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CONTENTS

ADVANTAGES OF THE DIGITAL X-RAY SYSTEM IN DENTAL IDENTIFICATION OF PERSONS WITH REFERENCE TO TWO MURDER CASES

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ABSTRACT

Direct digital X-ray technology was applied to dental identification of victims in two murder cases using the Compuray system. In both cases the digital radiography proved to be simple to use, quick and effective, allowing superimposition, enlargement and transportability to a mortuary. These are the first reported uses of the technology in Japan and further development promises the transmittability of data and images electronically to remote locations, further enhancing its usefulness. Comparing the skull with the dental ante-mortem X-ray films and records of a specific person who was reported "missing", we found many identical points between the two, especially in regard to the X-ray findings with the Compuray. In both cases we obtained a large number of X-ray images in a remarkably short time and this was very useful for identification by means of the teeth. **(J Forensic Odontostomatol 2001;19:22-5)**

Key words : Person identification, direct digital X-ray system, forensic odontology

INTRODUCTION

It is well known that dental evidence plays a very important role in the identification of bodies,[1-7] and of the various types of dental evidence, X-ray films are considered the most reliable and valid.[2,4] In recent years digital X-ray photography techniques have been developed and applied in the fields of clinical dentistry [8-10] and forensic science[11,12] and in the latter a Compuray* was used to identify victims in two murder cases (Fig. 1). In this paper we report on the usefulness of the direct digital X-ray system for person identification in two further cases of homicide.

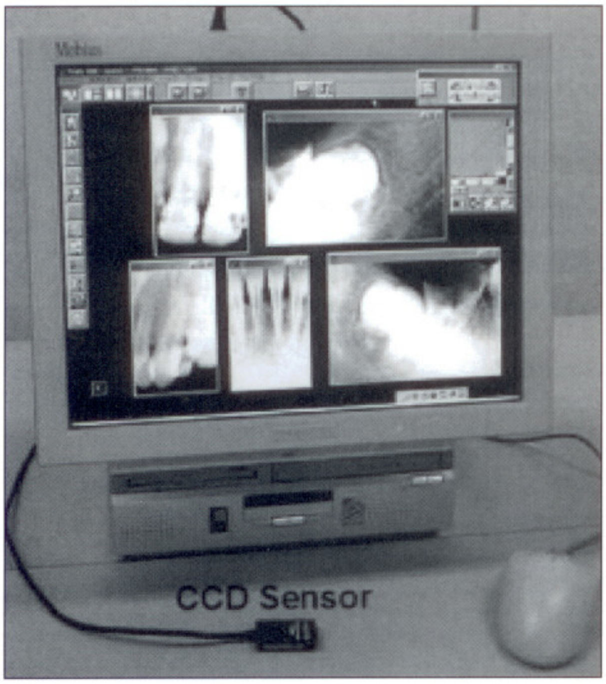

Fig.1: *The direct digital X-ray system (Compuray). A number of images are displayed at the same time*

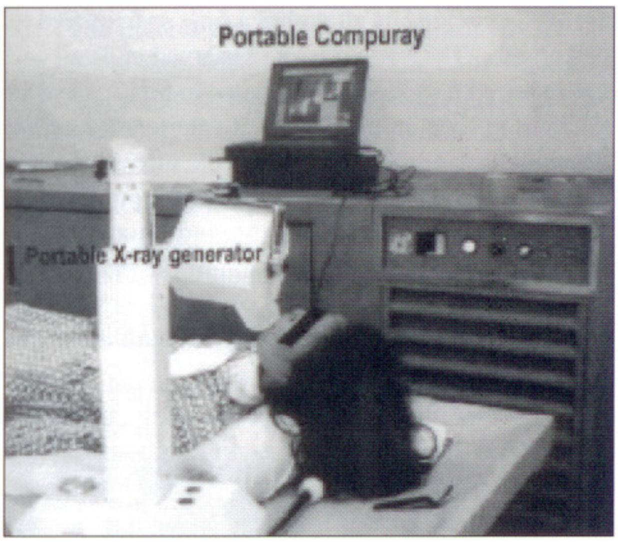

Fig.2: *Scene of dental identificationb using the portable Compuray in Case 1.*

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CASE REPORTS

Case 1

On 14 September 1997, the body of a deceased female was found on a path in Chiba Prefecture. At autopsy the cause of death was determined to be asphyxia by strangulation and although the body and clothes were intact and the post-mortem interval was estimated to be only a few hours, there was insufficient information for positive identification and the Chiba Prefectural Police Headquaters requested a dental examination to assist with identfication. The examination was carried out immediately and the radiography was performed with a portable Compuray in the mortuary (Fig. 2).

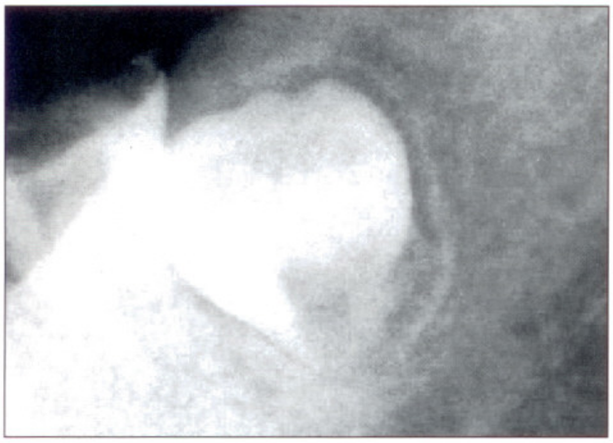

Fig.3: Digital X-ray image of third molar showing a root that has not yet calcified

We obtained over 20 digital images of different parts of the remains from various angles (exposure dose: 4 - 6 μC/kg) (Fig. 1), all within a time span of five to six minutes. The findings were observed in detail and the deceased person's age estimated to be 17±1) years taking into account the degree of calcification of the unerupted mandibular third molars, attrition in the mandibular anterior teeth and size of the pulp cavity. The absence of attrition in the mandibular anterior teeth and the "A" type dimension of the pulp cavity of all teeth indicated that the deceased was a teenager.[13, 14] Furthermore, the finding that although the tooth crown was complete, the root of the unerupted mandibular third molar was incomplete and thus indicated that the deceased was between 16 and 18 years old[15-17](Fig.3). Three weeks later an identification was established after the newspapers published a portrait of the victim together with her estimated age. Her actual age was in fact 18 years old and this was the first person identification case in which the direct digital X-ray system was used in Japan.

Case 2

On 2 March 1998 a human skull was found in the trawling net of a fishing boat in the coastal waters of Japan 27.3 nautical miles from Inubosaki Lighthouse (Fig. 4).

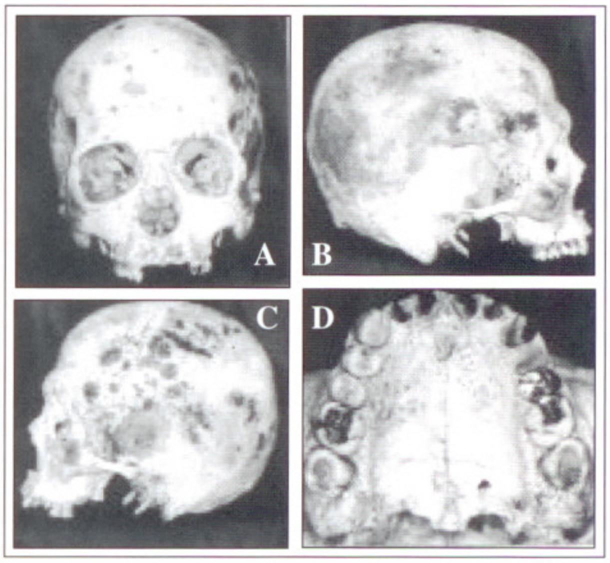

Fig.4: Skull found in Case 2. A:front view, B: right view, C: left view, D: occlusal view of maxilla

Based on circumstantial evidence the Japanese Coastguard Choshi Division regarded this case as murder and sent the skull to us for dental examination, charting and comparing PM data with AM data of a specific person who had been reported missing for a month. We used the Compuray once again and obtained a number of radiographic images from various angles within a short time (Fig. 5).

Comparing the PM records with the dental antemortem X-ray films and records supplied by the missing person's dentist, we found many concordant

Fig.5: Post-mortem dental X-ray images of upper jaw obtained using the Compuray

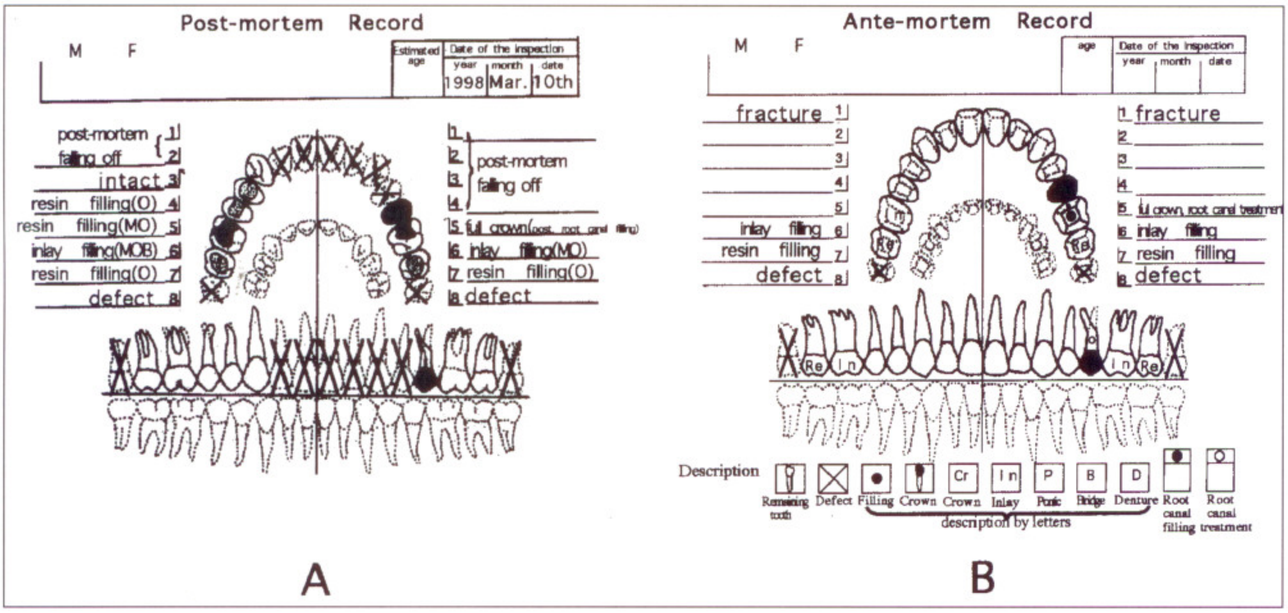

Fig.6: Comparison of dental charts between the ante- and post-mortem records. A: post-mortem record. B: ante-mortem record. Agreements in the methods of dental treatment were observed

points between the two and the skull proved indeed to be that of the missing person (Figs. 6 and 7A and B). We were also able to superimpose the ante- and post-mortem dental images thus confirming that they were from the same person. The superimposition and resulting composite image proved to be a useful diagnostic tool and was obtained rapidly and simply with an image processor (Fig.7C).

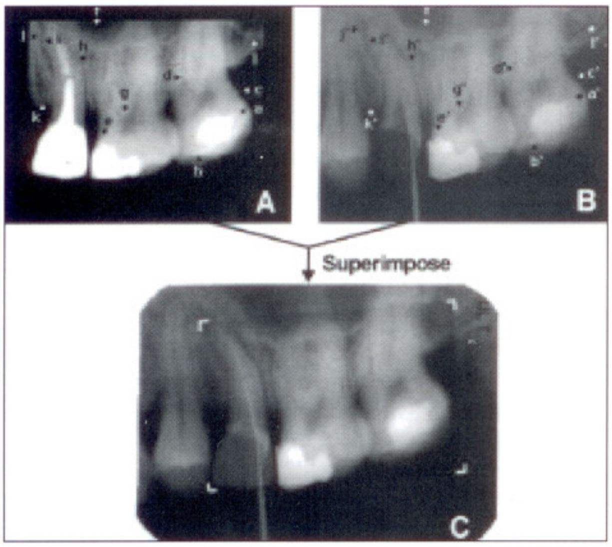

Fig.7: Comparison of X-ray images. A: post-mortem digital X-ray image. B: ante-mortem X-ray photograph. Many identical points (a:a' - k:k') were found. C: superimposition of images A and B.

DISCUSSION

The advantages of the direct digital X-ray system are as follows:

1. The irradiation dose is relatively low.[18]
2. It takes only 2-3 seconds to obtain X-ray images after the exposure, and imaging does not require the additional equipment of darkroom, developer, fixer and the other items for developing conventional X-ray films.[8-11, 19, 20]
3. The images can be easily analyzed, expanded, measured and coloured.[8-11, 19, 20]
4. The images can be stored electronically.[8-11, 19, 20]
5. Receiving, sending and storing clear digital X-ray images through computer networks is effortless.[19, 20]

We consider these advantages to be very relevant to dental identification, and were eager to experience the practical application of the direct digital X-ray system. As a result, in both of the two cases reported, we were able to obtain a large number of radiographic pictures within a remarkably short time, and to enlarge them as required. Further, in Case 2, the comparison of ante- and post-mortem images was possible through enlargement and superimposition. Because superimposition requires ante- and post-mortem images from the same angle it has been somewhat difficult to conduct until now. On this occasion however it was possible to obtain X-ray images of the body from the same angle as the ante-mortem radiographs which could be displayed on the monitor. The superimposition was then performed rapidly using an image processor, as previously mentioned. In addition, as a result of the development of the transportable digital X-ray system, it is possible to conduct a detailed dental examination in the mortuary.

These results indicate that the direct digital X-ray system is useful and convenient for dental identification and it is felt that these advantages justify its cost (about AU$40000). In the near future it is expected that this system will be transportable to a location remote from where the ante-mortem dental records are kept, because both ante- and post-mortem records will be transmissible through computer networks as clear digital data. This possibility therefore opens up limitless opportunities for dental identification on a global scale.

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A MODIFICATION OF THE DEMIRJIAN METHOD FOR AGE ESTIMATION IN CHILDREN

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ABSTRACT

The Demirjian method for age estimation in children by means of dental development is widely used and forms a basis on which a universal dental maturity score can be calculated. This score is then translated into a chronological age with aid of tables specific for each population. Such tables are, however, available for only a few populations and usually not where age estimations are needed. In several studies on age estimation in children it has been found that the original studies by Demirjian and co-workers do not give enough information to allow the construction of corresponding tables for other populations. The main reason for this is that the regression lines in the original graphs were obtained by manual smoothing to combine the individual plots and the tables were thereafter compiled from these graphs. In an attempt to avoid manual, and more or less subjective, construction of the regression line, an attempt was made to fit the plots into a regression line by a series of predefined functions. The aim was to find a model with the best possible explanation factor of the correlation between dental maturity score and chronological age. A cubic function was found to give a good fit to the plots with an R^2 of about 0.95. This modification of the original Demirjian method for age estimation of children is therefore recommended for the construction of population-specific tables. The use of a mathematical function also makes it possible to calculate confidence intervals to be used to describe the accuracy of an individual estimation. **(J Forensic Odontostomatol 2001;19:26-30)**

Keywords: Age determination, children, dental development

INTRODUCTION

The most common method for age estimation in children using dental development was first published by Demirjian *et al.*,[1] and a few years later subjected to a major revision.[2] This method is based on a sample of 4,756 Canadian children of French descent and describes a universal method to calculate a dental maturity score, which can subsequently be entered into a table allowing transformation to a chronological age. The maturity score is a measure of the dental development and the corresponding chronological age can be used to estimate the age of a child with missing or uncertain birth data. As populations may differ in maturity rate, the usefulness of the method in populations other than the French-Canadian one[2] depends on the availability of tables specific for the population in question. Such tables are still rare, and if absent the best estimation is made using tables from a genetically close population.

During attempts to compile transformation tables for some other populations, it was found that the original reports by Demirjian and co-workers[1,2] do not contain enough information on how the tables and graphs were obtained. After personal contact with, and kind help from, two of the authors (Demirjian[3] and Goldstein[4]) it was established that the tables were derived from regression lines, which had been produced as the best fit of the individual plots by manual smoothing. The lines for the confidence intervals were also manually fitted. It was therefore not possible to reproduce the original results or to produce new population-specific tables exactly equivalent to the original ones. Consequently, the few studies aimed at compiling population-specific tables do not describe how the tables and regression curves were produced.[5,6]

The aim of this study was to find a simple mathematical function of the relationship between maturity score and chronological age, and finally, to compare the resulting regression line with that of the French-Canadian population as presented by Demirjian *et al.*[1,2]

Table 1:

CORRELATIONS BETWEEN MATURITY SCORE (sumscore) AND AGE (age)

Gender: GIRLS

Independent Variable: Age

Dependent Variable	Method	Rsq	d.f.	F	Sigf	b 0	b 1	b 2	b 3
sumscr	LIN	.703	240	568.93	.000	34.9922	5.0952		
sumscr	LOG	.855	240	1416.57	.000	-25.278	49.5312		
sumscr	INV	.904	240	2251.34	.000	128.021	-370.27		
sumscr	QUA	.935	239	1716.40	.000	-32.995	20.1730	-.7538	
sumscr	CUB	.944	238	1336.79	.000	-63.683	31.2842	-1.9534	.0396
sumscr	COM	.579	240	329.46	.000	38.0001	1.0808		
sumscr	POW	.766	240	784.32	.000	14.0896	.7877		
sumscr	S	.902	240	2210.80	.000	5.1205	-6.2170		
sumscr	GRO	.579	240	329.46	.000	3.6376	.077		
sumscr	EXP	.579	240	329.46	.000	38.0001	.0777		
sumscr	LGS	.579	240	329.46	.000	.0263	.9253		

Gender: BOYS

Independent Variable: Age

Dependent Variable	Method	Rsq	d.f.	F	Sigf	b 0	b 1	b 2	b 3
sumscr	LIN	.772	241	815.45	.000	25.3275	5.6715		
sumscr	LOG	.894	241	2022.24	.000	-35.163	52.5303		
sumscr	INV	.898	241	2120.81	.000	125.245	-371.94		
sumscr	QUA	.944	240	2024.95	.000	-34.355	19.5170	-.7035	
sumscr	CUB	.946	239	1401.23	.000	-49.486	25.11161	-1.3161	.0204
sumscr	COM	.659	241	365.94	.000	31.9618	1.0934		
sumscr	POW	.828	241	1160.15	.000	11.4343	.8617		
sumscr	S	.923	241	2895.65	.000	5.1077	-6.4261		
sumscr	GRO	.659	241	465.94	.000	3.4645	.0893		
sumscr	EXP	.659	241	465.94	.000	31.9618	.0893		
sumscr	LGS	.659	241	465.94	.000	.0313	.9146		

MATERIAL AND METHODS

Dental panoramic radiographs were obtained from 485 Swedish children, 242 girls (mean age 10.0 yrs., range 2.6 – 17.2 yrs.) and 243 boys (mean age 9.6 yrs., range 2.8 – 17.2 yrs.), living in various parts of the country. Part of the sample (197 individuals aged 5, 6, 9 and 12 yrs., all within a range of ± one month) came from the files of a number of specialist clinics for orthodontics or paedodontics and has been described in detail previously,[7,8] including studies of intra- and interexaminer variations.[9] The other part of the sample was collected from the files of the Department of Oral Radiology at the Dental School, Huddinge, Sweden and was evenly distributed between the age ranges. Both subsamples were drawn sequentially from the files, provided the child had a typical Swedish name, thus ensuring genetic homogeneity. All children were healthy and had a full set of permanent mandibular teeth. The chronological ages were rounded to the first decimal place of a year (Fig.1).

The radiographs were examined on a light table with the aid of a magnifying glass and a pair of callipers. The dental development, as seen in the radiographs, of each individual tooth was compared with the radiographic images, drawings and descriptions given by Demirjian *et al.*,[1] and given a score of A through H. Each of these alphanumeric scores was then translated into a numerical "self-weighted score for dental development" according to the tables in the updated report.[2] The scores for the seven mandibular teeth were then added and a dental "maturity score" was derived.

With the aid of the SPSS statistical program,[10] the original scores, A through H, were processed and transformed by running batch files containing the constants given in the paper by Demirjian and Goldstein.[2] The calculated sum of the individual scores, the maturity score, was then used to correlate with the chronological age.

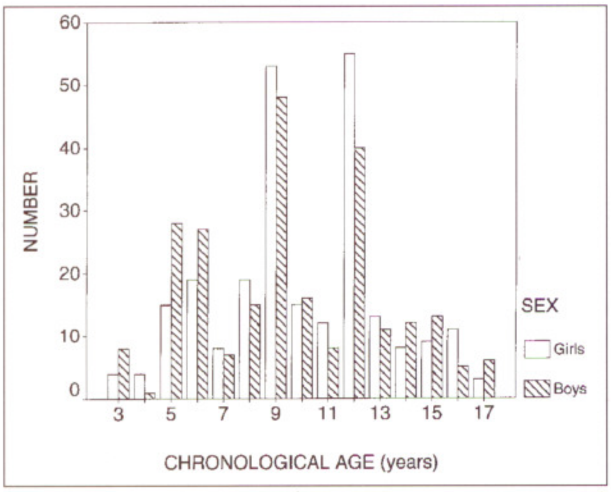
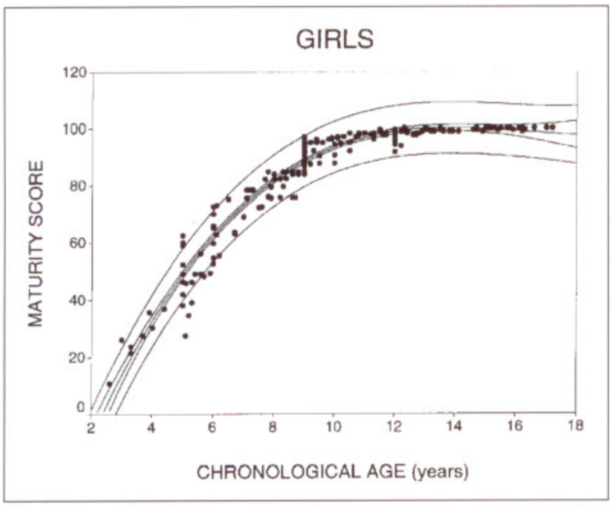


Fig.1: *Age and gender distribution of the material. (242 girls and 243 boys, mean age 9.8 years, range 2.6 - 17.2 years).*

Since the maturity scores corresponding to the revised data[2] are not tabulated, the maturity scores of the Canadian population were obtained from the tables in Demirjian *et al.*[1]

The maturity score was plotted against chronological age, and the best fitting regression line was tested with a series of curve estimation models (linear, logarithmic, inverse, quadratic, cubic, compound,



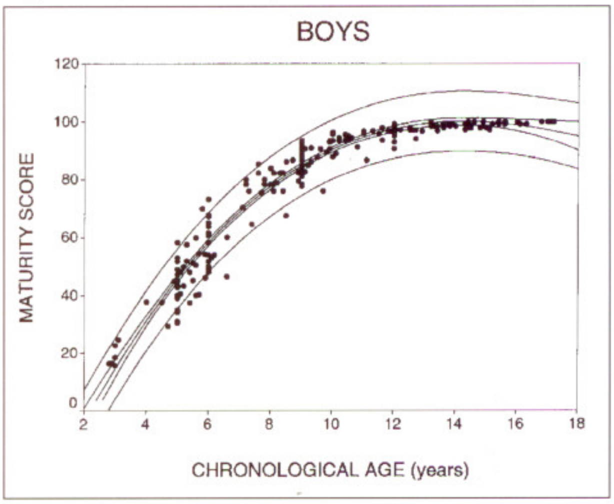


Fig.2 a and b: *Scatterplots of maturity score against chronological age for girls and boys, respectively. Inner pair of lines denotes, mean regression prediction and the outer pair, individual regression prediction at a confidence interval of 95%*

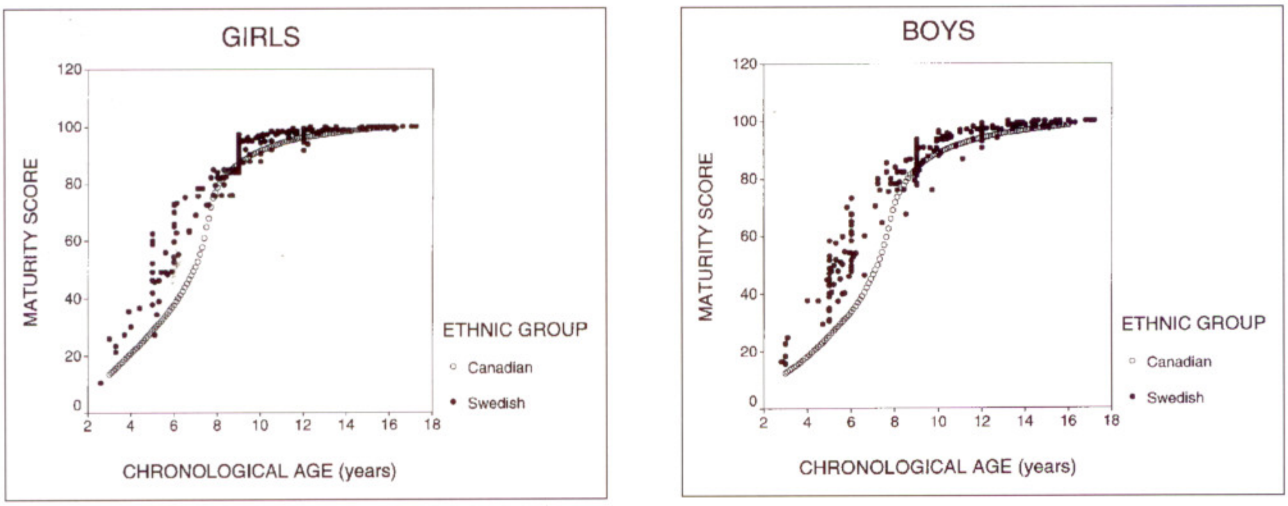


Fig.3 a and b: *Comparison of scatterplot of maturity score against chronological age for girls and boys, respectively. Filled plots Swedish children and open plots Canadian children. The Canadian data compiled from Demirjian et al. (1973)*

power, S, growth, exponential and logistic), available in the SPSS statistical package.

RESULTS

The correlation between the maturation score and chronological age is shown in Table 1 and in Figs. 2a and b. Table 1 shows the squared correlation coefficients (R^2) and some selected statistical factors and constants. The highest degrees of explanation (R^2) were obtained by the models using the cubic ($R^2 = 0.94$ for girls and $R^2 = 0.95$ for boys), quadratic ($R^2 = 0.94$ for both genders) and S ($R^2 = 0.90$ and 0.92) functions. By comparing the cubic and quadratic models with an F test, the cubic function proved to be the better model ($p < 0.005$). The cubic function also gave an apparently good fit of the individual plots, and this function was therefore chosen for the subsequent studies. Figs. 2a and b demonstrate the correlation and the fitting with the aid of the cubic function for girls and boys, respectively. Figs. 3a and b show the corresponding scatter plots together with the data from the Canadian population as extracted from the tables in Demirjian *et al.*[1]

The cubic function of the best fitting lines in Figs. 2a and b were:

Girls: maturity score = - 63.7 + 31.3 * (age) - 1.95 * $(age)^2$ + 0.0396 * $(age)^3$

Boys: maturity score = - 49.5 + 25.1 * (age) - 1.32 * $(age)^2$ + 0.0204 * $(age)^3$

It appears from Figs. 3a and b that the shape of the plots from the Swedish and Canadian populations differs. The Swedish population follows a cubic function better than the Canadian population, which is more S-shaped.

DISCUSSION

The method by Demirjian and co-workers[1,2] for age estimation of children with uncertain or unknown date of birth was a break-through when published almost 30 years ago. An important feature of the Demirjian method is its applicability to transform the universal maturity score into a chronological age. However, as also expressed by the original authors, each population then needs its own transformation table to obtain a chronological age since there appear to be differences in maturation rates of the dentitions in different populations.[3,5,9-11] Another important disadvantage with the original method is that modern forensic methods aim not only at an accurate estimated age, but also need some quantification of the dispersion around the estimate. In the original articles the dispersions were expressed as percentiles, which do not allow advanced statistical calculations.

It has been repeatedly shown that the Scandinavian population is up to one year ahead of its French-Canadian counterparts, as described in the original articles,[1,2] in its dental development when the Demirjian method has been used to compare the populations.[5,6,7,11] There could be many reasons for this difference, one being a genuine genetic difference but this seems unlikely since the genetic distance between the two populations is otherwise not especially pronounced. Other studies on more genetically distant populations[12,13] have also shown that the French-Canadian children seem to consistently lag behind when compared with the Demirjian method.

It appears from graphs in Figs. 3a and b that the plots from the Swedish population follow a cubic function although there is a tendency towards an S-shape, which however is much less pronounced than that seen in the Canadian population. The scale of the maturity score in Figs. 3a and b is linear, in contrast to the logarithmic scale in the original studies,[1,2] and the graphs can therefore not be directly compared. It could be that the manual fitting and the logarithmic scale have caused the S-shaped relationship to be exaggerated, which will give an over-estimate in those ages where the S displays the most vertical orientation, that is at the ages of 6 - 10 years, which unfortunately is when age estimations are often done.

The fitting with a cubic function is however also an approximation as there appear to be some deviations from the curve, which are especially pronounced in the lowest and highest age groups. At the ages above 15 years the downward deviation of the function is, however, of no practical importance since the method cannot in any case be used at these ages.

There also seems to be a deviation from the cubic function curve at the ages around 5 years, especially among girls, where the plots line up somewhat S-shaped, possibly causing a slight under-estimation at this age.

It is quite clear that the relationship between the maturity score and chronological age does not follow a simple mathematical function. Attempts were therefore also made to use an advanced analysis of regression with the aid of the maximum-likelihood method, with three different regression functions, linear up to the age of seven, quadratic between the ages of seven and 11 and a section of hyperbola for ages above 11 years. This method, however, does not give a better adaptation and it is not possible to carry out the calculations without a computer. The cubic function on the other hand can easily be utilised with the aid of a simple pocket calculator. The use of a modification of the original Demirjian method with the objective cubic function instead of the manual fitting is therefore recommended, and it has three major advantages. First, it makes it possible to describe a confidence interval around an estimated age, second, it makes possible the comparison of different populations, and third, it is possible to construct population specific tables out of even a small sample once the model is known.

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A COMPARISON BETWEEN DENTAL MATURITY RATE IN THE SWEDISH AND KOREAN POPULATIONS USING A MODIFIED DEMIRJIAN METHOD

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ABSTRACT

Several studies have examined variations in the rate of dental development in children from different populations using the Demirjian method for age estimation in children. Most of them have shown a more or less consistent difference between the French-Canadian population, used to construct the original method, and the population studied. In most instances the Canadian population was lagging behind in the dental development, varying from a few months up to about 1 year. In an earlier study[9] we have showed that there may be problems with the Demirjian method and a modification using a cubic regression model was suggested instead of the manually fitted original model. With this new model the rate of dental development between the Swedish and Korean populations was compared. There were highly statistically significant differences for both boys and girls, demonstrating that Swedish boys are about 2 months, and girls about 6 months earlier in their dental development at certain ages when compared to Korean children.
(J Forensic Odontostomatol 2001;19:31-5)

Keywords: Age determination, children, dental development, ethnic groups

INTRODUCTION

Several studies[1–6] have examined variations in the rate of dental development in children from different populations using the Demirjian method for age estimation in children.[7,8] Most of these studies have shown a more or less consistent difference between the French-Canadian population, used to construct the original method, and the population under investigation. In most studies the Canadian population was lagging behind in the dental development, varying from a few months up to about a year, especially so between the ages of 6 and 10 years.

The reason for this difference is difficult to understand. A genuine genetic difference is unlikely, since the genetic distance between for example the Scandinavian and the French-Canadian populations is otherwise not especially pronounced.

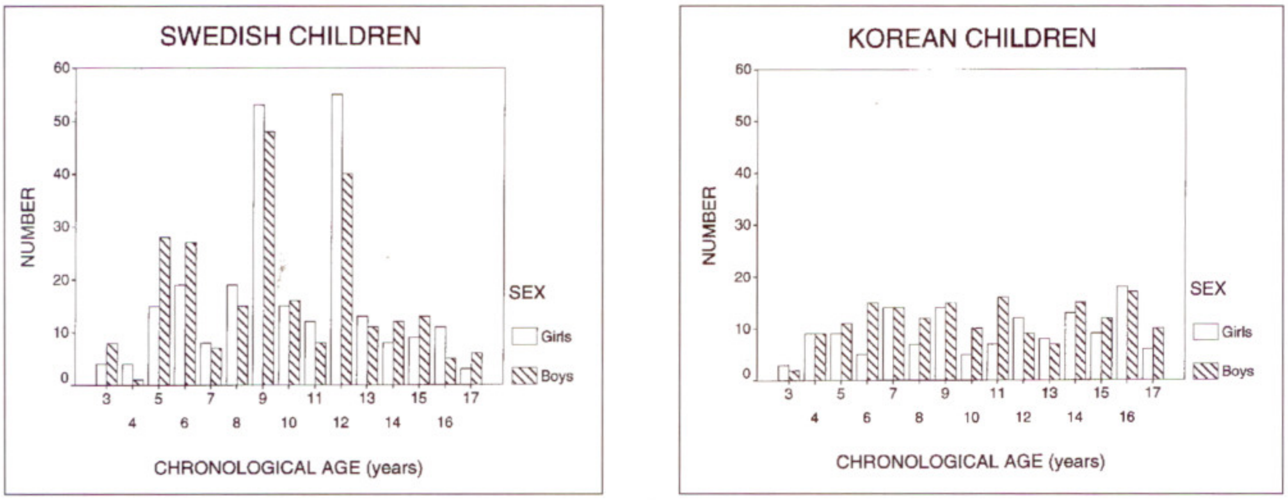
In earlier studies on age estimation of children[4, 9] it appeared that the description of the original method was not detailed enough to allow exact reproducibility, and the shape of the curves that described the relationship between age and dental maturation differed considerably at certain ages. The original method was therefore modified by introducing a mathematical model to be used instead of the original, manually fitted, model to correlate dental development with chronological age.[9] It was found that a cubic function gave a highly acceptable model of the relationship, which, for the first time, also makes it possible to compare different populations with regard to possible differences in the rate of dental development, with statistical methods.

The aim of this study was to compare the rate of dental development in two geographically different populations, that is Swedes and Koreans, using the modified Demirjian method.

MATERIAL AND METHODS

Dental panoramic radiographs were obtained from 485 Swedish and 310 Korean children of both genders, all being healthy and with a full set of permanent mandibular teeth.

The Swedish sample consisted of 242 girls (mean age 10.0, range 2.6 - 17.2 years) and 243 boys (mean age 9.6, range 2.8 - 17.2 years) living in various parts of the country. The sample was collected from the files of a number of specialist clinics of orthodontics or paedodontics. Part of the sample (197 individuals aged 5, 6, 9 and 12 years ± one month) has been used previously.[4,10,11] The additional sample,



Figs.1a and 1b: *Age and gender distributions of the Swedish and Korean children*

collected from the files of the Department of Oral Radiology at the Dental School, Huddinge, Sweden, was evenly distributed by age. The samples were drawn sequentially from the files provided the child had a typical Swedish name to ensure genetic homogeneity. The age and gender distributions are shown in Fig.1a.

The Korean sample consisted of 137 girls (mean age 10.6, range 3.0 - 17.0 years) and 173 boys (mean age 10.4, range 3.1 - 17.2 years) living in and around the city of Kwangju in the Republic of South Korea. The panoramic radiographs were collected from the files of the Dental College of Chosun University, Kwangju and age and gender distributions are shown in Fig 1b.

The radiographs were examined on a light table with the aid of a magnifying glass and a pair of callipers. The development of each tooth was compared with the radiographic images, drawings and descriptions given by Demirjian *et al.*,[7] and given a score of A through H. This score was translated into a numerical "self-weighted score for dental development" according to the table in the updated report by Demirjian and Goldstein.[8] These scores for the seven mandibular teeth were then added together, giving the "maturity score".

The "maturity score" was then correlated with the chronological age with the aid of a cubic function[9] using the GraphPad Prism[12] statistical program. Comparison between maturation rates in the two populations was made by comparing the entire curves using an F test. The F ratio was calculated using the following equation:

$$F = (SS_{combined} - SS_{separate})/(DF_{combined} - DF_{separate})/(SS_{separate}/DF_{separate})$$

Where $SS_{combined}$ is the sum of squares for the combined two populations, $SS_{separate}$ the total of the sum of squares for each of the two populations, $DF_{combined}$ the degree of freedom for the combined two populations, and $DF_{separate}$ the total of the degrees of freedom for each of the two populations.

To determine the corresponding p values the F distribution was used with 4 degrees of freedom in the numerator, and 418 and 371 degrees of freedom in the denominator for boys and girls respectively.

RESULTS

Figs. 2a - 2d show the total maturity score plotted against chronological age for the two ethnic groups separated by gender. A cubic function gave an apparently good fit of the plots in both populations, and this function therefore appeared justifiable in the study.

The constants and factors of the cubic functions, separated for ethnic group and gender, are shown in Table 1 where it appears that the square of the correlation coefficient (R^2) is high, and the model explains most of the correlation. There are no differences between the two populations in this respect.

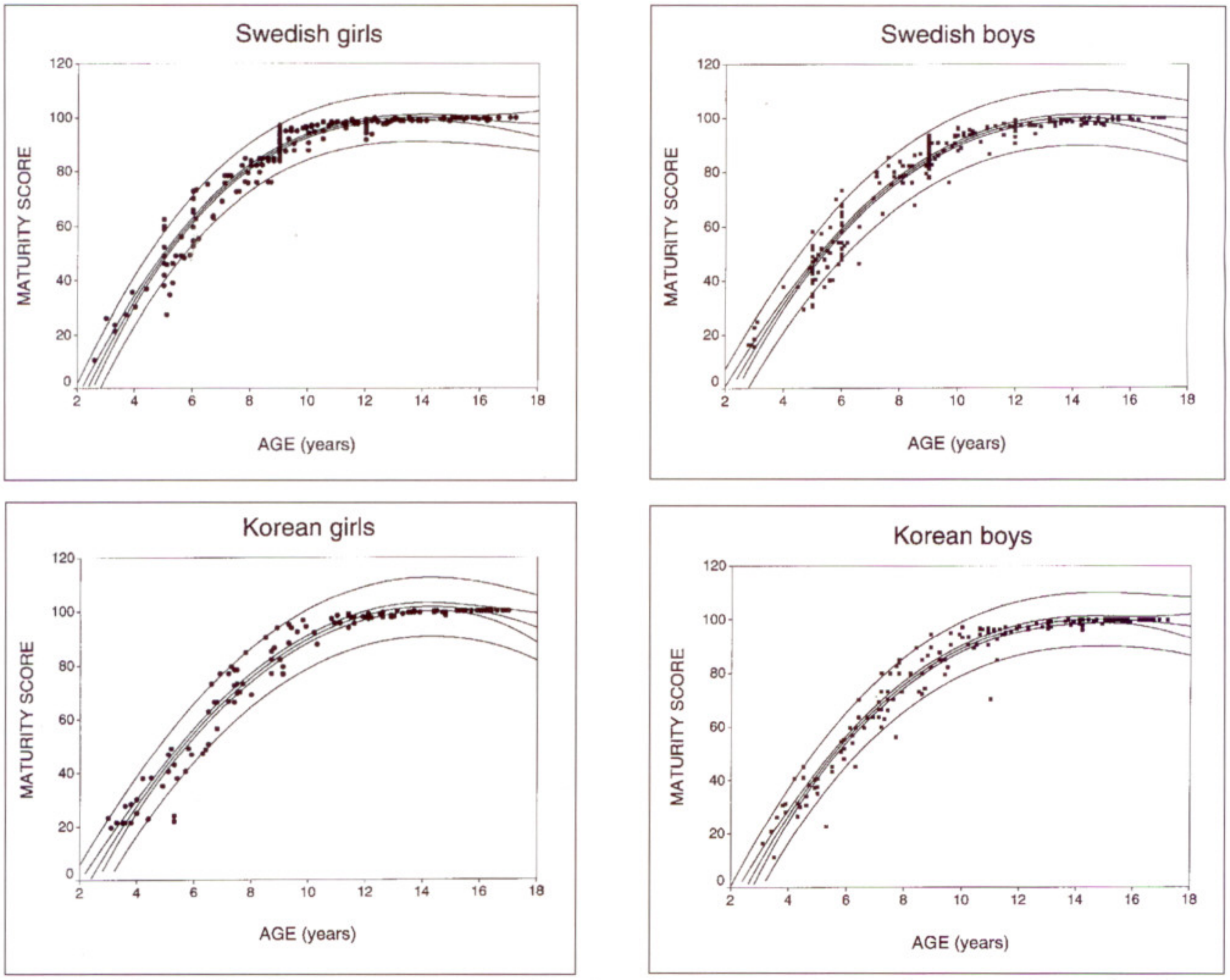


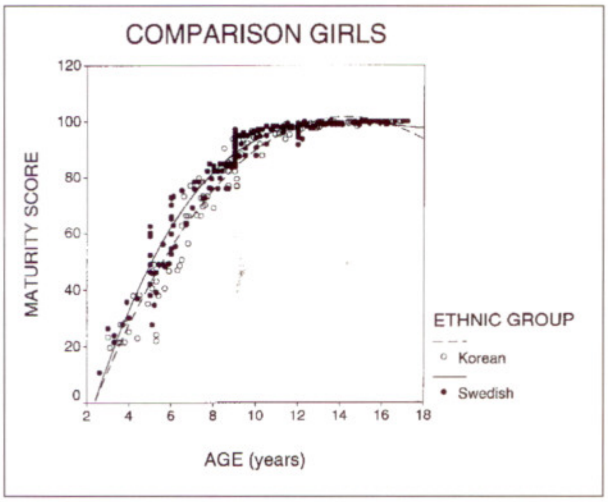
Fig 2a –2d: *Scatterplots of maturity score against chronological age using a cubic function* ($y = a + bx + cx^2 + dx^3$).

In Figs. 3a - 3b the plots and the corresponding regression curves for the two populations are superimposed. The regression curves for the Korean children are consistently shifted to the right of the curves of the Swedish children indicating that there is a slight general difference in the rate of dental development between the Swedish and Korean children. The Swedish boys are 1 - 2 months ahead of their Korean counterparts over all ages, whereas the Swedish girls appear to be up to 6 months ahead of the Korean girls over all ages, but especially so between the ages of 6 and 12 years.

In Figs. 4a and 4b the plots have been removed to display the regression curves together with their 95% confidence interval at group and individual levels. The F tests showed a statistically significant difference between the two populations at $p < 0.005$ ($F = 3.79$) and $p < 0.0001$ ($F = 15.97$) for boys and girls respectively.

DISCUSSION

The method by Demirjian and co-workers[7,8] for age estimation in children was an important development when published more than 25 years ago. It has been used world-wide since then, but a series of studies[1–6] has demonstrated that the ages of the individuals in the tested populations will be regularly over-estimated, which would mean that their dental development is earlier than that of the French-Canadian children on which the method was originally constructed. These findings, together with the fact that the description of the original method is not detailed enough to allow exact reproducibility, made it important to look further into the relationship between the dental development (here described as maturity score) and chronological age. In an earlier study [9] we found that a cubic function could be used as a model for this relationship and therefore could be suitable for the comparison of



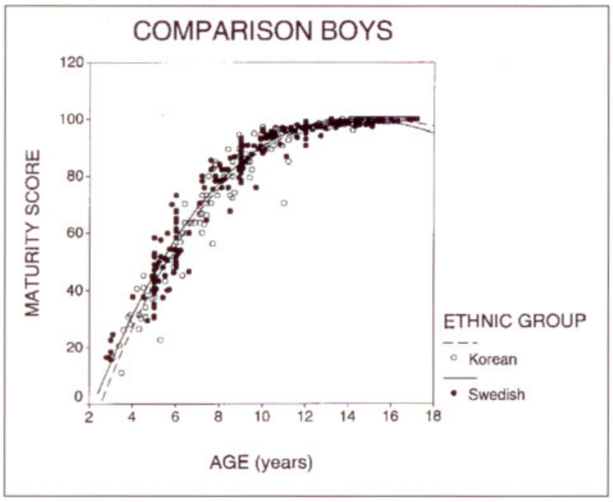
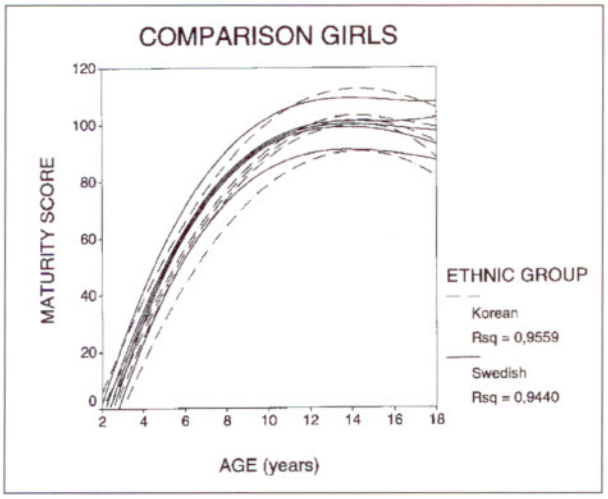


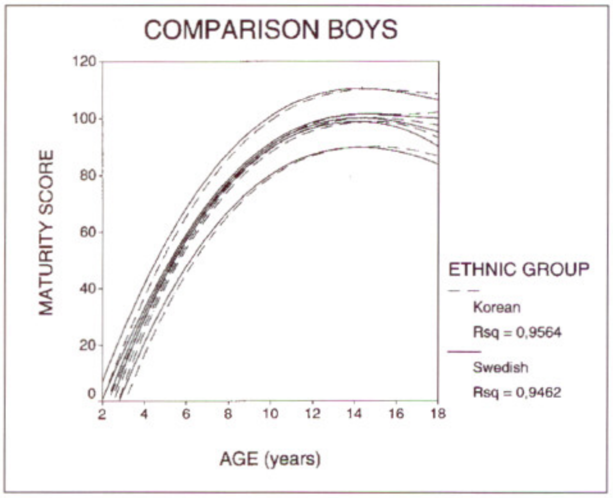
Fig.3a and 3b: *Comparison of scatterplots of maturity score against chronological age for girls and boys respectively. Filled plots represent Swedish children and open plots Korean children*

different populations. A model based on a mathematical function also has the advantage of describing confidence intervals around an estimate, and thus comparing different populations with established statistical methods.

It seems that the present results, using the cubic function, are scientifically better founded than are most of the results of earlier studies[1-6] using the original Demirjian method.[7,8] For the first time differences can be examined over the whole age scale, and not only as a mean value over several years, or only at certain ages. When comparing the Swedish and Korean populations with the modified method it was found that both Swedish boys and girls are earlier in their dental development than their Korean counterparts. The difference was only 2 – 3 months for boys, but up to half-a-year for girls, especially between the ages of 6 and 12 years.

Further studies have to confirm whether it is possible to demonstrate the difference between the French-Canadian children and most other populations with this modified method. It is possible that the shape of the maturity curve differs between populations, in which case other models have to be searched for. Unfortunately the French-Canadian population used in the original study cannot be tested since the raw data have never been published.





Figs.4a and 4b: *Same as Figs.3a and b, where the individual plots have been removed to display the lines for predictions. Inner pair of lines denotes mean regression prediction and outer pair individual regression prediction at a confidence interval of 95%*

Table 1:

CORRELATION TABLE: Dependant variable = maturity score, independent variable = age

Swedish	girls	.944	238	1336.79	.000	-63.683	31.683	-1.9534	.0396	4918
Korean	girls	.956	133	960.47	.000	-49.043	23.0579	-1.0121	.0095	4006
Swedish	boys	.946	239	1401.23	.000	-49.486	25.1161	-1.3161	.0204	6500
Korean	boys	.956	169	1235.64	.000	-60.314	27.3991	-1.5056	.0261	4318
Combined populations	girls	.942	375							10460
	boys	.949	412							11220

It seems unlikely that the difference, although statistically significant, between populations would be particularly important at individual level, since the individual variation is so large that it may mask smaller ethnic differences. It has been shown[10] that there are individual variations of up to two years around a certain stage of development, and on the other hand, that the developmental stage (on the scale A through H) of an individual tooth may vary up to five stages at a certain age.

In conclusion, using a cubic function to describe the relationship between dental development and chronological age, it seems that there are only minor, although statistically highly significant, differences in the rate of dental development between Swedish and Korean children. The Swedish girls seem to be, on average, six months ahead of the Korean girls between the ages of 6 and 12 years, and the boys a couple of months earlier. However, these ethnic differences are much smaller than the individual variations within the populations.

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DENTAL MISIDENTIFICATION ON THE BASIS OF PRESUMED UNIQUE FEATURES

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ABSTRACT

Positive identification of skeletal remains by dental comparison depends on the demonstrable concordance between post-mortem and antemortem records. However, there is no accepted norm for the number of points of concordance and there are circumstances when a single (or a few) unique features may allow positive identification. We present a recent case in which superficial similarity may have led to misidentification. We argue that misidentification is particularly likely with over-reliance on apparently unique features. The fact that a single inexplicable inconsistency will rule out a positive dental identification is highlighted. **(J Forensic Odontostomatol 2001;19:36-9)**

Key Words: Dental identification, forensic anthropology

INTRODUCTION

The positive identification of a deceased person is of importance in civil, probate and criminal law.[1] Misidentification of skeletal remains can have serious legal implications that can lead to tortuous actions. In a well publicized case the erroneous identification of Lieutenant Colonel Thomas Hart led to large damages being awarded against the United States Army.[2] Many questions of forensic identification are best answered by using the comparative method in conjunction with special knowledge of the precise anatomy and features of the dentition and its dental restorations. The most controversial aspect of this approach is the level of concordance that is acceptable because there is simply no universally accepted number of concordant points for a positive dental identification.[3] In the present communication, we report a case where reliance on an apparently unique feature may in fact have been the cause of misidentification of a skeletonised human mandibular fragment.

CASE REPORT

On 11 May 2000 the Forensic Dental Unit at the School of Dentistry, University of Otago, received a human jaw fragment containing three teeth for examination and was requested to give a second opinion regarding its identification. The remains had previously been identified as belonging to a person who had been reported missing from Christchurch, New Zealand in September 1999. The jaw fragment had been found on 18 April 2000 washed up on a local beach.

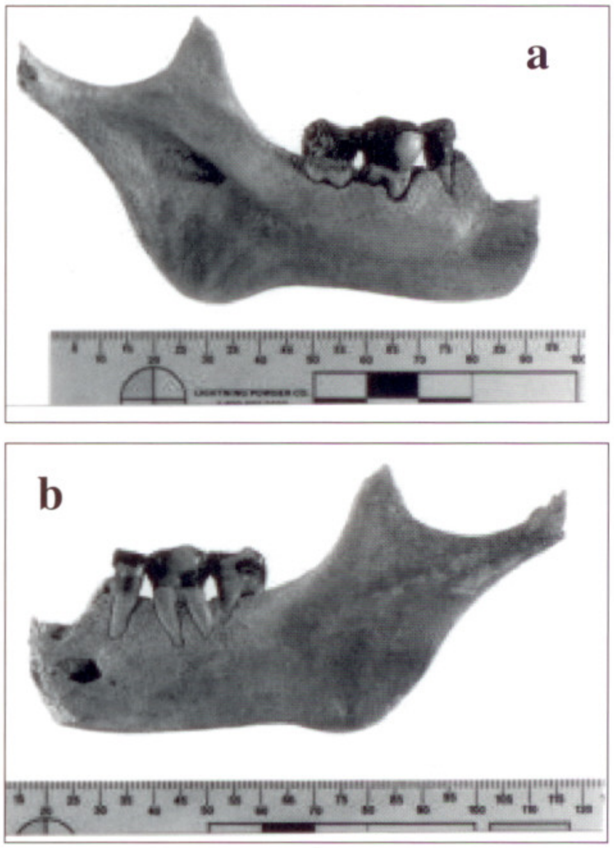

Fig.1: *Mandibular fragment washed ashore. Top is lingual view, bottom buccal view*

The specimen was that of a fragment of the lower left jaw of an adult human, fractured anteriorly near the socket of a missing first premolar and posteriorly at the junction of the neck of the mandible and the condyle (Figs. 1 a and b). While the specimen was quite well preserved, there was evidence of sand-caused erosion and subsequent loss of cortical bone, particularly on the buccal plate.

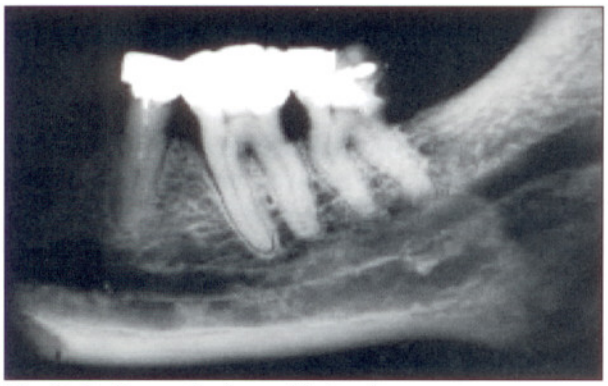

Fig.2: *Radiograph of mandibular fragment*

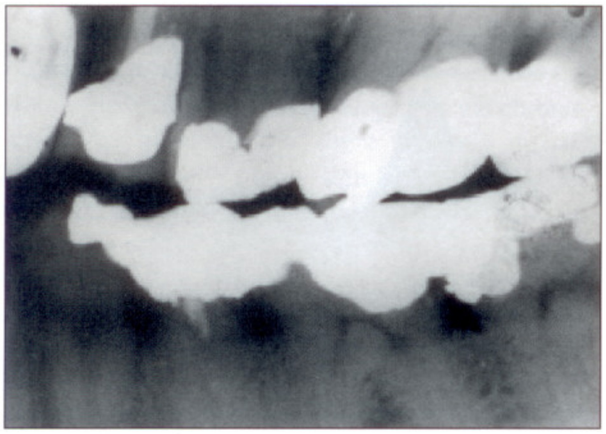

Fig.3: *Most recent antemortem dental radiograph*

Three teeth were present – the permanent mandibular second premolar, first molar and second molar. When examined and radiographed (Fig. 2), dental restorations were noted as follows:

Second premolar 35 had a complex restoration which was pin-retained over a poorly filled root canal.

First molar 36 had a large mesio-occluso-distal restoration with a small round buccal metal restoration above the origin of the distal root.

Second molar 37 had a mesio-occlusal restoration, fractured at the isthmus of what must have been a mesio-occluso-disto-lingual filling antemortem. There was a small, bean-shaped buccal restoration at the origin of the distal root.

When these postmortem features were compared to the most recent radiographs of the supposed victim, we noted the following (Figs. 3 and 4):

1. *Tooth 35* (antemortem) had a domed restoration which was flat-topped in the postmortem image (Fig. 4) (1). The root filling also differed between ante- and postmortem views and was more diffuse in the latter (Fig. 4 a and b).

2. *Tooth 36,* while displaying a large restoration on both views demonstrated that their lateral outline was only superficially similar. On careful examination the antemortem radiograph showed a bulbous distal extension while the postmortem filling was well short of the distal aspect of the pulp chamber, with the buccal filling creating an illusion of similarity to the antemortem view (Fig. 4) (2d). Additionally, the antemortem tooth appeared to have two distal canals whereas the postmortem tooth had only one (Fig. 4) (e).

3. *Tooth 37* showed the greatest discordance. What was clearly a mesio-occlusal filling antemortem was in fact a fractured mesio-occluso-distal filling postmortem. This filling had an overhang antemortem which was clearly absent postmortem (Fig. 4) (3f). There were two additional points of discordance – the shape of the cervical filling and also the curvature of the mesial roots (Fig. 4) (4g).

   Posterior bitewing radiographs were taken using a Philips Oralix50* intraoral unit set at 50kV and 7mA and Ektaspeed Plus film** (exposure time 0.4 seconds). The initial exposure was at an angle to duplicate optimal characteristics of a bitewing radiograph although further exposures were undertaken with the film positioned correctly and vertical and horizontal tube shifts were employed to duplicate the likely errors that may have occurred during the taking of the antemortem radiographs (Fig. 5).

*N.V. Philips, Medical System Division, Building QM 324, Eindhoven, Netherlands.

**Eastman Kodak Company, Rochester, New York, 14650, USA.

DISCUSSION

The foregoing case illustrates the dangers of an over-reliance on what appear to be unique features in the identification of this specimen. Silverstein[5] has defined the degrees of certainty of identification as follows:

1. *positive identification* depends on a pre- and postmortem match in such detail as to establish first that they are from the same individual and secondly that there are no irreconcilable discrepancies.

2. *possible identification* rests on pre- and postmortem features that match, but because of the quality of either the antemortem records or the postmortem remains it is not possible to establish a positive dental identification. There should be no unexplained discrepant features.

3. *insufficient evidence* implies that the information available is insufficient to provide grounds for a conclusive identification.

4. *exclusion* results from a mismatch of ante- and postmortem observations. A single inexplicable inconsistency can rule out a positive identification.[6]

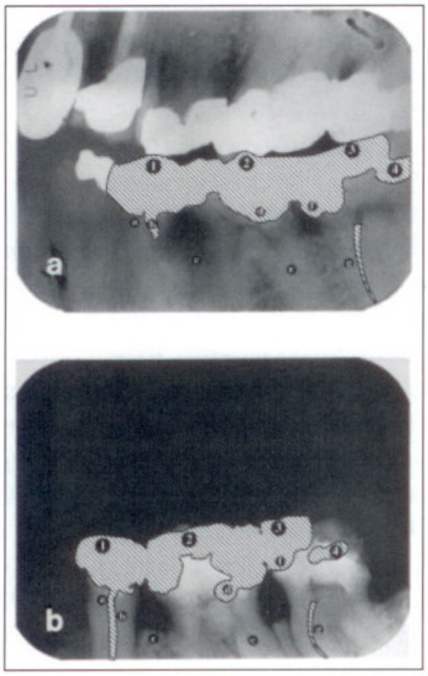

Fig.4: *Contrasting features antemortem (top) and post-mortem radiographs as discussed in text*

A detailed examination of such features as the radiographic appearance of restorations, pulpal morphology, root form, etc. may provide the necessary level of distinction or concordance needed to compare ante- and postmortem data. While the number of concordant points required for positive identification remains controversial,[7] it has been repeatedly stated that a simple unique characteristic may be sufficient to establish identity.[3,7,8] This case report illustrates the danger of focussing on what may be perceived to be unique distinguishing characters. Over-reliance on superficial similarity can favour misidentification, especially when faced with fragmented or partial remains.

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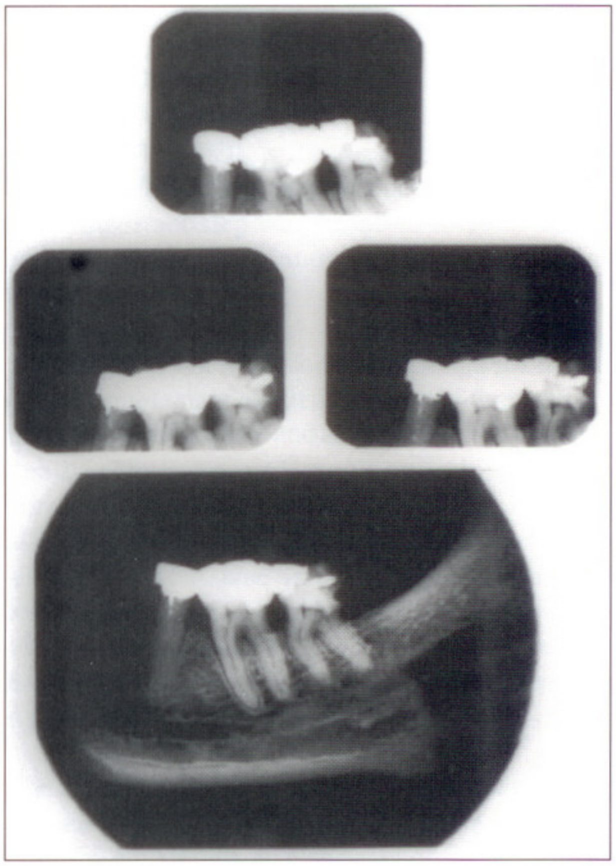

Fig 5: *Radiographs taken at an angle to duplicate optimal characteristics of a bitewing radiograph (top) and additional exposures with vertical (left) and horizontal tube shifts (right) to duplicate likely errors during antemortem radiography. Bottom radiograph is a reference to Fig. 1*

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DISASTER VICTIM IDENTIFICATION AT INTERNATIONAL LEVEL
The role of INTERPOL – now and in the future

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INTRODUCTION

Almost every week natural and man-made disasters cause multiple deaths around the world. As they involve international travellers and as the numbers of people involved increases, so will INTERPOL's role become more important in recovering and identifying the victims.

INTERPOL'S INVOLVEMENT IN DVI

In 1978 a container truck loaded with fuel exploded near a camping site in Los Alfaques, Spain, killing more than 150 persons of different nationalities. The co-ordination of the identification of those casualties was not easy and from that moment the International Police Organisation (INTERPOL) became involved in the handling of disasters and in organising the identification process of the victims. In 1980 at its 49th session in Manila the General Assembly adopted a resolution to create the INTERPOL Standing Committee on Disaster Victim Identification.

The membership of that Committee has risen from an initial 10 countries, most of them western European, to the current 29 countries from all continents, and is composed of senior police experts, forensic odontologists, forensic pathologists and forensic anthropologists. Over the years, co-operation and working relations have been developed with other international organisations including the United Nations Office for the Co-ordination of Humanitarian Affairs, the International Civil Aviation Organisation, the International Air Transport Association and the International Criminal Tribunal for the Former Yugoslavia in The Hague.

Since 1994 the INTERPOL DVI Standing Committee has had annual meetings, with the overall aim of this Committee to facilitate the sharing of information and experience, to pass on the lessons learned from previous disasters, to refine common procedures and standards for the benefit of all 177 INTERPOL member countries and to promulgate good practice in victim identification.

INTERPOL PROCEDURES AND STANDARDS

One of INTERPOL's first acts in 1984 was the creation of the ante-mortem and post-mortem forms. This important step was followed in 1986 by the publication of the Manual on Disaster Victim Identification.

The post-mortem (PM) form is designed for listing all obtainable data about a dead body that may be used for identification and establishing the cause of death. The layout of the form is intended to correspond to the actual sequence of events and allows a simultaneous examination of effects, body and teeth. At the same time the pathologists are also looking for elements which could explain the cause of the accident or disaster. Their findings are then handed over to the judicial authorities in a separate report outlining the chain of events.

The ante-mortem (AM) form is designed for listing any information that may be obtained from relatives, friends, physicians and dentists of the presumed victim or missing person and that may assist in identification, in order to compare that information with the data on the PM form.

Initially based on the field experiences of the members of the Committee the AM and PM forms have been revised over the years, and lately on new developments in investigation techniques such as genetic identification (DNA), which from experience have proved to be very successful in many large-scale incidents. The forms have also been adapted to allow the use of computers and to facilitate the exchange of information, eventually overcoming language barriers.

As a result of these alterations the Manual has been developed into a fully-fledged Guide on Disaster Victim Identification and intended for use in any country that has to manage a disaster and/or would like to assemble a DVI Team. The guide describes in a practical way the INTERPOL DVI philosophy based upon a global interdisciplinary approach taking into account the different customs, cultural, religious and ethnic considerations with respect to the victims' families.

The work in the field is based upon five well known steps, that is recovery and numbering of remains, PM examination and recording, temporary storage of remains, AM records and AM and PM record comparison and identification.

Use of these simple steps in a structured and co-ordinated way usually rewards the team with its ultimate goal: the identification of all the victims, but in a less than ideal world the reality is somewhat different.

THE REALITY

A number of well known problems have been experienced, namely, a lack of preparation, an excessive input of different agencies without the necessary co-ordination, an under-resourcing of personnel, especially forensic experts, a lack of adequate material resources, an unanticipated complexity of the situation, excessive fatigue and stress related and other factors, and all this despite the fact that internationally agreed standards and procedures are well established.

The problem almost all international organisations, and probably also all field workers involved in such disasters experience, is that as a general rule, organisations such as INTERPOL can only make recommendations and have no real power of enforcement. Consequently, things change slowly and in the meantime, in many cases the victims' relatives are left in limbo.

THE FUTURE

To facilitate the dissemination of the internationally agreed standards and procedures for police and experts involved in victim identification the Secretariat General of INTERPOL has included the AM and PM forms as well as the Guide on Disaster Victim Identification in their website at http://www.interpol.int/.

To facilitate an improved acceptance and usage of the DVI strategy at international level in the future all readers of this article, as a strategic target group, are asked to speak about the problem of victim identification in the many and varied contacts with their own authorities and to make them aware of the existence of internationally agreed AM and PM forms and procedures. This is not only in the interests of their own citizens who at any time can become primary or secondary victims of a disaster anywhere in the world but also in the interests of the people of those countries who cannot afford a DVI team because there are more urgent priorities; not to mention losing a loved one which carries grief common to every human being.

To those already involved in or interested in being involved in victim identification there is no better baseline to adopt than the established standards, especially in those cases where foreign nationals are involved. The INTERPOL AM and PM forms and the procedures can be used in cases involving single as well as multiple unidentified bodies. For a large number of bodies the only increased needs are more personnel, logistics and time.

It should however be remembered that, based upon the author's own experience and what he has been told by many police and experts working in the field: working in the area of victim identification will change one's life and the way one views people, and that is the reason all involved in DVI together with the INTERPOL Standing Committee should:

1. continue to promote the DVI philosophy and working procedures within the 177 member countries of INTERPOL,

2. promote the international DVI cause for those countries that are interested in creating their own DVI Team,

3. create the structures for an international DVI team composed of members and experts of national DVI teams who can be called in as a task force by those countries who are not in a material or economic position to create a team of their own and

4. continue to improve the standards and procedures and to refine the forms based upon practical experience gained from actual incidents and of developments in identification techniques.

CONCLUSION

This author asks whether the requirements stated are too overreaching? Are these DVI matters of sufficient importance?

These will remain rhetorical questions but suffice it to say that at any moment, anywhere in the world, a relative and loved one could be a victim of a disaster. It is therefore reassuring to know that an organisation such as INTERPOL has spent time and resources focusing on DVI activities so that all nations can call on it for assistance and/or expertise in disaster management when needed.

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