ORIGINAL ARTICLE

Evaluation of the radiographic visibility of the root pulp in the lower third molars for the purpose of forensic age estimation in living individuals

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Abstract The question of whether an individual has reached the age of 18 is of crucial importance in forensic age estimation practice. In some countries, the age threshold of 21 years is relevant as well. A completed mineralization of third molars is not a sufficient criterion for a diagnosis of a minimum age of 18 years with the required probability. In a material of 1,198 orthopantomograms from 629 females and 569 males aged between 15 and 40 years, the visibility of the root pulp of fully mineralized lower third molars was evaluated according to stages 0, 1, 2, and 3. In females, stage 0 was first noticed at age 17.2 years, in males at age 17.6 years. In either sex, the earliest observation of stage 1 was between 21.0 and 22.4 years. Stage 2 was first achieved by males between 22.3 and 22.7 years, by females between 23.4 and 24.7 years. The occurrence of stage 3 was first found in both sexes between 25.1 and 25.9 years. These findings indicate that for stage 0, an age below 18 years cannot be excluded. However, for stage 1, the examined individual must be over 18 years of age and most probably over 21 years of age. For stages 2 and 3, the age can safely be stated to be over 21 years of age. This method may be a powerful tool for forensic dentists in age estimation in asylum and criminal proceedings.

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Introduction

Today, an increasing number of asylum seekers arrive in western countries, many of whom give the information that they are under the age of 18. The foreign authorities in many countries may often be in doubt about this information. Children under the age of 18 have special rights according to the UN Child Convention and can often not be sent back to their countries of origin. Thus, the chance of being granted asylum is greatly increased. In addition, the age threshold of 18 years is often relevant in criminal proceedings for the application of juvenile or adult penal law. In some countries, such as Germany, the age threshold of 21 years is of importance as well.

Authorities want scientific proof whether the examined individual is under or over the age of 18. Scientific methods are based on dental panoramic and periapical radiographs, hand and wrist radiographs, and radiographs or CT scans of the medial clavicular epiphyses. A systematic recommendation for examinations like these was given by the Study Group on Forensic Age Diagnostics of the German Society of Legal Medicine [1].

It is still difficult to prove beyond reasonable doubt that a person is over 18 years of age, and it is even more difficult to prove that the person is over 21 years of age. Researchers have therefore been concentrating on the development of the teeth and the third molars in particular. It would be of great advantage to find a dental method to be applied after the complete root formation of the third molars.

In this study, we have examined the radiographic visibility of the root pulp of the third molars, and we have introduced a stage classification for age estimation purposes.

Table 1 Age and sex distribution of the sample (n=1198)

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
n	629	569

Materials and methods

Orthopantomograms (1,198) from 629 females and 569 males were examined. The material was divided into age groups of 1 year from the age of 15 to 40 years (Table 1). For example, age 15 was defined as from 15.0 to 15.9 years. The radiographs were obtained from a German population during the years 1987 to 2008. Dates of birth and exposure dates were proven but unknown to the examiner as the study was blinded.

The visibility of the root pulp of the lower third molars with completed root formation with apical closure was recorded in four stages as shown in the drawings and pictures in Fig. 1.

The stages were defined as follows:

Stage 0 = the lumen of all root canals is visible all the way to apex.
Stage 1 = the lumen of one root canal is not fully visible to the apex.
Stage 2 = the lumen of two root canals are not fully visible to the apex, or one canal may be virtually invisible in full length.
Stage 3 = the lumen of two root canals is virtually invisible in full length.

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.

The program 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 for females are shown in Table 2 and for males in Table 3.

For both sexes, the obtained data show that within the entire observed age interval, the minima and medians of the chronological age increased with increasing stage. Thus, they demonstrate a good correlation between the stages and the chronological ages of the subjects.

In females, stage 0 was first noticed at age 17.2 years, in males at age 17.6 years. In either sex, the earliest

Fig. 1 Schematic drawings and pictures of the stages of radiographic visibility of the root pulp in third molars
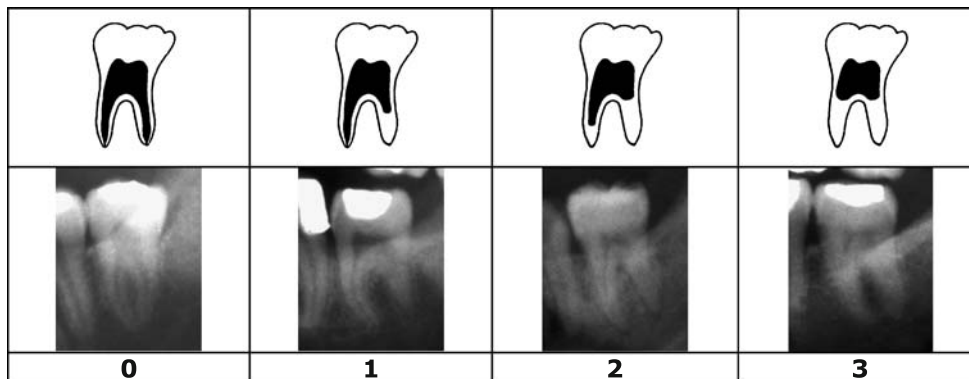
Table 2 Statistical data on the age (in years) of the stages of radiographic visibility of the root pulp of teeth 38 and 48, in females

Tooth	Stage	n	Min	Max	LQ	Median	UQ	Mean	SD
38	0	132	17.2	37.4	22.0	24.0	26.8	24.5	3.6
	1	15	21.6	36.2	22.8	25.5	31.4	27.3	4.9
	2	205	24.7	40.9	29.7	33.1	36.8	33.2	4.3
	3	51	25.2	40.5	34.1	36.4	38.8	35.6	3.9
48	0	134	17.2	40.2	22.1	24.3	26.8	24.7	3.7
	1	21	21.9	37.4	26.9	28.9	32.6	29.4	4.1
	2	218	23.4	40.5	29.9	33.2	36.7	33.1	4.4
	3	54	25.1	40.9	31.6	35.6	38.6	34.9	4.2

n number of cases, Min minimum age, Max maximum age, SD standard deviation, LQ lower quartile, UQ upper quartile

observation of stage 1 was between 21.0 and 22.4 years. Stage 2 was first achieved by males between 22.3 and 22.7 years, by females between 23.4 and 24.7 years. The occurrence of stage 3 was first found in both sexes between 25.1 and 25.9 years.

The medians for stage 0 were between 22.6 and 24.3 years. The medians of stage 1 showed a range between 25.5 and 28.9 years. For stage 2, the medians varied from 32.1 to 33.2 years and for stage 3 from 33.7 to 36.4 years.

Discussion

According to most investigations, the mean age of complete apical closure of third molars is between 20 and 23 years [2–5]. The chance of having fully formed roots of the wisdom teeth under the age of 18 is very low but cannot be excluded [3, 5, 6]. After the complete formation of the tooth, the radiographic method presented by [7] may give a possible indication of the age. This method is valid for the whole life of the individual, but for young individuals, we are at the bottom end of multiple regression. Experience has shown that a calculation of age in young individuals often results in an overestimation. In addition, the standard deviation is much higher than for the tooth formation. Furthermore, it can be difficult to apply the method to digital orthopantomograms [8]. Another alternative method may be the morphologic method presented by [9]. However, this method is heavily dependent on the color of the teeth. It is possible that

the color is subject to greater ethnical differences than other age-related factors. Moreover, artificial tooth whitening used today makes the method more unreliable.

The radiographic examination of the hand and wrist can achieve good results up to approximately the age of 19, but ages under 18 years can never be excluded as it has been shown that the minimum age for complete ossification for men is 16.7 years and for women 17.1 years [10]. So far, the only possibility for exclusion, based on skeletal development, is to assess the clavicular ossification [11–13]. Many radiologists are not familiar with this technique, and therefore, it is only used in a few countries. The method presented here could be an alternative technique to exclude that a person is below 18 years of age.

The disappearance of the pulp canal is an optical phenomenon. We do not claim that the pulp canal is completely obliterated, but the lumen may have been narrowed by secondary dentine formation to such an extent that it is not longer visible on radiographs. The reason for this phenomenon is that after the formation of the tooth has been completed, the secondary dentine formation is a lifelong process which gradually narrows the lumen of the pulp canal [14].

In the method presented here, the definitions and numbers of stages have caused some difficulties. We have tried different definitions and numbers of stages, and what we present here is what we consider to be best related to the age of the examined individuals.

In this study, radiographs of individuals from the age of 15 to 40 years were selected to cover the age group where

Table 3 Statistical data on the age (in years) of the stages of radiographic visibility of the root pulp of teeth 38 and 48, in males

Tooth	Stage	n	Min	Max	LQ	Median	UQ	Mean	SD
38	0	104	17.6	39.1	21.2	22.9	25.7	23.5	3.1
	1	13	22.4	40.0	23.2	27.1	30.4	28.1	5.5
	2	219	22.3	40.2	28.6	32.1	35.8	32.2	4.4
	3	51	25.2	40.6	30.4	34.8	37.0	34.1	3.9
48	0	102	17.6	38.0	21.0	22.6	24.6	23.5	3.4
	1	16	21.0	34.6	23.8	26.3	29.3	26.6	3.7
	2	238	22.7	40.5	28.7	32.3	36.3	32.4	4.6
	3	53	25.9	40.6	30.6	33.7	38.1	33.9	4.3

n number of cases, Min minimum age, Max maximum age, SD standard deviation, LQ lower quartile, UQ upper quartile

these changes take place. If we had included individuals up to 50 years of age, for example, it may have been possible that the median values of the last stages would have increased a little bit but certainly not the minimum. There are about 20 individuals in each age group for both females and males. A larger number of individuals might have been of advantage, but the difficulty in acquiring these radiographs has prevented us from increasing the material. Today, it is almost impossible to perform a prospective radiographic study on this phenomenon because of the prohibition caused by modern radiographic laws. Therefore, we had to use retrospective material taken for diagnostics and often for orthodontic treatment.

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

With this approach, we cannot exclude that the person in stage 0 is under 18 years of age, even though the median age was between 22 and 24 years. However, all individuals classified in stage 1, 2 or 3 were found to be at least 21 years old. Therefore, an age under 18 can easily be excluded in these stages, but the results indicate that it may be justified to also exclude an age below 21 years. The latter is of importance for German criminal courts, for example, as offenders under the age of 21 might get a milder punishment because a special juvenile criminal law may be applied.

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