Application of Dental Age Assessment Based on the Radiographic Visibility of the Root Pulp in Lower Molars in Thai Population

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Abstract

Nowadays, many undocumented immigrants have entered Thailand, which could not reveal their true age. Dental age is an accurate, minimally invasive, and thoroughly method of evaluating an individual's age. Root pulp visibility of lower molars seen on panoramic radiograph is the other interesting method for human age estimation. The objective of the present study was to analyze the radiographic visibility of the root pulp in completed root formation lower first and second molars in a group of Thai population.

Digital panoramic images from 1000 patients with ages ranging from 16 to 26 years were used in this study. The visibility status of root pulp of lower first and second molars was assessed. For each stage, the minimum age, maximum age, median, mean, and standard deviation were calculated. Spearman rho correlation statistics was used to determine the degree and direction of the association between chronological age and pulp visualization stages. The level of significance was defined at p < 0.05.

In lower left and right first molars, the minimum age found in the stage 0 - stage 3 was 16.00-17.00 years in both sexes. The earliest onset of stage 0 to stage 3 was 16.00 - 18.17 years for left and right second molars in males and females. For both sexes, Spearman's rho demonstrated a positive association between pulp stage and age (p < 0.05).

Radiographic visibility of the root pulp in lower first and second molars may be an alternative approach in chronological age assessment in the subject with missing or fused root of third molars. In case the root pulp visibility of mandibular first or second molars is found to be in stage 2, it may be confirmed that the individual is at least 18 years of age.

Clinical article (J Int Dent Med Res 2023; 16(1): 241-245)

Keywords: Age assessment, mandibular molars, panoramic, root pulp, Thai.

Received date: 09 October 2022   **Accept date:** 03 November 2022

Introduction

Age estimate for forensic purposes has grown increasingly essential. Legal and criminal processes, as well as numerous civil and social judgments, need forensic age assessment of live persons.[1,2] Furthermore, the increased number of non-national persons with uncertain birth dates needs forensic age estimation in a variety of situations, most notably during criminal, civil, or refuge processes.[3-5] The study group on forensic age diagnostics (AGFAD) has proposed guidelines for forensic age estimation. These consist of: (a) clinical examination, performing anthropometric measures and assessment of sexual maturity signs; (b) an x-ray examination of the left hand; (c) a dental evaluation with a clinical examination and analysis of an orthopantomogram (OPT); and (d) an x-ray examination or CT scan of the clavicles when hand skeletal development is completed.[6-9] Teeth-based age estimation is a well-known and routinely used historic technique that is accurate, reliable, and minimally invasive.[10] Dental development is widely used as an indicator of the chronological age of the minors, especially those younger than 18 years old. For many years, prediction of the legal age thresholds in children and sub-adults was done using the mineralization and maturation of the third molars.[11-14] Olze et al.[4] investigated regressive alterations in lower third molars with completed root development in

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younger age groups based on the radiographic visibility of the root pulp. The likelihood of completing 18 and 21 years of age was determined using the mean age and standard deviation at each stage. There are many studies confirming the radiographic pulp examination of the third molar as a reliable method and a valuable contribution in forensic age assessment in different ethnic groups.[15-18] This method's accuracy has been proven as a suitable age marker for the age thresholds of 18 and 21 years. However, the prevalence of missing third molars is high and varies from 17 to 28%.[19] To determine whether or not an individual has reached adulthood, it would be highly helpful to evaluate teeth other than third molars. Recently, there were the studies of radiographic root pulp visibility in the mandibular first molars. The authors concluded that root pulp visibility stages in mandibular first molars can be utilized to indicate whether an individual is 16 years or older.[20,21] Additionally, they are mentioned for further investigation on root pulp visibility in mandibular second molars.[20] As second molars complete their root development and reach the occlusal plane at the age 14-15 years. Radiographic evaluation of pulp visibility in these teeth might be a useful tool for age assessment. To the best of our knowledge, very few studies reviewed the chronological development of root pulp visibility in mandibular first molars [20,21], and there were no studies reviewing that in mandibular second molars. Therefore, the aim of the present study was to evaluate the radiographic visibility of root pulp in mandibular first and second molars using the classification of Olze et al.[4] in a group of Thai population in order to determine the suitability of this method in forensic age assessment, particularly for those over the age of 18 years.

Materials and methods

This study was approved by our institutional ethical board (IRB No. P10151/64). One thousand panoramic digital radiographs from Thai subjects aged from 16 to 25 years were assessed. Of these, 500 belonged to males and 500 belonged to females. All panoramic digital radiographs were taken for a variety of diagnostic objectives. Chronological age of each subject was calculated by subtracting the date of birth from the date of radiographic exposure.

The root pulp visibility of mandibular first and second molars with completed root formation was recorded in the four stages (defined by Olze et al.[4], Fig. 1):
Stage 0: The root pulp is visible along the full length of all roots;
Stage 1: The root pulp is invisible in one root from apex to more than half root;
Stage 2: The root pulp is invisible along almost the full length of one root or along part of the root in two roots or both;
Stage 3: The root pulp is invisible along almost the full length of two roots.
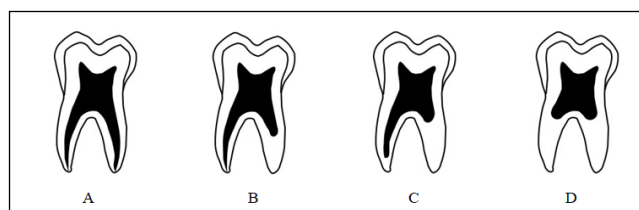
Figure 1. Schematic drawings of the radiographic visibility of root pulp in lower first and second molars; (A) stage 0 (B) stage 1 (C) stage 2 (D) stage 3 (modified from Olze et al.[4])

All panoramic digital radiographs were evaluated by an oral and maxillofacial radiologist with more than 10 years of experience in evaluating radiographic images. One hundred panoramic digital radiographs were selected randomly to calculate the intra- and inter-examiner agreement after one month of the first evaluation using Cohen's kappa test. Descriptive statistics were expressed in mean, standard deviation (SD), median with lower and upper quartiles, and minimum and maximum age of the root pulp visibility for the 4 stages. We used spearman rho correlation statistics to determine the degree and direction of the association between chronological age and pulp visualization stages. The level of significance was defined at $p < 0.05$.

Results

Kappa statistics revealed that intra-examiner agreement was 0.85 and inter-examiner agreement was 0.81, indicating strong to near-perfect agreement.
Table 1 showed the descriptive data of each stage of root pulp visibility of lower left and right first molars. Table 2 presented descriptive information about each stage of root pulp visibility

in the lower left and right second molars.

Sex	Stage	N	Min	Max	LQ	Median	UQ	Mean	SD
Males Tooth 36	0	8	16.17	21.33	16.48	18.17	19.96	18.28	1.85
	1	96	16.00	25.92	17.58	19.62	22.89	20.25	3.11
	2	384	16.00	25.92	18.83	21.25	23.31	21.10	2.71
	3	12	16.75	25.58	20.54	23.66	24.85	22.62	2.83
Females Tooth 36	0	36	16.00	24.92	16.50	18.08	19.96	18.70	2.76
	1	161	16.00	25.92	17.92	19.33	21.58	19.95	2.53
	2	278	16.00	25.92	19.67	22.17	24.02	21.78	2.71
	3	25	16.75	25.83	17.83	21.25	23.62	21.03	3.02
Males Tooth 46	0	7	16.00	20.33	16.00	16.67	18.58	17.38	1.64
	1	111	16.00	25.92	17.50	19.08	22.17	19.89	2.87
	2	370	16.00	25.92	19.17	21.42	23.35	21.25	2.70
	3	12	16.75	25.75	19.51	24.00	24.73	22.58	3.16
Females Tooth 46	0	50	16.00	25.92	16.50	18.37	21.08	18.98	2.99
	1	183	16.00	25.92	18.58	20.08	22.50	20.32	2.61
	2	248	16.00	25.92	19.50	22.00	24.00	21.68	2.76
	3	19	17.00	25.83	21.00	22.67	24.00	22.12	2.35

N: Number of tooth, Min: Minimum age, Max: Maximum age, LQ: Lower quartile, UQ: Upper quartile, SD: Standard deviation

Table 1. Data of chronological age according to sex and stage of root pulp visibility in tooth 36 and 46.

Sex	Stage	N	Min	Max	LQ	Median	UQ	Mean	SD
Males Tooth 37	0	46	16.00	25.33	16.42	17.62	19.39	18.21	2.29
	1	161	16.00	25.92	17.92	20.25	22.71	20.44	2.86
	2	275	16.00	25.92	19.58	21.92	23.75	21.55	2.58
	3	18	18.17	25.58	21.00	23.25	24.66	22.68	2.43
Females Tooth 37	0	114	16.00	25.83	16.92	18.58	20.50	18.95	2.42
	1	178	16.00	25.92	18.58	20.50	22.60	20.58	2.66
	2	185	16.00	25.92	20.21	22.92	24.42	22.27	2.55
	3	23	17.08	25.33	21.08	23.08	24.58	22.63	2.12
Males Tooth 47	0	46	16.00	25.33	16.42	17.62	19.39	18.21	2.29
	1	161	16.00	25.92	17.92	20.25	22.71	20.44	2.86
	2	275	16.00	25.92	19.58	21.92	23.75	21.55	2.58
	3	18	18.17	25.58	21.00	23.25	24.66	22.68	2.43
Females Tooth 47	0	114	16.00	25.83	16.92	18.58	20.50	18.95	2.42
	1	178	16.00	25.92	18.58	20.50	22.60	20.58	2.66
	2	185	16.00	25.92	20.21	22.92	24.42	22.27	2.55
	3	23	17.08	25.33	21.08	23.08	24.58	22.63	2.12

N: Number of tooth, Min: Minimum age, Max: Maximum age, LQ: Lower quartile, UQ: Upper quartile, SD: Standard deviation

Table 2. Data of chronological age according to sex and stage of root pulp visibility in tooth 37 and 47.

Sex	Stage	Total	< 18 Years		≥ 18 Years	
			N	%	N	%
Males Tooth 36	0	8	4	50.0	4	50.0
	1	96	33	34.4	63	65.6
	2	384	62	16.1	322	83.9
	3	12	1	8.3	11	91.7
Females Tooth 36	0	36	18	50.0	18	50.0
	1	161	41	25.5	120	74.5
	2	278	35	12.6	243	87.4
	3	25	6	24.0	19	76.0
Males Tooth 46	0	7	5	71.4	2	28.6
	1	111	37	33.3	74	66.7
	2	370	56	15.1	314	84.9
	3	12	2	16.7	10	83.3
Females Tooth 46	0	50	24	48.0	26	52.0
	1	183	41	22.4	142	77.6
	2	248	34	13.7	214	86.3
	3	19	1	5.3	18	94.7

Table 3. Distribution of root pulp visibility stages on panoramic radiographs between adults and minors in tooth 36 and 46.

Tables 3 and 4 showed the proportion of subjects who are under and over the age of 18 years. In lower left first molars, 91.7% of males who were classified as stage 3 were found to be 18 years or older, and 87.4% of females were found to be 18 years or older in stage 2. However, the results were different in lower right first molars, which 84.9% of males were classified as 18 years or older in stage 2, and 94.7% of females were classified as 18 years or older in stage 3 (Table 3). The relationships between chronological age and stage attainment of lower left and right second molars were shown in Table 4. In lower left second molars, one hundred percent of males who were classified as stage 3 and 95.7% of females who were classified as stage 2, were found to be 18 years or older. Similarly, 93.8% of males and 93.4% of females who were classified as stage 3, and stage 2, respectively, were found to be 18 years or over. For both sexes, Spearman's rho demonstrated a positive association between pulp stage and age ($p < 0.05$).

Sex	Stage	Total	< 18 Years		≥ 18 Years	
			N	%	N	%
Males Tooth 37	0	46	29	63.0	17	37.0
	1	161	41	25.5	120	74.5
	2	275	30	10.9	245	89.1
	3	18	0	0.0	18	100.0
Females Tooth 37	0	114	50	43.9	64	56.1
	1	178	37	20.8	141	79.2
	2	185	12	6.5	173	93.5
	3	23	1	4.3	22	95.7
Males Tooth 47	0	47	25	53.2	22	46.8
	1	174	46	26.4	128	73.6
	2	263	28	10.6	235	89.4
	3	16	1	6.3	15	93.8
Females Tooth 47	0	115	58	50.4	57	49.6
	1	177	27	15.3	150	84.7
	2	182	12	6.6	170	93.4
	3	26	3	11.5	23	88.5

Table 4. Distribution of root pulp visibility stages on panoramic radiographs between adults and minors in tooth 37 and 47.

Discussion

It is crucial to determine whether an individual is over the age of 18. AGFAD recommends that when skeletal development of the hand is completed, an examination of the clavicles (x-ray examination or CT scan) should be performed.[8] However, Garamendi et al.[9] stated that studying clavicle ossification only provides information until the age of 19 years and, moreover, Schulz et al.[22] concluded that it can be difficult to evaluate based on conventional postero-anterior radiographic images due to the superimposition of other structures and disagreement in staging between cases assessed by conventional radiography and CT.

Olze et al.[4] initially investigated the root pulp visibility in mandibular third molars for the goal of forensic age estimate. Despite the variation in third molar maturation, eruption pattern, size, contour, relative positions, and a higher incidence of agenesis, the main rationale to rely on this tooth is the scarcity of viable alternatives during this critical developmental stage. Third molar mineralization is frequently completed by the age of 20. As a result, alternative techniques emphasizing on the age of 18 years are essential.[15]

Visibility of the root pulp and periodontal ligament helps differentiate persons above the age of 18 years. We assessed the root pulp visibility in lower third molars of a group of Thai population and found that the occurrence of stages 2 or 3 in both males and females indicated that the subject is over 18 years of age.[23] The authors also found that all pulp visibility stages developed earlier in males than in females. However, there were many samples that could not be assessed because of missing, fused roots, or incomplete root formation of mandibular third molars. Therefore, in the present study, we evaluated this approach in lower first and second molars. The advantages of this method are, firstly, it can be applied in subjects without third molars, or those with incomplete root formation. Timme et al.[24] assessed the radiographic pulp and periodontal ligament visibility in third molars and reported higher number of missing third molars (46 to 60%) in their study, indicating it as a main limitation of this method. Secondly, high specificity values were obtained in both sexes, which is extremely important in the criminal law context, which expresses the rate of false positives.[25]

Balla et al.[20] explored the radiographic visibility of the root pulp of mandibular first molars in a group of Indian. They concluded that when the mandibular first molars reach stage 3 of pulp visibility in males, there is a very high probability of an age of above 18 years, and a high probability for females above 18 years. In addition, they mentioned that the accuracy of this method for estimating age threshold of 18 years ranged from moderate to high. However, another consideration for future studies to analyze stages of pulp visibility with respect to mandibular second molars, in which their root development was completed and reached the occlusal plane at 14-15 years of age was also mentioned. Evaluation of secondary dentin development within these teeth may be a useful method for determining the age of maturity. Manthapuri et al.[26] examined the radiographic visibility of the root pulp in mandibular second molars for the purpose of identifying age above 18 in Indians. According to their results, stage 2 in males indicated a minimum age of 18.6 years, while in females a minimum age of 15.2 years was reported. This is strong evidence that a male subject with complete root formation of the lower second molar and stage 2 root pulp visible is older than 18 years. However, the proportion of persons presented in stage 2 was extremely low, particularly in males. In the present investigation, we have tried the methodology proposed by Balla et al.[20] which investigated the root pulp visibility in mandibular second molars. It may be concluded that when stage 2 of pulp visibility is attained in either sex, there is high probability that the 18th year of age has been reached. In addition, we analyze stages of pulp visibility with respect to mandibular first molars in the same samples. When it reaches stage 2 of pulp visibility in either sex, there is high probability that an individual has attained 18 years, which was not in accordance with the results of Balla et al.[20] Manthapuri et al.[21] evaluated the visibility of the mandibular first molar root pulp proposed by Olze et al.[4] as an alternative age marker at the 16-year age threshold in the absence of mandibular third molars. They concluded that the stage 2 of root pulp visibility can be used to predict the age of 16 years or over. It may be said that the results of the present study were in consistent with the results of previous ones.[20,21,26] This is strong evidence that individuals (males and females) with completed root development of lower first or second molars and stage 2 root pulp visibility are at least 18 years of age.

Conclusions

The stage of root pulp visibility in mandibular first or second molars might be useful in diagnosis the age of 18 years or over. Additional study is needed to validate the use of root pulp visibility in teeth other than molars to predict children's and adolescent's attainment of legal age criterion.

Declaration of Interest

The authors report no conflict of interest.

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