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Forensic age estimation in living subjects: the ethnic factor in wisdom tooth mineralization

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Abstract Radiological assessment of the mineralization stage of third molars is a major criterion for age estimation of living people involved in criminal proceedings. To date insufficient knowledge has been obtained about how the ethnic origin can influence tooth mineralization. A comparative study of wisdom tooth mineralization was carried out on three population samples: one German, one Japanese and one South African. To this end, 3,652 conventional orthopantomograms were evaluated on the basis of Demirjian's stages. The Japanese subjects were on average 1–2 years older than their German counterparts upon reaching stages D–F, whereas the South African subjects were on average 1–2 years younger than the Germans when displaying stages D–G. To enhance the accuracy of forensic age estimates based on wisdom tooth mineralization we recommend the use of population-specific standards.

Keywords Dental age · Third molar · Tooth mineralization · Ethnicity

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Introduction

Forensic age estimation is one of the key research areas in the field of forensic medicine (Ohtani et al. 2003; Ritz-Timme et al. 2003; Schmeling et al. 2004; Takasaki et al. 2003). In recent years it has become increasingly important to determine, in particular, the age of living persons (Schmeling et al. 2001b). From a legal perspective, such age estimates are carried out to determine whether a suspect without valid identification documents has reached the age of criminal responsibility and whether general criminal law in force for adults is to be applied. In many countries the age thresholds of relevance to criminal prosecution lie between 14 and 18 (Dünkel et al. 1997).

Age evaluations carried out *lege artis* by order of a judge contribute substantially to enhancing legal security. They do so by promoting equitable treatment of offenders under the judicial system regardless of whether those concerned possess identity papers or not, and also by serving to disprove allegations of perjury if the statement a defendant has made about his or her age is thereby confirmed.

In line with recommendations drawn up by the international, interdisciplinary Study Group on Forensic Age Diagnostics (http://www.charite.de/rechtsmedizin/agfad/index.htm), a forensic age diagnosis for the purpose of criminal investigations should consist of a clinical examination, including the recording of body measurements and an evaluation of signs of sexual maturity, an X-ray examination of the left hand, and a dental examination which records dentition status and evaluates an orthopantomogram (Schmeling et al. 2001a). One major criterion for dental age assessment is the evaluation of third molar mineralization.

To date insufficient knowledge has been obtained about how ethnic origin can influence tooth mineralization. This, however, constitutes a restraint on the reliability of age estimates and hence on the forensic value of information essential to legal security. The present study is intended to present comparative data on third molar mineralization in Caucasoid, Mongoloid and African population samples.

Table 1 Age and gender distribution in the population samples examined

Age (years)	Number of German males	Number of German females	Number of Japanese males	Number of Japanese females	Number of South African males	Number of South African females
12	2	10	1	2	6	4
13	5	24	0	0	8	5
14	15	39	0	3	5	5
15	34	44	5	11	12	5
16	37	56	17	21	10	12
17	22	54	9	24	15	6
18	31	69	21	44	23	7
19	36	61	78	91	37	7
20	57	72	69	115	45	13
21	67	84	85	137	55	9
22	71	87	85	146	73	13
23	71	88	100	142	64	15
24	66	96	104	108	61	7
25	42	62	75	51	37	6
26	15	13	27	26	17	2
Total	571	859	676	921	468	116

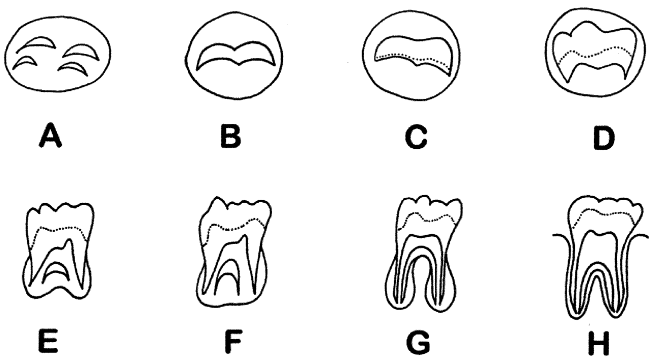

Fig. 1 Diagrammatic representation of the formation stages A–H of third molars as described by Demirjian et al. (1973)

Materials and methods

A total of 3,652 conventional orthopantomograms were examined from 1,430 German, 1,597 Japanese and 584 black South African subjects, all aged between 12 and 26 and with known dates of birth. The patient's identification number, gender, date of birth and date of X-ray were recorded. The patient's age was calculated from the date of birth and the date of the X-ray. Table 1 shows the age and gender distribution of the sample sets.

The mineralization status of the third molars was assessed using the formation stages described by Demirjian et al. (1973) (Fig. 1). All these assessments were carried out by the same observer (A.O.).

Results are expressed as mean ±standard deviation (SD) or median with lower and upper quartiles. Statistical analyses were performed using SPSS for Windows (Release 11.0.1, SPSS Inc. 1989–2001). To cope with outliers and/or skew distributions, differences between interesting groups of individuals were analysed using non-parametric statistical tests (Kruskal-Wallis test for several groups, Mann-Whitney-U test for two independent groups or Wilcoxon test for paired observations). Exact versions of the tests were applied to handle major differences in sample sizes (StatXact 5, Cytel Software Corp. Cambridge, MA). Significance was assessed at $p< 0.05$, exact and two-sided.

Results

In the present study, the Demirjian stages D–H were established for each sample population. Table 2 shows mean values and standard deviations as well as median values with lower and upper quartiles for tooth 48 at each stage in relation to ethnic group, age and gender. As the mean value and standard deviation for stage H, which marks the end of dental mineralization, depends on the age group under investigation, additional data are provided on age of first incidence and age of 50% frequency (Table 3).

Statistically significant differences between German and Japanese males were noted for stages D–G of mineralization. Significant differences between Japanese and German females were observed for stages D–F. According to our findings, Japanese males and females were approximately 1–2 years older than their German counterparts when they reached stages D–F.

Significant age differences between South African and German males applied to stages D–E and significant age differences between South African and German females were observed for stages E and G. The South African subjects were approximately 1–2 years younger than the German subjects upon achieving these stages of mineralization.

Significant age differences between the South African and Japanese samples were ascertained for both genders at stages D–G. The South African subjects were approximately 1–4 years younger than the Japanese subjects upon reaching these stages.

A similar structure of significance was derived for teeth 18, 28 and 38.

Discussion

A question of major practical relevance to estimating age is whether the reference data customarily used for foren-

Table 2 Statistical measurement data and significant population differences for tooth 48

Stage	Sample	Mean±SD	Median, LQ, UQ
D	German males	16.1±3.0[1,2]	15.3, 14.2, 16.9
	German females	15.8±2.6[1]	15.2, 14.2, 16.7
	Japanese males	18.1±2.9[1,3]	16.8, 15.8, 20.0
	Japanese females	18.0±2.5[1,3]	17.6, 15.9, 19.9
	South African males	13.9±1.3[2,3]	13.9, 12.9, 15.1
	South African females	14.5±2.3[3]	14.1, 12.6, 15.7
E	German males	16.7±2.1[1,2]	16.1, 15.3, 17.7
	German females	17.2±2.4[1,2]	16.8, 15.3, 18.9
	Japanese males	18.6±2.9[1,3]	19.1, 15.7, 20.2
	Japanese females	18.2±2.3[1,3]	18.5, 16.6, 19.7
	South African males	15.2±2.4[2,3]	15.2, 13.4, 16.2
	South African females	15.9±2.3[2,3]	15.6, 14.5, 16.8
F	German males	18.2±2.1[1]	18.1, 16.7, 19.4
	German females	19.0±2.5[1]	18.7, 17.3, 20.7
	Japanese males	19.8±2.2[1,3]	19.5, 18.8, 21.3
	Japanese females	20.3±1.9[1,3]	20.2, 19.1, 21.7
	South African males	18.7±2.3[3]	18.7, 17.0, 20.3
	South African females	17.4±2.5[3]	17.5, 15.9, 19.2
G	German males	21.2±1.9[1]	20.7, 19.9, 22.5
	German females	21.6±2.1[2]	21.7, 20.2, 23.1
	Japanese males	21.8±2.1[1,3]	21.8, 20.2, 23.6
	Japanese females	21.5±1.8[3]	21.4, 20.2, 23.0
	South African males	20.8±2.2[3]	20.6, 19.1, 22.5
	South African females	19.8±2.3[2,3]	20.1, 17.7, 22.1
H	German males	22.5±1.7	22.7, 21.4, 23.9
	German females	22.9±1.7	23.2, 21.6, 24.1
	Japanese males	22.5±1.8	22.8, 21.0, 23.9
	Japanese females	22.1±1.8	22.2, 21.1, 23.5
	South African males	22.6±1.9	22.8, 21.3, 24.2
	South African females	22.4±1.9	22.7, 21.0, 23.8

[1]Statistically significant differences ($p<0.05$) between Japanese and Germans.
[2]Statistically significant differences ($p<0.05$) between South Africans and Germans.
[3]Statistically significant differences ($p<0.05$) between Japanese and South Africans.
SD Standard deviation.
LQ Lower quartile.
UQ Upper quartile.

Table 3 Age at initial incidence and at 50% frequency for stage H

Sample	Age at initial incidence	Age at 50% frequency
German males	17	20–21
German females	17	22–23
Japanese males	18	21–22
Japanese females	16	23–24
South African males	17	20
South African females	17	20–21

sic diagnosis, derived from white North Americans on the one hand and central and northern Europeans on the other, can also be applied to members of other ethnic groups. In the context of this study, the term “ethnicity” is used exclusively to indicate a population’s origins by ancestry. Taking a typology of 110 genetic markers in over 1,800 indigenous populations as their basis, Cavalli-Sforza et al. (1994) divided the world’s population into 4 principal ethnic groups: Africans, Australians, Caucasoids and Mongoloids.

Extensive analysis of the literature on skeletal development has shown that ossification follows identical defined stages in the populations of all principal ethnic groups under investigation (Schmeling et al. 2000). Ethnic origin apparently exerts no noteworthy influence on the speed of ossification for a particular age group. Skeletal maturity is, on the other hand, greatly determined by the socio-economic status of a population. A relatively low socio-economic status delays development and is thus conducive to the underestimation of a subject’s age. Therefore, when the usual reference studies are applied to individuals from socio-economically less developed populations, these individuals are not disadvantaged in terms of criminal prosecution – quite the reverse.

In previous studies the methods used to assess dental mineralization varied from one author to another, so that the results are not directly comparable (Hägg and Matsson 1985; Pöyry et al. 1986).

Stages of formation have been defined differently in past publications by Gleiser and Hunt (1955), Moorrees et al. (1963) Kullman et al. (1992) and Köhler et al. (1994). The stages described in these classifications are sometimes numerous and difficult to match against each other. Moreover, a distinction is drawn between, for example one-quarter, one-third, one-half and two-thirds of the estimated future length of root, resulting in a rather subjective approach to estimation (Demirjian 1986).

Demirjian et al. (1973) presented a breakdown based on four distinct stages each for the crown and the root (stages A–H). The authors avoided numbering the stages in order not to create the impression that they are all of the same duration. Demirjian’s stages are defined by changes in shape and do not depend on speculative estimates of length. For this reason, we chose Demirjian’s classification as the most suitable for our investigation.

Few comparative studies are available on the subject of wisdom tooth mineralization.

Gorgani et al. (1990) examined 229 black and 221 white US citizens aged 6–14 years. Among the black subjects crown mineralization of the third molars was completed 1 year earlier.

Harris and McKee (1990) studied 655 white and 335 black US citizens aged 3.5–13 years. Whereas the black subjects reached the earlier stages of wisdom tooth mineralization about 1 year earlier, the gap appeared to narrow for later stages.

This trend is confirmed by the work of Mincer et al. (1993). They examined 823 US citizens (80% white, 19% black) aged 14–25 years but did not establish any significant differences in the time frame for wisdom tooth mineralization.

Daito et al. (1992) addressed wisdom tooth mineralization in 9,111 Japanese youngsters aged 7–16 years and compared their data with the values provided by Gravely

(1965), Rantanen (1967) and Haavikko (1970) for Caucasoid populations. No significant differences were discovered.

These studies only lend themselves to limited comparison due to small sample sizes, varying methods and assessment by different observers. A further problem lies in the fact that the age data for subjects of black African origin were often not verified (Krumholt et al. 1971). Moreover, most available studies focus on the earlier stages of mineralization.

As far as the present authors are aware, this is the first study to supply comparable reference data on wisdom tooth mineralization for Caucasoid, Mongoloid and African population samples of forensically relevant age for whom dates of birth have been checked under standardized conditions. Potential interobserver error was eliminated by ensuring that all estimates were performed by the same observer.

Summing up our results, we can state that if we consider the predominant stage of mineralization in any given age group, the Caucasoid sample we investigated occupied the middle position by age for each stage of mineralization investigated. For stages D–F the Mongoloid subjects were on average 1–2 years older, whereas for stages D–G the African subjects were about 1–2 years younger than Caucasoid subjects who had obtained the same level of mineralization.

The population differences observed here may be due to differences in palatal dimensions between the ethnic groups surveyed. The largest palatal dimensions are observed in Africans and the smallest in Mongoloids, with Caucasoids assuming the middle rank (Byers et al. 1997). Inadequate space in the maxillary crest causes delay in wisdom tooth eruption, if not retention (Fanning 1962). In turn, retained wisdom teeth mineralize later than teeth where eruption has not been impeded (Köhler et al. 1994). This would explain why Caucasoid populations occupy the middle position in relative terms when it comes to wisdom tooth mineralization, while Mongoloid populations display a comparative delay and African populations a relative acceleration.

It may safely be concluded that population-specific standards would enhance the accuracy of forensic age estimates based on wisdom tooth mineralization in living subjects.

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