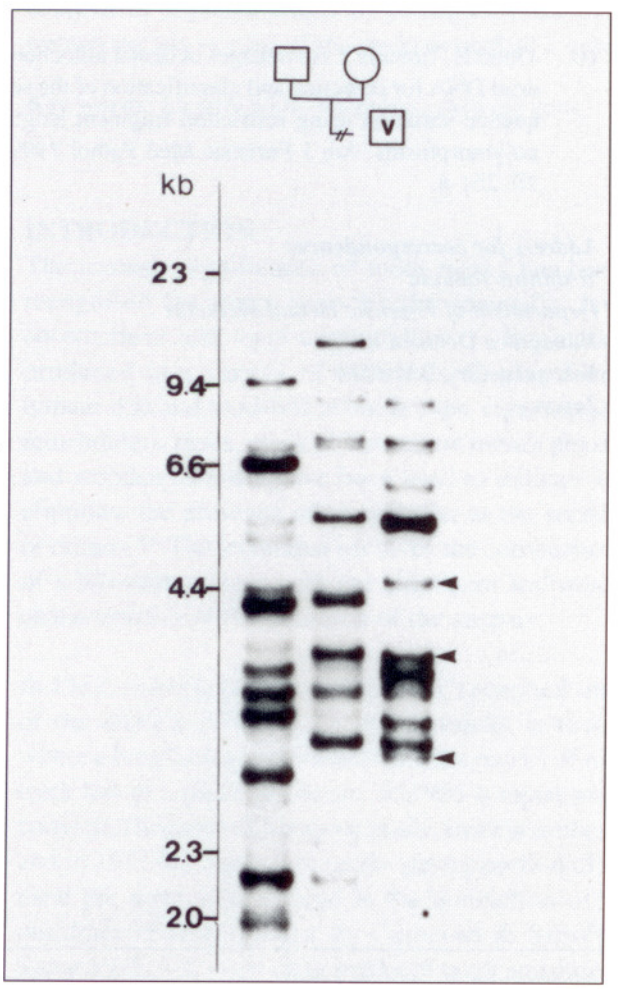

Fig.3: *Paternity testing in prenatal diagnoses with the ^{32}P-labelled multi-locus DNA probe Myo using Hae III in an exclusion case (case2). DNA fingerprints of blood DNA from the father (left) and the mother, and of DNA extracted from the chorionic villi (v) are shown. The paternal fragments are arrowed.*

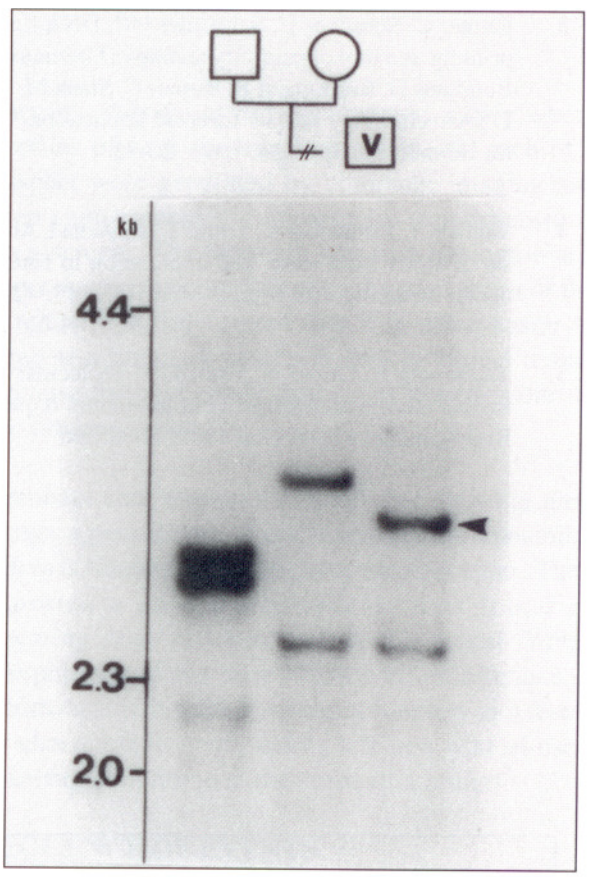

Fig.4: *Paternity testing in prenatal diagnoses as shown in Fig.3. The filter was rehybridized with the ^{32}P-labelled single locus DNA probe pYNH24. The paternal fragments are arrowed*

highly sensitive non-isotopic probes detected by chemiluminescence is a conceivable procedure for mainstream use, but the DNA analysis using a radioisotope is rarely carried out today, and would be in the future.

DNA analysis in paternity testing based on RFLP is restricted by the condition of the sample but if analysis is possible RFLP will provide much more information than DNA analysis based on PCR and provide improved clarification of a parental relationship.

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ERRATUM: An error occurred in the last edition of this journal Volume 18, No.2, December 2000. On Page 46 in the article entitled "Wounding dynamics in distorted bitemarks: two case reports" the authors should read: "S. Sakoda, M.Q. Fujita, B-L. Zhu, S. Oritani, K. Ishida, M. Taniguchi and H. Maeda" - all from Japan.

IDENTIFICATION FROM A BITEMARK IN A WAD OF CHEWING GUM

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ABSTRACT

A wad of used chewing gum recovered from the scene of a burglary contained impressions of human teeth. Casts of these impressions displayed unique morphological characteristics which were found to show concordance with corresponding features present on casts of the posterior teeth of a suspect. **(J Forensic Odontostomatol 2001;19:5-8)**

Key words: Identification, bitemarks, chewing gum

INTRODUCTION

The forensic significance of tooth marks has been recognised for many years by the scientific, law enforcement and legal communities.[1,2] Bitemarks produced in a variety of materials ranging from human skin and foodstuff to bottle caps, cigars, cigarette holders, pipes, musical instrument mouth pieces and wooden cabinets have been used to indicate or eliminate the presence of an offender at the scenes of crimes.[3,4] The technique involves the comparison of a bitemark pattern with the alignment and other characteristics of the dentition of the suspect.

In 1933, Humble (cited by Whittaker[5]) reported one of the earliest (1906) cases of bitemarks in food, where a burglar was convicted from the marks of his teeth left in a piece of cheese. In 1955 a rapist was convicted because of his tooth marks in a cucumber[4] and in 1971 the marks left on the pastry portion of a meat pie were instrumental in the conviction of a murderer (Furness, cited by Cameron & Sims[6]). Some foods will elicit clear marks of teeth and cases have been reported of convictions resulting from evidence of bites on apple, chocolate, roast pork[7] and cheese[8]. Aboshi *et al.*[9] documented a case where profiles of both the bitemark and dental arch of a suspect were generated by computer imaging and then simultaneously compared by superimposition on a screen. The bitemark was in a lamington and this comparison contributed to the conviction of the offender. Ström[10] stated that it is often easier to analyse a bitemark in a food than in human tissue, because the skin easily distorts as it moves during the biting episode.

Furuhata and Yamamoto[3] stated that chewing gum leaves a poor record of bitemarks but the remaining saliva is suitable for blood group identification. They reported a case where indentations found in chewing gum failed to reveal the actual dental morphology of the biter. However, an offender in South Australia was convicted of burglary as a result of characteristic tooth marks left in a wad of used chewing gum found at the scene of a crime.

SEQUENCE OF EVENTS

In May 1990, the business premises of a physiotherapy clinic in Murray Bridge, South Australia

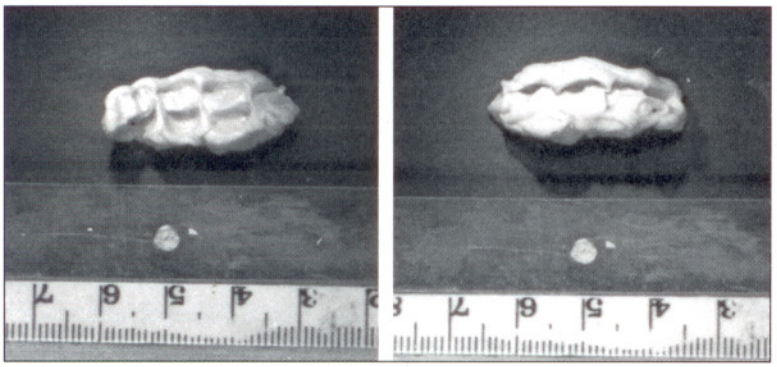

Fig.1: The wad of used chewing gum displaying bitemarks on both the surfaces

were broken into and a number of items were stolen. The owner reported the matter to police and during a full investigation of the scene a wad of chewing gum was found (Fig. 1) which the owner certified was not present prior to the burglary. The chewing gum displayed indentations suggesting human tooth marks and was retained by the police as evidence.

There had been a spate of house and business break-ins around the Murray Bridge area at the time, all with common characteristics. Among them was the manner of entry which was always by smashing of a window, and the items stolen included foodstuffs which indicated the offender(s) were probably juveniles of a small stature.

Fingerprints were also found at some of the crime scenes which were subsequently identified as those of a suspect who was a male aged 15 years. The suspect was eventually located, interviewed and arrested but at the time he denied involvement in the break-ins. When questioned specifically about the break-in at the physiotherapy clinic where the chewing gum had been found, he again denied any involvement.

Acting under Section 81 of the Summary Offences Act, 1953 (South Australia), the police arranged for impressions of the teeth of the suspect to be obtained by a local dentist. These, together with the chewing gum wad were referred to the Forensic Odontology Unit, University of Adelaide for examination.

Upper and lower casts were prepared from the suspect's dental impressions (Fig. 2) and a thorough examination of the chewing gum performed. It was pink coloured, with an aroma suggestive of strawberry flavour and measured about 29 mm in length and 12 mm in maximum breadth, roughly oval in shape with an abrupt curve at one end. Impressions of human teeth were present on two opposing surfaces. Photographs were taken of both surfaces and positive replication of the tooth impressions made with a polyvinyl siloxane impression material (Fig. 3).

Although there was some distortion of the tooth marks, it was possible to recognise clearly certain morphological characteristics of the teeth, and when these were compared with the corresponding teeth on the casts, both directly and by means of photographs, the following observations were made:

a) The impressions of teeth 23, 24, 25, 26 were produced on one surface of the chewing gum. There were 7 morphological features present on these teeth

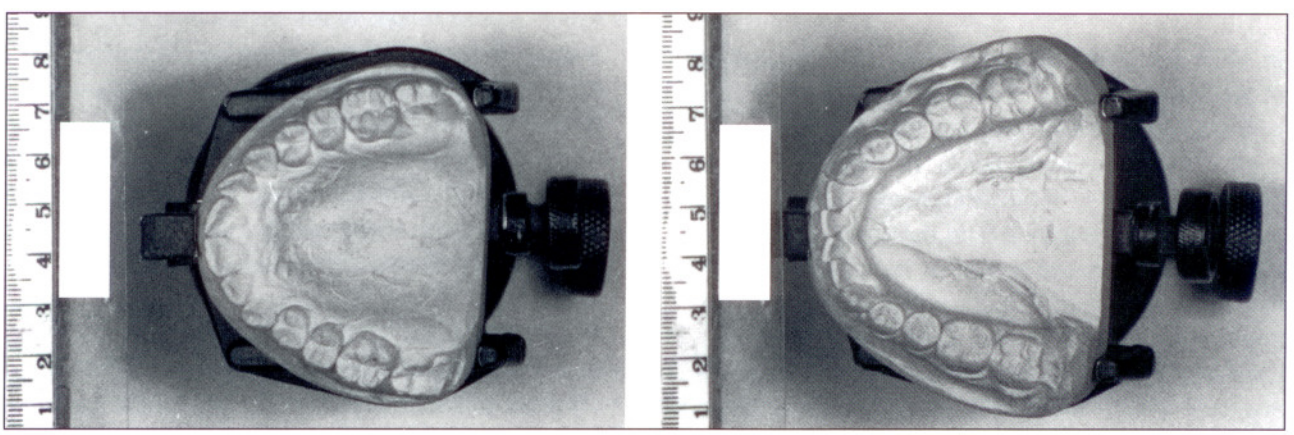

Fig.2: Upper and lower casts of the suspect

which were concordant with the corresponding teeth of the upper cast (Fig. 4).

b) On the reverse surface of the chewing gum it appeared that teeth 34, 35 and 36 had produced impressions but there was insufficient detail for teeth 34 and 36 to provide any positive comparison. However, tooth 35 demonstrated six morphological features which were concordant with the corresponding tooth of the lower cast (Fig. 5).

The results of these comparisons indicated that the impressions were indeed human tooth marks produced by teeth 23, 24, 25, 26, 34, 35 and 36. They also demonstrated that certain characteristic morphological features observed on their reproductions were concordant with corresponding features in the respective teeth of the casts of the suspect.

When confronted with the fingerprint evidence, a guilty plea to all charges was entered by the suspect in early 1991. A guilty plea was also entered to the charge of burglary at the physiotherapy clinic following the submission of the evidence confirming the positive identification of the tooth marks in the chewing gum as those of this same suspect.

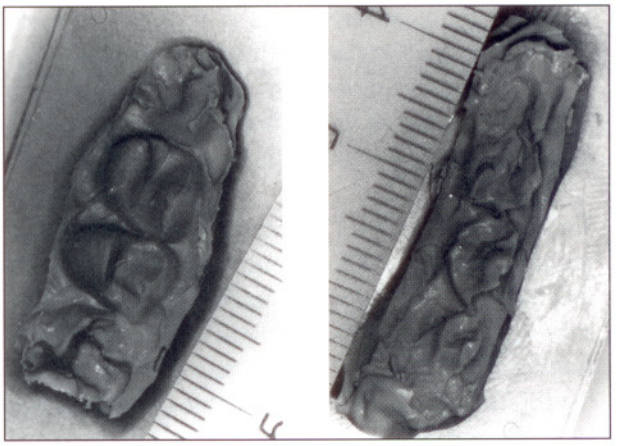

Fig.3: *Positive replication of the teeth impressions in the chewing gum*

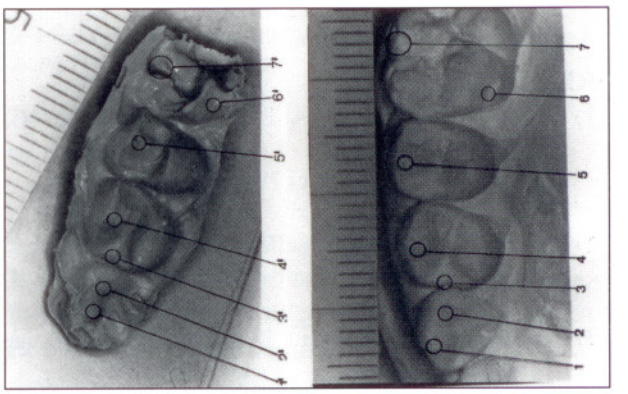

Fig.4: *Concordant features of teeth 23, 24, 25, 26 with corresponding teeth of the upper cast of the suspect*

DISCUSSION

This case illustrates that chewing gum can in some circumstances render sufficient detail of an offender's teeth for comparison and is probably only the second case on record which resulted in a conviction. In the first in 1981, Sperber[11] reported a case where chewing gum had been an essential part of the evidence in a homicide conviction of an adult female. In this case the imprint of the lingual opening of an endodontic procedure in an upper incisor and the mesial cavity of the same tooth was reproduced in the gum - favouring a valid, positive comparison with the teeth of the suspect.

In the majority of cases, qualitative evaluation of the bitemarks is usually easier with bitten foodstuffs than human skin although it must be emphasized that certain foods make poor media for bitemark registration. The case of chewing gum is

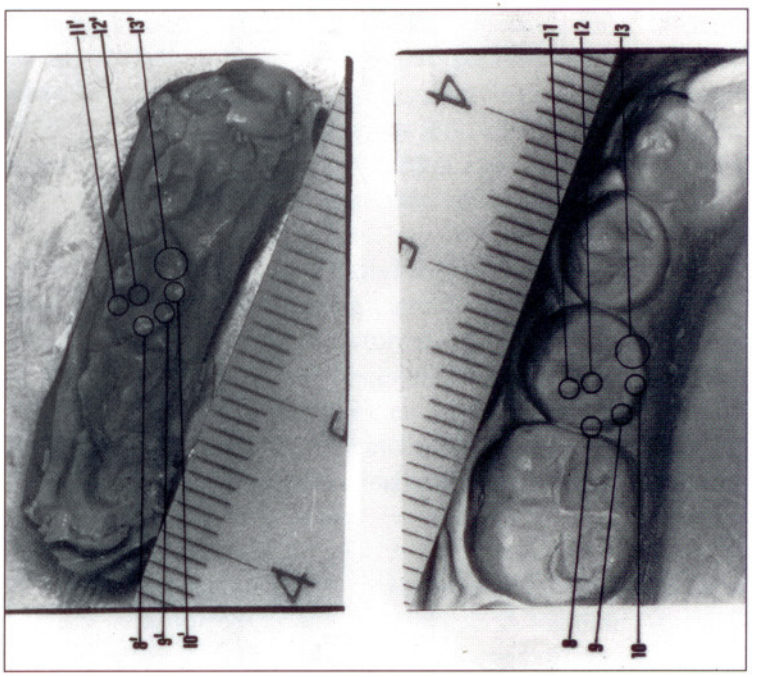

Fig.5: *Concordant features of tooth 35 with corresponding tooth of the lower cast of the suspect*

however quite different and is probably the only "food" which will record in relative detail the occlusal surfaces of posterior teeth, providing information which is unique and unlike that obtained by the more common incising of other foods.

The interpretation of a bitemark is difficult and requires a considerable amount of experience on the mechanics of human biting and the understanding of subsequent changes that occur in the bitten material. It is definitely a highly specialized skill belonging to the forensic dental experts by virtue of their training in tooth morphology, occlusion, articulation and the ability to reproduce fine details of the marks by modern impression technology.

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A REVIEW OF THE MOST COMMONLY USED DENTAL AGE ESTIMATION TECHNIQUES

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ABSTRACT

This review of literature provides an overview of the most commonly used dental age estimation techniques and focuses on dental age estimation scoring systems in children and adults. In order to obtain a more reliable and reproducible age estimation the forensic odontologist should use several of these available methods whenever an age estimation in the living or dead is required. **(J Forensic Odontostomatol 2001;19:9-17)**

Key words: Dental age estimation, forensic odontology

INTRODUCTION

Age estimation is a sub-discipline of the forensic sciences and should be an important part of every identification process, especially when information relating to the deceased is unavailable. The estimation should be as accurate as possible since it narrows down the search within the police Missing Persons files and enables a more efficient and time saving approach. Age estimation is of broader importance in forensic medicine, not only for identification purposes of deceased victims, but also in connection with crimes and accidents. In addition, chronological age is important in most societies for school attendance, social benefits, employment and marriage.

Dental maturity has played an important role in estimating the chronological age of individuals because of the reported low variability of dental indicators. Techniques for chronological age estimation in children based on dental maturation may be divided into those using the atlas approach and those using scoring systems whereas in adults there are the morphological and radiological techniques.

Dental age estimation in children

(a) Atlas approach

The use of radiographs is characteristic of techniques using the atlas approach where the morphologically distinct stages of mineralization that all teeth share are observed. Compared to bone mineralization, tooth mineralization stages are much less affected by variation in nutritional and endocrine status and developing teeth therefore provide a more accurate indication of chronological age.

The Tables of Schour and Massler[1] have become a classic example of an atlas approach. They described about 20 chronological stages of dental development starting from 4 months after birth until 21 years-of-age and comparing an individual's dental development with these tables can result in a useful estimation of the chronological age.

Moorrees *et al.*[2] divided dental maturation of the permanent dentition into 14 different stages ranging from "initial cusp formation" up to "apical closure complete" and designed different tables for males and females. For each tooth an estimation of chronological age can be read from these tables based on the mineralization and stage of development of that specific tooth.

Anderson *et al.*[3] further developed the system of Moorrees *et al.*[2] for all the teeth including the third molars. The Tables they compiled[3] are considered very comprehensive and can be applied to a much larger age range of juveniles.

(b) Scoring system

Demirjian *et al.*[4,5] tried to simplify chronological age estimation and restricted the number of stages of tooth development to 8 giving them a score of 'A' through 'H' (Fig.1) and confined the analysis to the first seven teeth of the left lower quadrant. Based on statistical analysis they were able to assign a maturity score for each of these seven teeth to almost each of the 8 developmental stages and differentiated for boys and girls as can be seen in Tables 1 and 2.[4] Finally, adding these 8 scores results in an overall maturity score that leads to an estimation of chronological age (Table 3 and 4).[4]

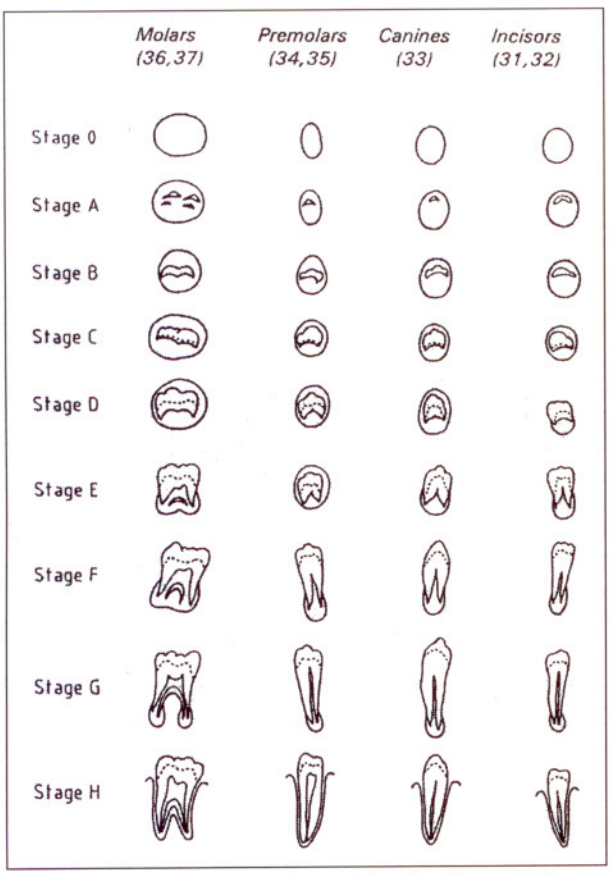

Fig.1: *Graphical presentation of the developmental stages as presented by Demirjian et al.*[4]

Based on several literature reports mentioning a consistent overestimation when using Demirjian's technique[6-9] Willems *et al.*[9-10] repeated Demirijian's study for a Belgian Caucasian population. Statistical analysis of the results led to the creation of new Tables (Tables 5 and 6) for boys and girls with maturity scores expressed in years. Adding the maturity scores for the different teeth directly gives the estimate of the individual's chronological age.

Dental age estimation in adults

Apart from the above mentioned techniques for age estimation in children and young adolescents several methods are described in the literature that address age estimation in adults. Among these techniques are refined and relatively accurate methods, some of which are conservative and do not invade tooth structure.

(a) Morphological techniques

An early age estimation technique was published by Gustafson.[11] It is based on the measurement of regressive changes in teeth such as the amount of occlusal attrition, the amount of coronal secondary dentine formation, the loss of periodontal attachment, the apposition of cementum at the root apex, the amount of apical resorption and the transparency of the root. For each of these parameters Gustafson assigned different scores on a scale from 0 to 3 and by adding these an overall score was obtained which was linearly related to an estimated age. Gustafson's linear regression formula for age estimation was:

Age = 11.43 + 4.56X (Equation 1)

where X equalled the overall score. This technique, which was actually based on a small sample of 40 teeth, has been improved through the years first by Dalitz[12] and then by Johanson.[13] Maples[14] tried to improve Gustafson's estimation method by including a correction factor for tooth position but did not succeed in producing a significantly more accurate technique, despite his multiple regression analysis. Finally Maples and Rice[15] found that Gustafson miscalculated his regression formula and they reported the correction:

Age = 13.45 + 4.26X (Equation 2)

The improvements in the original technique implemented by Johanson[13] are actually the most widely accepted among forensic odontologists. He differentiated between seven different stages instead of the original four and evaluated the same six criteria (Fig.2). In addition, he was able to obtain a multiple regression formula based on these six variables but was not able to differentiate for tooth position.

The following formula[13] may therefore be used for performing an age estimation based on the six

criteria mentioned earlier: attrition (A), secondary dentine formation (S), periodontal attachment loss (P), cementum apposition (C), root resorption (R) and apical translucency (T):

Age =11.02 + (5.14*A) + (2.3*S) + (4.14*P) + (3.71*C) + (5.57*R) + (8.98*T) (Equation 3)

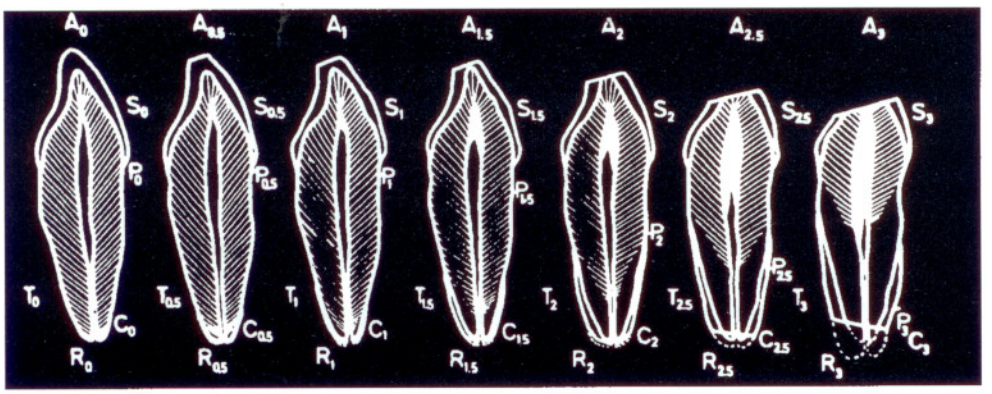

Fig.2: Seven different stages with corresponding scores from 0 to 3 relevant for dental age estimation as reported by Johanson[13]

Earlier in 1970, Bang and Ramm[16] presented a method for age estimation based on the measurement of only one parameter: the length of the apical translucent zone in mm of a given tooth. They differentiated for tooth position, for side and for the kind of tooth substrate that was being used, namely intact tooth versus tooth section. Based on a large sample the authors were able to present a second-degree polynomial regression formula for the estimation of age based on a single measurement on a single tooth:

$Age = B_0 + (B_1*X) + (B_2*X^2)$ (Equation 4)

They further differentiated the age estimation based on the total length of the translucent zone. For translucent zones smaller than or equal to 9 mm equation 4 was used. In case of translucent zones larger than 9 mm a first-degree polynomial regression formula was used:

$Age = B_0 + (B_1*X)$ (Equation 5)

The regression constant and the regression coefficients for the given equations can be found in Table 7. Care has to be taken to look for the corresponding values according to the total length of the translucent zone and the absence or presence of tooth sectioning.

Finally, but certainly not least, in an effort to improve on existing methods or techniques that showed statistical shortcomings or smallness of samples, Solheim[17] reported his technique for dental age estimation in 1993. He measured different parameters related to change over time for over 1000 teeth and for each individual tooth selected those parameters showing the strongest correlation with age. For each individual tooth a multiple regression analysis was run with age as the dependent variable. Since both the gender of the deceased may be unknown and the colour of the tooth may be influenced by post-mortem changes, separate multiple regression analyses were run for each individual tooth including and excluding both parameters. Table 8 shows the multiple regression formulae with age as the dependent variable and the age changes, including colour and gender versus exclusion of colour and gender, as independent variables to be measured. Among the age changes that were evaluated were:

AJ (attrition measured according to Johanson[13]),
ARA (area of attrition on occlusal tooth surface measured in square mm),
C1 (sum of cementum thickness on vestibular + lingual surfaces measured at 1/3 of root length from apex)
CAP (crown pulp area measured in square mm)
CEST (colour estimation of root dentine)
EX3 (tooth extracted for caries or related conditions Yes: score 0 - No: score 1)
LC1 (LOG10[C1])
LPMEAN (log10 PMEAN where PMEAN is the mean periodontal attachment loss in mm of a tooth),
SC (pulp diameter/root diameter at cervical area)
SEX (gender score male: score 0 - female: score 1)
SJ (secondary dentine measured according to Johanson[13])
SRS (surface roughness score)
ST (sum of pulp diameters/sum of root diameters)
TD (translucency of root apex scored according to Dalitz[12])
TID (length in mm of translucent zone in dry intact tooth)

The way in which these age changes are evaluated is described in the articles referred to for each of the measurements and in the work by Solheim.[17]

Special attention should now be drawn to the regression formulae for calculating dental age based on a maxillary central incisor and a mandibular central incisor, both when the independent variables "gender and colour" are excluded. When comparing these formulae in Table 8 with the original reported formulae some small but important corrections brought about by typing errors should be noted. These were actually discovered during a joint pilot study between the author and Solheim[22] during which the original data were statistically recalculated. For the maxillary central incisors the regression constant to be multiplied by C1 should be 0.02 and not 0.2 as originally reported and for the mandibular central incisors 4.6SRS should be added and not subtracted as originally reported.

With respect to the procedures used and the number of teeth included in this major study it is fairly safe to state that the reported formulae are sufficiently reliable to be recommended for age estimation in identification procedures. The fact that some calculations are based on unsectioned tooth measurements makes this technique of particular interest in cases were tooth preservation is necessary.

(b) Radiological techniques

Of additional interest are the following techniques since they are based fully on radiographs and are suitable for age estimations in living persons or where teeth cannot be removed or invaded.

Kvaal *et al.*[18] developed a method for estimating the chronological age of an adult from measurements of the size of the pulp observed on periapical radiographs from six types of teeth: maxillary central and lateral incisor and second bicuspid and mandibular lateral incisor, canine and first bicuspid. The age estimation is based on gender (G) and the calculation of several length and width ratios in order to compensate for magnification and angulation of the original tooth image on the radiograph: pulp/root length (P), pulp/tooth length (R), tooth/root length (T), pulp/root width at cemento-enamel junction (A), pulp/root width at midpoint between level C and A, pulp/root width at midroot length (C), mean value of all ratios excluding T (M), mean value of width ratios B and C (W), mean value of length ratios P and R (L). The results of the regression analyses with age as the dependent variable and the two predictors (M and [W-L]) and gender as independent variables are shown in Table 9. Gender was only included as an independent variable in the formula for the age estimation of the lower lateral incisors because of its higher correlation with age for that specific tooth (male: score 1, female: score 0). The coefficient of determination for the regression also appeared to be the strongest when the ratio for all six types of teeth from both jaws was employed. This coefficient decreased when teeth from only one jaw were included and was the weakest when only mandibular canines were measured.

This method[18] is actually the successor of the following method by Kvaal and Solheim[19] where the former excludes all parameters to be measured on extracted teeth whereas the latter requires an extracted tooth.

Kvaal and Solheim[19] presented a method where radiological and morphological measurements are combined in order to estimate the age of an individual. Depending on the type of tooth present, the following parameters are measured: apical translucency in mm (T), periodontal ligament retraction in mm (P), pulp length measured on radiographs (PL), root length measured on radiographs on mesial surface (RL), pulp width at cemento-enamel junction on radiographs (PWC), root width at cemento-enamel junction on radiographs (RWC), pulp width at midroot on radiographs (PWM), root width at midroot on radiographs (RWM), FL (PL/RL), FWC (PWC/RWC) and FWM (PWM/RWM).

Table 10 shows the multiple regression formulae for age calculation with the size of the pulp chamber on dental radiographs, the periodontal retraction and apical translucency as independent variables. A separate equation is given which excludes apical translucency where applicable.

Finally, when using these techniques in humans the large spread that exists in nature should be taken into account. As far as the methods of dental age estimation in adults are concerned and in view of the relative accuracy of the age estimations performed one should keep in mind that the standard deviations

of such age estimations are in general about 10 to 12 years.[20-21]

CONCLUSION

This review of dental age estimation techniques gives an overview of different methods available, all of which have advantages and disadvantages. The most important aspect of dental age estimation for the forensic odontologist to remember is that he or she should not be restricted to only one age estimation technique but to apply the different techniques available and perform repetitive measurements and calculations in order to establish maximum reproducibility. Doing so, it will be possible to provide an age estimation that is as reliable as possible since it was based on a variety of techniques.

	A	B	C	D	E	F	G	H
31				0	1.9	4.1	8.2	11.8
32			0	3.2	5.2	7.8	11.7	13.7
33			0	3.5	7.9	10	11	11.9
34		0	3.4	7	11	12.3	12.7	13.5
35	1.7	3.1	5.4	9.7	12	12.8	13.2	14.4
36			0	8	9.6	12.3	17	19.3
37	2.1	3.5	5.9	10.1	12.5	13.2	13.6	15.4

Table 1: *Individual maturity scores for boys for each of the developmental stages as reported by Demirjian et al.*[4]

	A	B	C	D	E	F	G	H
31				0	2.4	5.1	9.3	12.9
32			0	3.2	5.6	8.0	12.2	14.2
33			0	3.8	7.3	10.3	11.6	12.4
34		0	3.7	7.5	11.8	13.1	13.4	14.1
35	1.8	3.4	6.5	10.6	12.7	13.5	13.8	14.6
36			0	4.5	6.2	9.0	14.0	16.2
37	2.7	3.9	6.9	11.1	13.5	14.2	14.5	15.6

Table 2: *Individual maturity scores for girls for each of the developmental stages as reported by Demirjian et al.*[4]

Age	score	Age	score	Age	score	Age	score	Age	score
3	12.4	5.6	30.3	8.2	75.1	10.8	91.6	13.4	96
3.1	12.9	5.7	31.1	8.3	76.4	10.9	91.8	13.5	96.1
3.2	13.5	5.8	31.8	8.4	77.7	11	92	13.6	96.2
3.3	14	5.9	32.6	8.5	79	11.1	92.2	13.7	96.3
3.4	14.5	6	33.6	8.6	80.2	11.2	92.5	13.8	96.4
3.5	15	6.1	34.7	8.7	81.2	11.3	92.7	13.9	96.5
3.6	15.6	6.2	35.8	8.8	82	11.4	92.9	14	96.6
3.7	16.2	6.3	36.9	8.9	82.8	11.5	93.1	14.1	96.7
3.8	17	6.4	39	9	83.6	11.6	93.3	14.2	96.8
3.9	17.6	6.5	39.2	9.1	84.3	11.7	93.5	14.3	96.9
4	18.2	6.6	40.6	9.2	85	11.8	93.7	14.4	97
4.1	18.9	6.7	42	9.3	85.6	11.9	93.9	14.5	97.1
4.2	19.7	6.8	43.6	9.4	86.2	12	94	14.6	97.2
4.3	20.4	6.9	45	9.5	86.7	12.1	94.2	14.7	97.3
4.4	21	7	46	9.6	87.2	12.2	94.4	14.8	97.4
4.5	21.7	7.1	48.3	9.7	87.7	12.3	94.5	14.9	97.5
4.6	22.4	7.2	50	9.8	88.2	12.4	94.6	15	97.6
4.7	23.1	7.3	52	9.9	88.6	12.5	94.8	15.1	97.7
4.8	23.8	7.4	54.3	10	89	12.6	95	15.2	97.8
4.9	24.6	7.5	56.8	10.1	89.3	12.7	95.1	15.3	97.8
5	25.4	7.6	59.6	10.2	89.7	12.8	95.2	15.4	97.9
5.1	26.2	7.7	62.5	10.3	90	12.9	95.4	15.5	98
5.2	27	7.8	66	10.4	90.3	13	95.6	15.6	98.1
5.3	27.8	7.9	69	10.5	90.6	13.1	95.7	15.7	98.2
5.4	28.6	8	71.6	10.6	91	13.2	95.8	15.8	98.2
5.5	29.5	8.1	73.5	10.7	91.3	13.3	95.9	15.9	98.3
								16	198.4

Table 3: *Overall maturity scores for boys as reported by Demirjian et al.*[4]

Age	score	Age	score	Age	score	Age	score	Age	score
3	13.7	5.6	34	8.2	81.2	10.8	94	13.4	97.7
3.1	14.4	5.7	35	8.3	82.2	10.9	94.2	13.5	97.8
3.2	15.1	5.8	36	8.4	83.1	11	94.5	13.6	98
3.3	15.8	5.9	37	8.5	84	11.1	94.7	13.7	98.1
3.4	16.6	6	38	8.6	84.8	11.2	94.9	13.8	98.2
3.5	17.3	6.1	39.1	8.7	85.3	11.3	95.1	13.9	98.3
3.6	18	6.2	40.2	8.8	86.1	11.4	95.3	14	98.3
3.7	18.8	6.3	41.3	8.9	86.7	11.5	95.4	14.1	98.4
3.8	19.5	6.4	42.5	9	87.2	11.6	95.6	14.2	98.5
3.9	120.3	6.5	43.9	9.1	87.8	11.7	95.8	14.3	98.6
4	21	6.6	45,2	9.2	88.3	11.8	96	14.4	98.7
4.1	21.8	6.7	46.7	9.3	88.8	11.9	96.2	14.5	98.8
4.2	22.5	6.8	48	9.4	89.3	12	96.3	14.6	98/9
4.3	23.2	6.9	49.5	9.5	89.8	12.1	96.4	14.7	99
4.4	24	7	51	9.6	90.2	12.2	96.5	14.8	99.1
4.5	24.8	7.1	52.9	9.7	90.7	12.3	96.6	14.9	99.1
4.6	25.6	7.2	55.5	9.8	91.1	12.4	96.7	15	99.2
4.7	26.4	7.3	57.8	9.9	91.4	12.5	96.8	15.1	99.3
4.8	27.2	7.4	61	10	91.8	12.6	96.9	15.2	99.4
4.9	28	7.5	65	10.1	92.1	12.7	97	15.3	99.4
5	28.9	7.6	68	10.2	92.3	12.8	97.1	15.4	99.5
5.1	29.7	7.7	71.8	10.3	92.6	12.9	97.2	15.5	99.6
5.2	30.5	7.8	75	10.4	92.9	13	97.3	15.6	99.6
5.3	31.3	7.9	77	10.5	93.2	13.1	97.4	15.7	99.7
5.4	33	8	80.2	10.6	93.7	13.2	97.6	15.8	99.9
5.5	29.5	8.1	73.5	10.7	91.3	13.3	95.9	15.9	98.3
								16	100

Table 4: *Overall maturity scores for girls as reported by Demirjian et al.*[4]

	A	B	C	D	E	F	G	H
31	0.00	0.00	1.68	1.49	1.50	1.86	2.07	2.19
32	0.00	0.00	0.55	0.63	0.74	1.08	1.32	1.64
33	0.00	0.00	0.00	0.04	0.31	0.47	1.09	1.90
34	0.15	0.56	0.75	1.11	1.48	2.03	2.43	2.83
35	0.08	0.05	0.12	0.27	0.33	0.45	0.40	1.15
36	0.00	0.00	0.00	0.69	1.14	1.60	1.95	2.15
37	0.18	0.48	0.71	0.80	1.31	2.00	2.48	4.17

Table 5: *Individual maturity scores for boys expressed directly in years for each of the developmental stages.*[10]

Table 6: *Individual maturity scores for girls expressed directly in years for each of the developmental stages.*[10]

	A	B	C	D	E	F	G	H
31	0.00	0.00	1.83	2.19	2.34	2.82	3.19	3.14
32	0.00	0.00	0.00	0.29	0.32	0.49	0.79	0.7
33	0.00	0.00	0.6	0.54	0.62	1.08	1.72	2
34	-0.95	-0.15	0.16	0.41	0.6	1.27	1.58	2.19
35	-0.19	0.01	0.27	0.17	0.35	0.35	0.55	1.51
36	0.00	0.00	0.00	0.62	0.9	1.56	1.82	2.21
37	0.14	0.11	0.21	0.32	0.66	1.28	2.09	4.04

	<9mm			<9mm			>9mm		>9mm	
Tooth	Intact Roots			Tooth Sections			Intact Roots		Tooth Sections	
	B0	B1	B2	B0	B1	B2	B0	B1	B0	B1
11	20.30	5.74	0.000	21.02	6.03	-0.060	20.34	5.74	22.36	5.39
21	24.30	6.22	-0.119	26.84	6.00	-0.155	26.78	4.96	30.18	4.30
12	18.80	7.10	-0.164	23.09	7.04	-0.197	22.06	5.36	25.55	5.23
22	20.90	6.85	-0.223	24.62	5.18	-0.077	25.57	4.38	25.90	4.39
13	26.20	4.64	-0.044	21.52	6.49	-0.171	28.13	4.01	28.01	4.23
23	25.27	4.58	-0.073	24.64	5.22	-0.143	27.59	3.65	29.41	3.32
14/24	23.91	3.02	0.203	29.98	2.73	0.107	18.42	5.40	28.44	3.81
15	23.78	5.06	-0.064	24.76	4.81	0.000	25.33	4.28	24.75	4.81
25	25.95	4.07	-0.067	22.34	7.59	-0.393	26.92	3.37	26.21	4.03
41	9.80	12.61	-0.711	13.63	12.11	-0.683	29.00	4.23	31.78	4.19
31	23.16	9.32	-0.539	26.46	8.79	-0.511	37.56	2.94	37.89	3.08
42	26.57	7.81	-0.383	21.77	10.19	-0.581	38.81	2.81	38.49	3.03
32	18.58	10.25	-0.538	22.22	9.07	-0.444	33.65	3.53	35.19	3.49
43	23.30	8.45	-0.348	24.34	8.38	-0.358	37.80	3.50	40.32	3.05
33	27.45	7.38	-0.289	23.88	8.76	-0.388	41.50	2.84	42.07	2.73
44	24.83	6.85	-0.237	21.54	8.63	-0.395	30.83	4.05	33.10	3.66
34	29.17	5.96	-0.173	26.02	7.00	-0.234	34.97	3.74	32.79	4.11
45	29.42	4.49	-0.065	14.90	9.93	-0.451	30.68	3.76	27.46	4.17
35	18.72	5.79	-0.082	23.87	5.50	-0.098	20.87	4.79	25.60	4.41
16/26mr	30.25	3.23	-0.018	28.22	4.82	-0.101	30.56	3.00	30.03	3.48
36/46mr	27.39	6.25	-0.239	33.42	5.18	-0.302	30.32	3.66	35.27	2.78
16/26dr	34.73	0.67	0.211	20.43	6.09	-0.182	29.49	3.32	26.89	3.55
36/46dr	30.21	5.52	-0.181	29.91	4.97	-0.102	31.46	3.77	30.31	4.22
16/26pr	27.43	3.64	0.039	25.15	4.34	-0.032	26.81	4.07	25.83	3.95

Table 7: *Regression constant and the regression coefficients as reported by Bang and Ramm[16]. Differentiation was made on the level of substrate (intact or sectioned teeth) and length of the translucent zone (<9 mm and >9 mm). (m = mesial; d = distal; p = palatal; r = root)*

#	COLOUR AND GENDER INCLUDED
MAXILLARY	
1	AGE = 24.3 + 8.7CEST + 5.2TD - 2.3CAP - 4.3SEX
2	AGE = 38.7 - 126ST + 4.7CEST + 4.2TD + 0.05C1
3	AGE = 10.1 + 2.3TID + 4.4SJ + 6.1CEST
4	AGE = 8.0 + 7.3CEST + 4.1 SJ + 1.4TID
5	AGE = 6.1 + 9.1CEST + 3.3AJ + 7.3 LPMEAN + 1.4TID
MANDIBULAR	
1	AGE = - 21.8 - 55.3SC + 32.8LC1 - 10.3SEX + 2.6TID
2	AGE = - 24.5 + 4.9CEST + 2.1TID - 7.0SEX +20.1LC1 + 2.4AJ
3	AGE = 19.2 + 1.7TID + 5.1CEST + 3.5SJ
4	AGE = - 28.1 + 3.0TID + 0.6ARA + 24.1LC1 - 5.6SEX + 7.3LPMPEAN
5	AGE = 7.5 + 2.7TID + 4.9SJ + 4.9SRS
#	COLOUR AND GENDER EXCLUDED
MAXILLARY	
1	AGE = 25.3 + 7.1TID - 3.1CAP + 5.3SRS - 7.5EX3 + 0.02C1
2	AGE = 46.7 - 142ST + 6.5TD + 0.05C1
3	AGE = 12.1 + 2.9TID + 4.9SJ + 3.9SRS
4	AGE = 14.6 + 6.3SJ + 2.5TID
5	AGE = 14.2 + 2.5TID + 4.1AJ + 8.9LPMEAN + 3.0SJ
MANDIBULAR	
1	AGE = -32.1 - 52.5SC + 31.1LC1 + 1.9TID + 4.6SRS
2	AGE = 37.1 + 2.7TID + 5.9SRS - 46.3SC
3	AGE = 27.5 + 2.6TID + 4.4SJ
4	AGE = -26.9 + 3.2TID + 0.5ARA + 22.3LC1 + 7.1LPMEAN
5	AGE = 7.5 + 2.7TID + 4.9SJ + 4.9SRS

Table 8: *Multiple regression formulae with age as the dependent variable. For each tooth type, parameters that were strongly correlated with age were used in the regression formulae. Explanations for the abbreviations used may be found in the overview above.*[17]

TEETH	EQUATION	r^2
11/21 12/22 15/25		
32/42 33/43 34/44	AGE = 129.8 - 316.4(M) - 66.8(W-L)	0.76
11/21 12/22 15/25	AGE = 120.0 - 256.6(M) - 45.3(W-L)	0.74
32/42 33/43 34/44	AGE = 135.3 - 356.8(M) - 82.5(W-L)	0.71
11/21	AGE = 110.2 - 201.4(M) - 31.3(W-L)	0.70
12/22	AGE = 103.5 - 216.6(M) - 46.6(W-L)	0.67
15/25	AGE = 125.3 - 288.5(M) - 46.3(W-L)	0.60
32/42	AGE = 106.6 - 251.7(M) - 61.2(W-L) - 6.0(G)	0.57
33/43	AGE = 158.8 - 255.7(M)	0.56
34/44	AGE = 133.0 - 318.3(M) - 65.0(W-L)	0.64

Table 9: *Multiple regression formulae for dental age estimation based on radiological measurements.*[18]

TOOTH		EQUATION
11/21		AGE = 71.2 - 133.7FWM - 56.0 FWC
12/22		AGE = 69.3 - 14.5FWM - 63.0FWC
13/23		AGE = 120.2 - 62.5FL
14/24		AGE = 82.0 - 95.9FWC + 2.0T + 1.7P - 50.6FL
	*	AGE = 112.6 - 85.0FWC + 2.4P - 116.3FWM - 64.8FL
15/25		AGE = 30.8 + 2.5P -96.0FWC + 3.7T
	*	AGE = 36.9 + 2.9P - 102.9FWC
31/41		AGE = 40.3 - 122.4FWC + 4.4T
	*	AGE = 68.5 - 124.4FWC
32/42		AGE = 72.1 - 173.6FWC
33/43		AGE = 43.8 - 139.6FWC + 3.8T
	*	AGE = 75.9 - 174.7FWC
34/44		AGE = 75.5 - 185.9FWC - 105.4FWM + 1.4P
35/45		AGE = 54.0 - 107.0FWM - 97.0FWC + 2.4T
	*	AGE = 80.0 - 192.7FWM - 96.6FWC

* excluding apical translucency

Table 10: *Multiple regression formulae for dental age estimation based on radiological measurements.* [19]

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DIET AND AGE-AT-DEATH DETERMINATIONS FROM MOLAR ATTRITION A REVIEW RELATED TO THE LOW COUNTRIES

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ABSTRACT

To elucidate the impact of diet on age-at-death determinations based on molar attrition a comparison was made between the established rate of attrition in three populations; a pre-mediaeval (British), a late mediaeval (Dutch) and a 17-18th century (Dutch) (western European). It appeared that the rate decreased dramatically during the overall time span and that this change was probably diet related and owing to the coarseness of foodstuffs. This result strongly indicated that molar age-attrition tables should only be used for age-at-death determinations if their application is restricted to a particular cultural period and diet. **(J Forensic Odontostomatol 2001;19:18-21)**

Keywords: attrition, age determination, molar, diet

INTRODUCTION

For many years Brothwell's[6] method for age-at-death determination has been the most popular and widely used of the many existing ones based on molar attrition.[1-9] With the help of his pictorial classification, the degree of molar attrition, that is the pattern of occlusal wear of enamel and exposed dentine, could easily be scored with the naked eye (Fig. 1). For subsequent age-at-death diagnosis the interrelated scores of the juxtaposed first, second and third molars could be directly linked to a certain age-at-death interval in the accompanying age/attrition table (Fig. 2). It should be realized however that the method was developed by observations on western European skeletal remains from the pre-mediaeval period and that owing to cultural evolution and ongoing changes in food processing the coarseness of the diet and thus the rate of resulting molar attrition decreased in time. Age/attrition tables have consequently to be adapted to such shifts. Although the influence of cultural variability on tooth wear was stressed as early as 1971,[5] in practice very few forensic and archaeological investigators using the method applied it with a correction for this factor.[3] To elucidate the impact of diet on age-at-death determinations based on molar attrition a comparison was made between the known data from three populations, a pre-mediaeval (British), a late mediaeval (Dutch) and a 17-18th century (Dutch) (western European).

MATERIALS AND METHODS

The British material investigated by Brothwell[6] consisted of specimens dating from the neolithic (4000 BC) to mediaeval period. Skeletal ages-at-death of the individuals were established by observing the ageing status of the symphyseal face of the pubic bone. The late mediaeval Dutch material consisted of the dentitions of 76 citizens buried between 1275-1575 AD in the churchyard of a Franciscan friary in the City of Dordrecht.[10] The 17-18th century material was composed of the complete dentitions of 45 Dutch whalers buried on Spitsbergen.[11] In the latter two samples gender and skeletal ages-at-death were determined according to the Workshop of European Anthropologists[12] which, together with other age indicators, also uses the symphyseal face of the pubic bone as an indicator.

In all dentitions molar attrition was scored according to Brothwell[6] and Maat and Van der Velde.[11] The numerical classification of molar wear had an ordinal interval scale from one (no wear) to seven (only roots remaining) (Fig. 1). For reasons of computing this classification was transcribed to algebraic numbers, for example: 1+ = 1.333 and the attrition on the most intact side of the mouth was recorded. On that side all maxillary and mandibular molars were scored to achieve a mean for M1 (first molar), M2 (second molar) and M3 (third molar). Data were

only eliminated from calculations in case of atypical wear patterns, for example M1 scoring lower than M2, while the functional age of M1 should be six years in advance due to its earlier eruption. With respect to the data collected by Maat *et al.*[10] and Maat and Van der Velde[11] means were compared with student's t test for paired observations and regression analyses were done using the simple linear regression model.

RESULTS

After computing the recorded scores the results from the linear regression model were displayed similarly to Brothwell[6] in his age-attrition table (Figs. 2, 3 and 4).

In the pre-mediaeval period the degree of attrition increased gradually from 3(M1), 2+(M2), 1(M3) for the 17-25 years interval to 5+(M1), 5(M2), 4+(M3) for the 35-45 years interval and to any degree greater than that for the 45+ years age group[6] (Fig. 2).

In the late mediaeval period the degree of attrition increased from 3-(M1), 2-/2(M2), 1+(M3) for the 14-17 years interval to 5-/5(M1), 4(M2), 3+(M3) for the 65+ years age group[10] (Fig. 3).

In the 17-18th century samples the degree of attrition increased from 2+(M1), 1+/2-(M2), 1(M3) for the 14-17 years interval to 5-(M1), 4-/4(M2), 3/3+(M3) for the 65+ age group[11] (Fig. 4).

With respect to the data from the late mediaeval period and from the 17-18th century, it should be mentioned that for every degree of attrition of M1, M2 and M3 the 95% confidence limits for single observations showed an accompanying age-at-death interval of ca. 25 years.[10,11]

DISCUSSION

After comparing the three age/attrition tables (Figs. 2, 3 and 4) it was clear that at least in some parts of western Europe i.e. Britain and the Low Countries, the rate of molar attrition decreased dramatically during the time span covered by the three samples. The average wear pattern as seen in the 35-45 age interval during the pre-medieval period was never reached during later periods, even by individuals of the oldest age-at-death interval (65-70+ years). The average wear pattern as seen in the 25-35 age interval during the pre-mediaeval period was only reached in the 55-65 age interval of the late mediaeval period and in the 65+ age interval of the 17-18th century. If compared to the pre-mediaeval period the latter two shifts in functional age of teeth represented approximately 30 and 40 years respectively.

These decreases in rate of attrition were most likely the result of a substantial decrease in coarseness of foodstuffs in the diet. For instance it was known that during the transition from the mediaeval period to the 17-18th century grain millers started to sift flour through fine cloth sieves to remove coarse particles of bran.[13,14] As a matter of course the overall rate of attrition decreased considerably. Presently, due to further substantial reductions in the amount of abrasives in our diet, molar attrition of "modern man" seems to have been reduced to a trifle. The impact of these diet changes has to be taken into consideration when applying molar age/attrition tables for age-at-death determinations.

The best way to do this is by computing a specific reference age/attrition table for a particular cultural period with the help of dentitions of individuals of documented or osteologically well established skeletal age from that same period. The paragraph on Materials and Methods and Figs. 3 and 4 show how this can be accomplished. More simply, and in an even more direct way this can be done by hand by lining up in order of increasing age the dentitions of individuals of well established skeletal age and once the ranking is complete the ages-at-death of the unknowns can be read by comparison and seriation (fitting in) of their molar attrition. Whatever procedure is used it has to be kept in mind that, if a statistical confidence level of 95% is required, the resulting individual skeletal ages will always fall within an age range of ca. 25 years which is the closest realistic result attainable.

It is not recommended that a molar age/attrition table be constructed by extrapolating the rate/gradient of molar wear from data of skulls of the young, of which the age was assessed from the state of development of dentition, for the estimation of ages of older individuals.[2-4,8,9,15] The basis for this method is a calculated attrition rate from the difference in attrition between M1 (erupting at the age of 6 years) and M2 (erupting at the age of 12 years). In such a procedure those six years of functional age and its

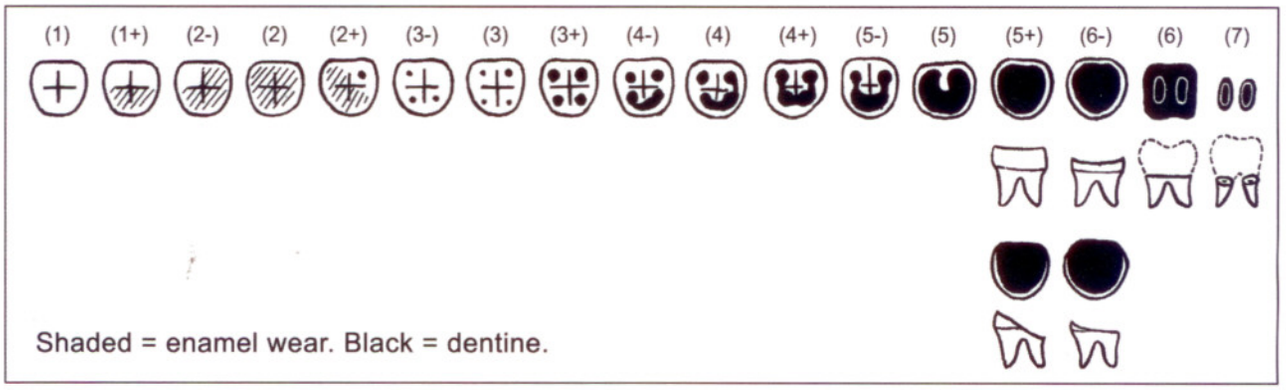

Fig.1: *Numerical classification of molar attrition modified from Brothwell*[6]

AGE INTERVAL (years)**	17 - 25			25 - 35			35 - 45			45+		
MOLAR	M1	M2	M3	M1	M2	M3	M1	M2	M3	M1	M2	M3
NUMERICAL CLASSIFICATION	3	2^+	1	4^+	4^-	3^-	5^+	5	4^+	Any greater degree		
WEAR PATTERN										Any greater degree		

* Modified from Brothwell, and scored according to Maat and Van der Velde.[6,11] Several early British groups.
** Ages are skeletal ages assessed by the pubic symphyseal face.

Fig.2: *Molar attrition during the pre-mediaeval period**

AGE INTERVAL (years)**	14 - 17			17 - 25			25 - 35			35 - 45			45 - 55			55 - 65			65 - 70+		
MOLAR	M1	M2	M3	M1	M2	M3	M1	M2	M3	M1	M2	M3	M1	M2	M3	M1	M2	M3	M1	M2	M3
NUMERICAL CLASSIFICATION	3^-	$2^-/2$	1^+	$3^-/3$	2	$1^+/2^-$	$3/3^+$	$2^+/3^-$	$2^-/2$	4^-	$3^-/3$	$2/2^+$	4	$3/3^+$	$2^+/3^-$	$4^+/5^-$	4^-	3	$5^-/5$	4	3^+
WEAR PATTERN																					

* Scored according to Brothwell, and Maat and Van der Velde.[6,11] N = 76 citizens buried in a churchyard of a Fransiscan friary in the City of Dordrecht i.e., 3, 11, 19, 15, 14, 10 and 4 cases for the successive age intervals.
** Ages are skeletal ages assessed according to the WEA.[12]

Fig.3: *Molar attrition during the period ca. 1275-1572 AD**

AGE INTERVAL (years)**	14 - 17			17 - 25			25 - 35			35 - 45			45 - 55			55 - 65			65 - 70+		
MOLAR	M1	M2	M3	M1	M2	M3	M1	M2	M3	M1	M2	M3	M1	M2	M3	M1	M2	M3	M1	M2	M3
NUMERICAL CLASSIFICATION	2^+	$1^+/2^-$	1	$2^+/3^-$	2	$1/1^+$	$3^-/3$	$2/2^+$	$2^-/2$	$3^+/4^-$	$2^+/3^-$	$2/2^+$	$3^+/4^-$	$2^+/3^-$	2^+	4^-	$3^-/3$	$2^+/3^-$	5^-	$4^-/4$	$3/3^+$
WEAR PATTERN																					

* Scored according to Brothwell, and Maat and Van der Velde.[6,11] N = 45 whalers with complete dentitions buried on Spitsbergen (Maat and Van der Velde)[11] i.e., 2, 7, 9, 9, 3, 12 and 3 cases for the successive age intervals.
** Ages are skeletal ages assessed according to the WEA.[12]

Fig.4: *Molar attrition during the period ca. 1650-1800 AD**

rate/gradient have to be extrapolated ten times, assuming the rate will remain constant throughout life, to estimate the ages of the elderly! It is possible however that such a procedure overstretches the short trend of the onset period because after the age of 12 years the overall occlusal surface will change in size and aspect, the masticatory power will increase, and in many cultures after infancy the diet will change.[16] In short, too many unpredictables would be taken for granted in order to achieve realistic forecasts.

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