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ORIGINAL ARTICLE

Assessment of the radiographic visibility of the periodontal ligament in the lower third molars for the purpose of forensic age estimation in living individuals

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Abstract The main criterion for dental age estimation in living individuals is the mineralisation of third molars. However, the mineralisation of third molars can be completed before the forensically relevant age of 18 years has been attained. In a material of 1,198 orthopantomograms from 629 females and 569 males aged between 15 and 40 years, the radiographic visibility of the periodontal membrane of fully mineralised third molars was assessed according to stages 0, 1, 2 and 3. Stage 0 first appeared at the age of 17.2 years in females and at the age of 17.6 years in males. Stage 1 was first achieved by females between 18.9 and 20.0 years and by males between 20.1 and 20.2 years. The earliest appearance of stage 2 was between 22.5 and 23.1 years in females and at 22.3 years in males. The occurrence of stage 3 was first found between 24.6 and 25.2 years in females and between 25.4 and 26.2 years in males. If stage 1 is determined, it is, therefore, possible to prove that an individual has already attained the legally relevant age of 18 years. For stages 2 and 3, it can be stated beyond reasonable doubt that a person is over 21 years of age.

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Introduction

Forensic age estimation in living adolescents and young adults is an established research field in forensic science [1, 3, 5, 10, 11]. The reason for the increasing importance of forensic age estimation in living individuals today is cross-border migration, which has led to an increasing number of non-nationals giving doubtful information about their date of birth. In these cases, age estimation is necessary in the course of criminal, civil or asylum proceedings [8]. In most European countries, the age of 18 years is of special importance as individuals below that age are considered minors and have special rights according to the UN Child Convention. In addition, the age limits of 14, 16 and 21 years are also of importance in some countries.

In accordance with the updated recommendations for age estimation in criminal proceedings of the Study Group on Forensic Age Diagnostics of the German Society of Legal Medicine for an age estimation a physical examination, an X-ray examination of the hand as well as a dental examination should be performed. If the skeletal development of the hand is completed, an additional X-ray examination or CT scan of the clavicles should be carried out [9].

The main criterion for dental age estimation in the relevant age group may be mineralisation stages of the third molars; however, the root mineralisation of third molars can be completed under the age of 18 [2, 4, 6]. In a recently published paper, [7] described the radiographic visibility of the root pulp in third molars as a potential age estimation criterion after completed formation of the root. In this

Table 1 Age and sex distribution of the material (n=1,198)

Age	Female	Male
15	25	24
16	25	26
17	29	25
18	22	15
19	26	13
20	25	26
21	25	27
22	25	24
23	27	22
24	22	18
25	26	18
26	25	24
27	23	25
28	26	24
29	22	25
30	26	24
31	24	25
32	26	24
33	20	25
34	25	23
35	25	14
36	25	25
37	21	21
38	24	20
39	25	23
40	15	9
Total	629	569

study, we examined whether the radiographic visibility of the periodontal membrane of fully mineralized third molars might be helpful for the exclusion of ages under 18 years as well.

Materials and methods

One thousand, one hundred ninety-eight OPGs from 629 females and 569 males were examined. The material was divided into age groups of 1 year from 15 to 40 years. For example, the age of 15 years was defined as 15.0 to 15.9 years. The age and sex distribution of the material is shown in Table 1. The radiographs were taken of a German population during the years 1987 to 2008. The ethnicity of the study population was not recorded. However, it can be assumed that almost all subjects were Caucasian. Dates of birth and exposure dates were proven but unknown to the examiner as the study was blinded.

The visibility of the periodontal ligament of third molars with completed root formation including apical closure was recorded in four stages as shown in Fig. 1.

The stages are defined as:

Stage 0 = The periodontal ligament is visible along the full length of all roots.
Stage 1 = The periodontal ligament is invisible in one root from apex to more than half root.
Stage 2 = The periodontal ligament is invisible along almost the full length of one root or along part of the root in two roots or both.
Stage 3 = The periodontal ligament is invisible along almost the full length of two roots.

In third molars with one root only stages 0, 1 (periodontal ligament invisible from apex to more than half root) and 2 (periodontal ligament invisible along almost the full length of the root) can be determined.

Microsoft Excel tables were used for the registration of data. Patient identification number, sex, date of birth, date of radiographic exposure and stage of radiographic visibility of the root pulp were recorded for each case.

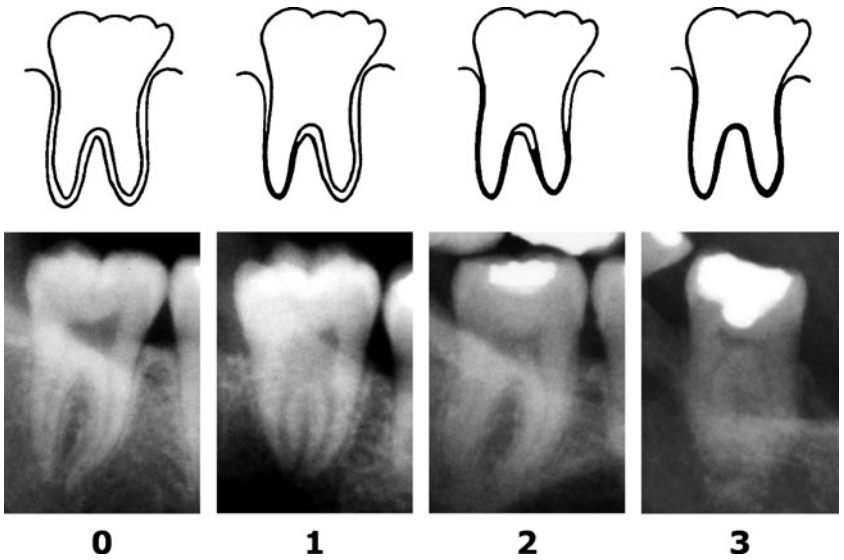

Fig. 1 Schematic drawings and pictures of the stages of radiographic visibility of the periodontal ligament in third molars

Table 2 Statistical data on the age (in years) of the stages of radiographic visibility of the periodontal ligament of teeth 38 and 48, by stage, in females

Tooth	Stage	Number	Min	Max	LQ	Median	UQ	Mean	SD
38	0	33	17.2	25.2	19.8	20.8	22.5	21.1	1.9
	1	37	20.0	28.8	21.9	22.5	23.7	22.9	1.9
	2	273	23.1	40.5	27.3	31.3	35.3	31.4	4.8
	3	60	25.2	40.9	33.0	37.0	39.0	35.7	4.0
48	0	39	17.2	24.5	20.2	21.7	23.1	21.5	1.9
	1	34	18.9	30.0	21.9	23.0	25.0	23.5	2.3
	2	298	22.5	40.6	27.6	31.3	35.3	31.6	4.7
	3	55	24.6	40.9	33.7	36.2	38.3	35.4	4.0

Min minimum age, *Max* maximum age, *SD* standard deviation, *LQ* lower quartile, *UQ* upper quartile

The programme SPSS 16.0 for Windows was used for statistical analysis. Each individual age was calculated as date of exposure minus date of birth and recorded as years and 1/10 of years. For each stage, a minimum and a maximum were found and a median with lower and upper quartiles as well as a mean with standard deviation were calculated.

Results

The results of the statistical analysis are shown in Table 2 for females and in Table 3 for males.

Stage 0 first appeared at the age of 17.2 years in females and at the age of 17.6 years in males. Stage 1 was first achieved by females between 18.9 and 20.0 years and by males between 20.1 and 20.2 years. The earliest appearance of stage 2 was between 22.5 and 23.1 years in females and at 22.3 years in males. The occurrence of stage 3 was first found between 24.6 and 25.2 years in females and between 25.4 and 26.2 years in males.

For stage 0, the medians varied for both sexes between 20.8 and 21.7 years. The medians of stage 1 were between 22.2 and 23.0 years. The medians for stage 2 showed a range between 30.7 and 31.3 years. For stage 3, the medians varied between 33.8 and 37.0 years.

Discussion

The individuals in this material were 15 to 40 years of age, and it should be satisfactory for a study like this. It should also be noted that the distribution in different ages was comparatively equal. In most age groups, the material comprised more than 20 individuals for both males and females. A problem with the material may be that it is not randomly selected. Today, this is almost impossible to obtain as radiographic laws will prevent taking radiographs for research purposes. Only retrospective material taken for diagnostics and often for orthodontic treatment may be available.

On radiographs, the assessment of the periodontal ligament of the upper jaw may generally be problematic as the maxillary wisdom teeth are often overshadowed by bone structures. Therefore, the study was restricted to the evaluation of the lower third molars.

In many countries, proof of that an individual has attained 18 years of age may be of special importance for age estimation in living individuals. The development of the root of the wisdom tooth is completed around the age of 20 years, but in a few cases, it has been shown that individuals could be under 18 years of age [2, 4, 6]. Thus, it is difficult to exclude this possibility in a given case.

The disappearance of the periodontal ligament is an optical phenomenon. The biological background for this may be that

Table 3 Statistical data on the age (in years) of the stages of radiographic visibility of the periodontal ligament of teeth 38 and 48, by stage, in males

Tooth	Stage	Number	Min	Max	LQ	Median	UQ	Mean	SD
38	0	40	17.6	24.0	20.5	21.3	22.2	21.3	1.3
	1	30	20.1	26.4	21.0	22.4	23.6	22.4	1.5
	2	253	22.3	40.6	27.3	31.3	34.8	31.3	4.7
	3	64	26.2	40.5	30.0	33.8	36.9	33.7	4.0
48	0	44	17.6	30.3	20.5	21.4	22.4	21.5	1.9
	1	25	20.2	24.5	20.8	22.2	23.6	22.2	1.4
	2	259	22.3	40.5	27.1	30.7	34.7	31.1	4.8
	3	81	25.4	40.6	30.3	34.5	37.8	34.2	4.3

Min minimum age, *Max* maximum age, *SD* standard deviation, *LQ* lower quartile, *UQ* upper quartile

the membrane becomes so narrow that one cannot see it on radiographs. Also, the surface of the tooth root becomes rougher with time and thus, perhaps also the alveolar bone adjacent to it.

We observed that the radiographic image of the periodontal ligament disappears some time after the age of 20 years. Therefore, a systematic classification into four stages was designed assuming that the development starts in the apical end of the root and proceeds cervically. In this paper, we tested whether this can be proven statistically and thus be of use in cases of forensic age estimation. The results confirmed that with higher stages both the minimum and the median of the age of the subjects increased.

With this new approach, the minimum age for stages 1 to 3 was over 18 years of age. If a person is found to be in one of these stages, one is safer in excluding that this person could be under 18 years of age.

In criminal proceedings, it may also be important to assess whether the person was under 18 years of age at the time of the offence, which may be a year or more ago. Also, in these cases, a safe exclusion based on the findings in this study might be of great importance to the court.

In Germany, for example, the age of 21 years is also of relevance in the application of adult criminal law. Our investigation showed that from stage 2 all individuals were over 21 years of age. Thus, the findings could be applied in these cases for the German court.

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