J Forensic Sci, March 2009, Vol. 54, No. 2
doi: 10.1111/j.1556-4029.2008.00961.x
Available online at: www.blackwell-synergy.com

TECHNICAL NOTE

Patrick W. Thevissen,[1] *D.D.S.; Pisha Pittayapat,*[2] *D.D.S.; Steffen Fieuws,*[3] *M.Sc., Ph.D.; and Guy Willems,*[1] *D.D.S., Ph.D.*

Estimating Age of Majority on Third Molars Developmental Stages in Young Adults from Thailand Using a Modified Scoring Technique*

ABSTRACT: The aim of this study was to achieve a referral database for dental age estimation of unaccompanied minors of Thai nationality. A total of 1199 orthopantomograms were collected from original Thai women and men equally divided in age categories between 15 and 24 years. On the radiographs, the developmental stage of the third molars was scored applying a modified scoring technique. Inter- and intra-observer reliabilities were tested using kappa statistics. Correlation between the scores of all four wisdom teeth and left–right symmetry were evaluated with Pearson's correlation coefficient. Student's *t*-test on asymmetry was performed and regression formulas were calculated. The present database was the first to assemble third molar developmental scores on radiographs of Thai individuals and provides more appropriate dental age estimation of unaccompanied Thai minors. Future research on similar databases of different nationalities worldwide may expose ethnical influences on dental development.

KEYWORDS: forensic science, forensic odontology, age estimation, third molar development, ethnicity, Thailand

Dental age estimating methods employed in forensic odontology (1,2) are based on the changes in development (3–7), morphology (8–13), and biochemical (14–16) structure of teeth. Estimating the age of individuals or victims narrows the search for antemortem data during identification procedures of unknown remains (17,18), helps in establishing the difference between the juvenile and adult status of an individual in law cases (19–21), and aids persons without a birth certificate finding out their presumed age (22). Nowadays the judicial need to classify human beings lacking age information into the adult or juvenile group increases continually. Dental age estimation methods based on the analysis of the radiological determined developmental stages of third molars are the only tooth formation approaches for the judgment of this specific lifetime period (6,23). Although several population-specific dental age estimation researches on third molar development have been carried out, the collection of referral databases consisting of orthopantomograms of youngsters from the same national origin is strongly needed to ameliorate the accuracy of dental age estimation procedures. For consideration as a valuable age estimation database, it needs to contain large-sized samples of individuals with the same national or ethnic origin (24,25). The dental age estimation results obtained based on these databases have to be compared and integrated with the results collected by other methods, such as clinical observation (19), psycho-social age approach (26), evaluation of changes in secondary sex characteristics (27), epiphysial fusion of hand-wrist and sternoclavicular bones (28–31), changes in pubic symphysis (32) and anterior iliac crest (33), fusion of cranial sutures (34,35), cranial size changes (36), and occlusal tooth wear (11).

The aim of the present paper was the establishment of a radiological database of orthopantomograms from young adults with original Thai nationality so as to obtain regression formulas for age estimation of Thai individuals.

Materials and Methods

In this retrospective study, 1199 orthopantomograms were collected and selected at the Faculty of Dentistry, at the Chulalongkorn University (Bangkok, Thailand). The radiographs were digitally generated on a Kodak 8000C Digital Panoramic and Cephalometric System (Kodak Dental Systems, Atlanta, GA) and stored as TIF files in the period from 2005 to 2007. All the X-rays were captured from persons of Thai nationality and mongoloid ethnicity, with known chronological age at the moment of radiologic exposure. During the selection, only orthopantomograms of individuals with no medical history, no visible dental pathology on the radiographs, and at least one upper and one lower third molar present, were retained. The selected group was split into 613 women and 586 men, with each an age spread older than 15 years and younger than 24 years (Table 1).

All of the 4530 third molars visible on the orthopantomograms (Table 2) were observed and classified by the 10-point developmental scoring system as proposed by Gleiser and Hunt (37) and modified by Köhler et al. (38) (Fig. 1), and if necessary imported into Adobe® Photoshop® (Adobe Systems Incorporated, San José,

[1]Department of Dentistry, Oral Pathology and Maxillo-Facial Surgery, Section Forensic Odontology, Katholieke Universiteit Leuven, Leuven, B 3000, Belgium.
[2]Department of Dentistry, Section Radiology, Chulalongkorn University, Bangkok, 10330, Thailand.
[3]Centre of Biostatistics, Katholieke Universiteit Leuven, Leuven, B 3000, Belgium.

*Presented at the 60th Annual Meeting of the American Academy of Forensic Sciences, February 18–23, 2008, in Atlanta, GA.

Received 12 Mar. 2008; and in revised form 22 April 2008; accepted 26 April 2008.

TABLE 1—*Number of orthopantograms in different age categories split up for female and male.*

Age Range in Years	Frequency	Female	Male
15–16	115	59	56
16–17	133	68	65
17–18	126	62	64
18–19	147	81	66
19–20	143	68	75
20–21	138	70	68
21–22	131	68	63
22–23	133	68	65
23–24	132	68	64

TABLE 2—*Number of third molars for each developmental score.*

	Third Molar							
	UR		UL		LL		LR	
D.S.	Freq.	Cum.Freq.	Freq.	Cum.Freq.	Freq.	Cum.Freq.	Freq.	Cum.Freq.
1	1	1	0	0	0	0	0	0
2	2	3	2	2	2	2	2	2
3	12	15	10	12	15	17	12	14
4	41	56	47	59	44	61	47	61
5	109	165	105	164	105	166	104	165
6	147	312	150	314	132	298	118	283
7	103	415	99	413	110	408	121	404
8	118	533	105	518	127	535	129	533
9	89	622	94	612	122	657	132	665
10	512	1134	530	1142	465	1122	467	1132

UR, upper right; UL, upper left; LL, lower left; LR, lower right; D.S., developmental score; Freq., frequency; Cum.Freq., cumulative frequency.

CA). In case of doubt between two adjacent scoring stages, the concerned radiograph was integrated into Adobe® Photoshop® to blow up the view, to select the mesial and distal enamel cement junction of the involved wisdom tooth and the preceding second molar, to draw a line between them with the line tool, to determine a second line from the middle of the root end perpendicular to the first line detailing the length of the roots of both teeth, and to calculate their proportions (Fig. 2). On pluriradicular wisdom teeth the least developed root was examined.

All the samples were scored by one well-trained observer. With an interval of 30 days, 50 randomly chosen orthopantomograms were graded by a second examiner and rescored by the main one. To evaluate intra-observer bias, the absolute difference between the first and second scores of the main observer was calculated. Similar calculations were carried out for the scores of the main investigator and the second observer to check inter-observer agreements. Kappa statistics were employed for this purpose.

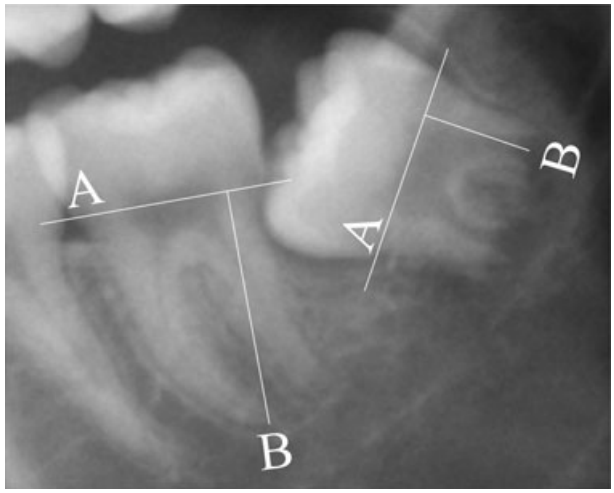

FIG. 2—*Section of orthopantomogram imported in Adobe® Photoshop® showing a developing third molar for scoring. Two lines are drawn, one between the mesial and distal enamel–cement junction (A) and one from the middle of the root end perpendicular to the first line (B). Next the ratio between root length of third and second molar is calculated so as to obtain an idea of third molar root length developed so far. Root length third molar is 3.80. Root length second molar is 7.39. Ratio is 0.51. Developmental score is 6 (root ½ calcified).*

Pearson's correlation coefficient between the developmental scores of different wisdom teeth was calculated. Left–right symmetry in third molar development was evaluated with Student's *t*-test. Multiple regression analysis was performed on the collected database so as to obtain multiple regression formulas for age estimation for males and females separately.

Results

Kappa statistics (Tables 3–6) revealed no significant intra- or inter-observer effects, which indicates that both observers were well calibrated.

In more than 98%, the differences between the developmental score of the left and the corresponding right third molar was less than or equal to 2 (Table 7). Student's *t*-test for left and right asymmetry found for each jaw separately no significant difference, confirming left–right symmetrical third molar development (Table 8).

A high Pearson correlation coefficient was found between the right and left third molars in both of the jaws (Table 9), confirming the earlier symmetrical findings for females and males.

Multiple regression analysis resulted in regression formulas for both females and males enabling dental age estimations taking into

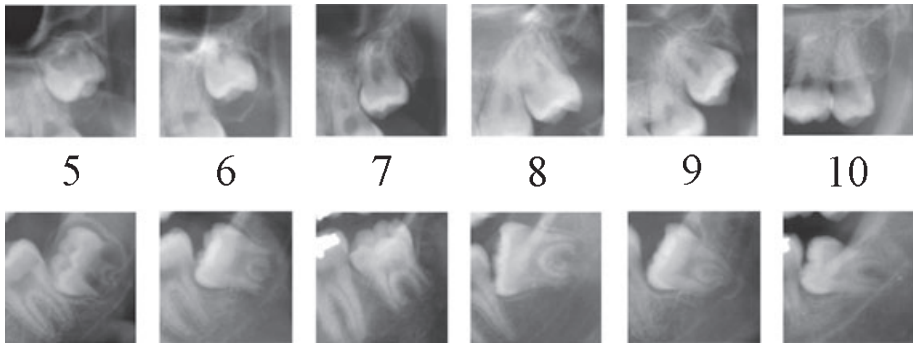

FIG. 1—*Radiographical images of third molar developmental stages corresponding to scores 5–10 for upper and lower third molars.*

TABLE 3—*Percent of absolute difference in intra-observer developmental scores.*

	Percent of Total Scores			
A.D.	UL	UR	LR	LL
0	82.61	89.58	86.67	80.43
1	15.22	8.33	13.33	19.57
2	2.17	2.08	0	0

A.D., absolute difference in developmental score between first and second observer; UL, upper left third molar; UR, upper right third molar; LR, lower right third molar; LL, lower left third molar.

TABLE 4—*Kappa statistics on intra-observer agreement.*

Statistic	Value	ASE	95% Confidence Limits	
Simple kappa	0.8341	0.0661	0.7045	0.9638
Weighted kappa	0.9348	0.0288	0.8784	0.9912

ASE, asymptotic standard error.

TABLE 5—*Absolute difference in inter-observer developmental scores.*

	Percent of Total Scores			
A.D.	UL	UR	LR	LL
0	84.78	85.42	84.44	84.78
1	13.04	14.58	13.33	13.04
2	2.17	0	2.22	2.17

A.D., absolute difference in developmental score between first and second observer; UL, upper left third molar; UR, upper right third molar; LR, lower right third molar; LL, lower left third molar.

TABLE 6—*Kappa statistics on inter-observer agreement, separately for each third molar score.*

Statistic	Value	ASE	95% Confidence Limits	
UR				
Simple kappa	0.7645	0.0722	0.6230	0.9061
Weighted kappa	0.9206	0.0275	0.8667	0.9746
LR				
Simple kappa	0.7626	0.0769	0.6119	0.9133
Weighted kappa	0.9084	0.0343	0.8412	0.9756
UL				
Simple kappa	0.7459	0.0762	0.5966	0.8951
Weighted kappa	0.9067	0.0332	0.8417	0.9718
LL				
Simple kappa	0.7769	0.0753	0.6293	0.9244
Weighted kappa	0.9121	0.0345	0.8445	0.9798

ASE, asymptotic standard error; UL, upper left third molar; UR, upper right third molar; LR, lower right third molar; LL, lower left third molar.

account the high correlation between development of left and right third molars (Table 10).

For both the upper and lower jaw in a Thai population, wisdom teeth develop earlier in females than males up to at least 4 months for lower wisdom teeth, when the developmental stage equals 10.

Discussion

The increasing ease of worldwide traveling, the multiplying migrations, and the growing globalization of our societies urge the need to take into account, when performing dental age estimation, the origin or nationality of the individual at stake. Especially dental age estimation for determining the age of majority in young individuals should be based on data collected in the appropriate biological group. Several studies examined dental age estimation on different

TABLE 7—*Difference in developmental score between corresponding left and right third molars on same orthopantomogram.*

	Upper		Lower	
Diff. L-R	Frequency	Percent	Frequency	Percent
−5	1	0.09	0	0
−4	2	0.19	1	0.09
−3	6	0.56	2	0.19
−2	30	2.79	17	1.61
−1	83	7.71	114	10.81
0	825	76.60	809	76.68
1	90	8.36	96	9.10
2	28	2.60	13	1.23
3	8	0.74	1	0.09
4	4	0.37	1	0.09
5	0	0	1	0.09

Diff. L-R, difference in left–right developmental score.

TABLE 8—*Student's* t*-test for left–right asymmetry.*

	Upper			Lower		
Test	Statistic		*p* Value	Statistic		*p* Value
Student's *t*	t 0.469786		Pr > |t| 0.6386	t −1.17975		Pr > |t| 0.2384
Sign	M 4		Pr ≥ |M| 0.6593	M −11		Pr ≥ |M| 0.1805
Signed rank	S 463		Pr ≥ |S| 0.6771	S −1398.5		Pr ≥ |S| 0.1738

TABLE 9—*Spearman correlation coefficients between developmental scores of third molars.*

	UR	UL	LL	LR
UR	1.00000	0.90987	0.85432	0.85042
	1134	<.0001	<.0001	<.0001
		1077	1060	1074
UL	0.90987	1.00000	0.85777	0.84193
	<.0001		<.0001	<.0001
	1077	1142	1085	1076
LL	0.85432	0.85777	1.00000	0.94002
	<.0001	<.0001		<.0001
	1060	1085	1122	1055
LR	0.85042	0.84193	0.94002	1.00000
	<.0001	<.0001	<.0001	
	1074	1076	1055	1132

UL, upper left third molar; UR, upper right third molar; LR, lower right third molar; LL, lower left third molar.

TABLE 10—*Multiple regression formulas for age estimation of young adults from Thai origin.*

	Regression Formula	S.D.
Males	Age = 11.50 + (L × 0.96)	1.75
	Age = 12.17 + (U × 0.87)	1.90
	Age = 11.23 + (U × 0.22) + (L × 0.77)	1.74
Females	Age = 12.95 + (L × 0.85)	1.82
	Age = 13.63 + (U × 0.76)	1.84
	Age = 12.75 + (U × 0.21) + (L × 0.67)	1.80

S.D., standard deviation in years; U, developmental score of upper third molar; L, developmental score of lower third molar.

populations (24,39–43), but the need for a uniform approach of data collection and analysis is increasing. In this study, the database and corresponding regression formulas provide forensic odontologists at any global location with a specific scientific tool when asked to provide judicial advice concerning the age of majority of a person from Thai origin. The same findings can be of great importance with regard to further investigations where equal data collection of populations with individuals of common nationality provide comparable materials and findings. It can offer directly scientific tools for examination of an individual out of a country with an existing dental developmental database (20). This way common practice of adjusting the few contemporary existing methods based on databases calibrated on a specific population, by increasing the standard deviation of their recommended regression formulas or by choosing wider confidence intervals can be excluded. Implicating unnecessary jurisdictional procedures can be avoided.

The integration of the radiographs in case of doubt in classifying its exact developmental score, into Adobe® Photoshop® and the application of the prescribed protocol provides a more uniform scoring system (44). Although this system is not applicable before score 4 (beginning of root formation), this is of no significance when estimating age of majority. Indeed in this study, stages 1, 2 and 3, falling outside the age range of this research, were only scored in 1.28% of the cases. Direct impact of the new developed scoring modification was seen in a pilot set up. Two observers scored 30 orthopantomograms with all third molars present (minimal stage of development = score 4) twice, separate from each other and at different moments using for each scoring, the integration technique into Photoshop®. For intra- and inter-observer agreement, there was no difference in developmental score in more than 95% of the 120 evaluations.

The obtained regression formulas are independent of the left–right position of the evaluated third molar. In cases where at both sides, third molars in a different developmental stage are available, the choice between left and right is legally speaking the one providing an age result in favor of the examined person. In the same philosophy, during the data scoring, the least developed root of pluriradicular third molars was examined. Scientifically, the side providing the best fit is taken. This way, scoring teeth in unfavorable positions, in radiographic overlap with surrounding anatomic structures, or positioned out of the sharply depicted plane of the orthopantomogram can be avoided.

To obtain best age determination, all possible age estimation methods suitable for the particular case should be carried out (45). Each obtained outcome should be evaluated in function of its mutual weight and proportionally taken into account in the final report. Therefore, if possible all the regression formulas found in this study should be calculated and the mean reported as estimated dental age. In cases where the upper third molars are due to frequently appearing radiological overlap with maxillary tuberosita or the bottom of the maxillary sinus is more difficult to score, the formula only involving a lower wisdom tooth should be used. The higher difference and absolute difference between the first and second scores of the main observer in the upper jaw compared to the lower, point out this overall greater difficulty in scoring maxillary molars.

As four of the six acquired regression formulas are taking into account one tooth, in many cases age estimation could, certainly when at least a small part of the tooth has penetrated the oral mucosa, be performed after taking one periapical dental radiograph. In certain forensic circumstances, where no panoramic radiographic unit is available, or in cases where maximum reduction of radio doses (46) has to be taken into consideration, for example when investigating a young pregnant woman, this can be useful. Moreover, forensic odontologists should always consider the ethical justification principles on radiological protection (47) and check the legality of taking radiographs for aging in their jurisdiction.

Conclusion

A referable database of developmental stages of third molars in a population of Thai individuals was established. For dental age estimation of these young adults, three regression formulas were obtained for both men and women.

Similar database collection of populations of varying origin may reveal in further studies more specific age-estimation techniques and possible differences or agreements in dental development between members of diverse nationalities or distinct ethnical groups.

References

1. Willems G. A review of the most commonly used dental age estimation techniques. J Forensic Odontostomatol 2001;19(1):9–17.
2. Ritz-Timme S, Cattaneo C, Collins MJ, Waite ER, Schütz HW, Kaatsch HJ, et al. Age estimation: the state of the art in relation to the specific demands of forensic practise. Int J Legal Med 2000;113(3):129–36.
3. Demirjian A, Goldstein H, Tanner JM. A new system of dental age assessment. Hum Biol 1973;45(2):211–27.
4. Demirjian A, Goldstein H. New systems for dental maturity based on seven and four teeth. Ann Hum Biol 1976;3(5):411–21.
5. Kullman L, Johanson G, Akesson L. Root development of the lower third molar and its relation to chronological age. Swed Dent J 1992;16(4):161–7.
6. Mincer HH, Harris EF, Berryman HE. The A.B.F.O. study of third molar development and its use as an estimator of chronological age. J Forensic Sci 1993;38(2):379–90. Erratum in: J Forensic Sci 1993;38(6):1524.
7. Mesotten K, Gunst K, Carbonez A, Willems G. Dental age estimation and third molars: a preliminary study. Forensic Sci Int 2002;129(2):110–5.
8. Kvaal SI, Solheim T, Bjerketvedt D. Evaluation of preparation, staining and microscopic techniques for counting incremental lines in cementum of human teeth. Biotech Histochem 1996;71(4):165–72.
9. Solheim T. A new method for dental age estimation in adults. Forensic Sci Int 1993;59(2):137–47.
10. Kolltveit KM, Solheim T, Kvaal SI. Methods of measuring morphological parameters in dental radiographs. Comparison between image analysis and manual measurements. Forensic Sci Int 1998;94(1–2):87–95.
11. Kim YK, Kho HS, Lee KH. Age estimation by occlusal tooth wear. J Forensic Sci 2000;45(2):303–9.
12. Yang F, Jacobs R, Willems G. Dental age estimation through volume matching of teeth imaged by cone-beam CT. Forensic Sci Int 2006;159(Suppl. 1):S78–83.
13. Maat GJ, Gerretsen RR, Aarents MJ. Improving the visibility of tooth cementum annulations by adjustment of the cutting angle of microscopic sections. Forensic Sci Int 2006;159(Suppl. 1):S95–9.
14. Yekkala R, Meers C, Hoogmartens J, Lambrichts I, Willems G, Van Schepdael A. An improved sample preparation for an LC method used in the age estimation based on aspartic acid racemization from human dentin. J Sep Sci 2007;30(1):118–21.
15. Balin AK, Allen RG. Molecular bases of biologic aging. Clin Geriatr Med 1989;5(1):1–21.
16. Ogino T, Ogino H, Nagy B. Application of aspartic acid racemization to forensic odontology: post mortem designation of age at death. Forensic Sci Int 1985;29(3–4):259–67.
17. Olze A, Geserick G, Schmeling A. Age estimation of unidentified corpses by measurement of root translucency. J Forensic Odontostomatol 2004;22(2):28–33.
18. Kvaal SI. Collection of post mortem data: DVI protocols and quality assurance. Forensic Sci Int 2006;159(Suppl. 1):S12–4.
19. Solheim T, Vonen A. Dental age estimation, quality assurance and age estimation of asylum seekers in Norway. Forensic Sci Int 2006;159(Suppl. 1):S56–60.
20. Olze A, Reisinger W, Geserick G, Schmeling A. Age estimation of unaccompanied minors. Part II. Dental aspects. Forensic Sci Int 2006;159(Suppl. 1):S65–7.

21. Schmeling A, Olze A, Reisinger W, Geserick G. Age estimation of living people undergoing criminal proceedings. Lancet 2001;358(9276):89–90.
22. Melsen B, Wenzel A, Miletic T, Andreasen J, Vagn-Hansen PL, Terp S. Dental and skeletal maturity in adoptive children: assessments at arrival and after one year in the admitting country. Ann Hum Biol 1986;13(2):153–9.
23. Friedrich RE, Ulbricht C, von Maydell LA, Scheuer HA. Identification of developmental stages of wisdom teeth on orthopantomograms of adolescents and young adults as an aid for forensic-odontological age-estimations: predictive values for the chronological age of 18 years. Arch Kriminol 2005;216(3–4):73–88. German.
24. Gunst K, Mesotten K, Carbonez A, Willems G. Third molar root development in relation to chronological age: a large sample sized retrospective study. Forensic Sci Int 2003;136(1–3):52–7.
25. Prieto JL, Barbería E, Ortega R, Magaña C. Evaluation of chronological age based on third molar development in the Spanish population. Int J Legal Med 2005;119(6):349–54.
26. Deary IJ, Gow AJ, Taylor MD, Corley J, Brett C, Wilson V, et al. The Lothian Birth Cohort 1936: a study to examine influences on cognitive ageing from age 11 to age 70 and beyond. BMC Geriatr 2007;7:28.
27. Greil H, Kahl H. Assessment of developmental age: cross-sectional analysis of secondary sexual characteristics. Anthropol Anz 2005;63(1):63–75.
28. Cameriere R, Ferrante L, Mirtella D, Cingolani M. Carpals and epiphyses of radius and ulna as age indicators. Int J Legal Med 2006;120(3):143–6.
29. Tanner JM, Gibbons RD. A computerized image analysis system for estimating Tanner-Whitehouse 2 bone age. Horm Res 1994;42(6):282–7.
30. Kreitner KF, Schweden FJ, Riepert T, Nafe B, Thelen M. Bone age determination based on the study of the medial extremity of the clavicle. Eur Radiol 1998;8(7):1116–22.
31. Greulich WW, Pyle SI. Radiographic atlas of skeletal development of the hand wrist. Stanford: Stanford University Press, 1959.
32. Telmon N, Gaston A, Chemla P, Blanc A, Joffre F, Rougé D. Application of the Suchey-Brooks method to three-dimensional imaging of the pubic symphysis. J Forensic Sci 2005;50(3):507–12.
33. Owings W, Myers S. Epiphyseal union of the anterior iliac crest and medial clavicle in a modern multiracial sample of American males and females. Am J Phys Anthropol 1985;68:457–66.
34. Korbmacher H, Schilling A, Püschel K, Amling M, Kahl-Nieke B. Age-dependent three-dimensional microcomputed tomography analysis of the human midpalatal suture. J Orofac Orthop 2007;68(5):364–76.
35. Bednarek J, Bloch-Bogušlawska E, Engelgardt P, Wolska E, Sliwka K. The degree of closure of the cranial sutures as a quick method for adult age evaluation in autopsy. Arch Med Sadowej Kryminol 2005;55(3):185–9.
36. Braga J, Treil J. Estimation of pediatric skeletal age using geometric morphometrics and three-dimensional cranial size changes. Int J Legal Med 2007;121(6):439–43.
37. Gleiser I, Hunt E. The permanent mandibular first molar: its calcification, eruption and decay. Am J Phys Anthropol 1955;13(2):253–83.
38. Köhler S, Schmelzle R, Loitz C, Püschel K. Development of wisdom teeth as a criterion of age determination. Ann Anat 1994;176(4):339–45.
39. Olze A, Taniguchi M, Schmeling A, Zhu BL, Yamada Y, Maeda H, et al. Studies on the chronology of third molar mineralization in a Japanese population. Leg Med (Tokyo) 2004;6(2):73–9.
40. Bolaños MV, Moussa H, Manrique MC, Bolaños MJ. Radiographic evaluation of third molar development in Spanish children and young people. Forensic Sci Int 2003;133(3):212–9.
41. Solari AC, Abramovitch K. The accuracy and precision of third molar development as an indicator of chronological age in Hispanics. J Forensic Sci 2002;47(3):531–5.
42. Uzamiş M, Kansu O, Taner TU, Alpar R. Radiographic evaluation of third-molar development in a group of Turkish children. ASDC J Dent Child 2000;67(2):136–41, 83.
43. Harris EF, McKee JH. Tooth mineralization standards for blacks and whites from the middle southern United States. J Forensic Sci 1990;35(4):859–72.
44. Dhanjal KS, Bhardwaj MK, Liversidge HM. Reproducibility of radiographic stage assessment of third molars. Forensic Sci Int 2006;159(Suppl. 1):S74–7.
45. Schmeling A, Reisinger W, Geserick G, Olze A. Age estimation of unaccompanied minors. Part I. General considerations. Forensic Sci Int 2006;159(Suppl. 1):S61–4.
46. Ngan DC, Kharbanda OP, Geenty JP, Darendeliler MA. Comparison of radiation levels from computed tomography and conventional dental radiographs. Aust Orthod J 2003;19(2):67–75.
47. International Commission on Radiological Protection. The 2007 Recommendations of the International Commission on Radiological Protection. ICRP publication 103. Ann ICRP 2007;37(2–4):1–332.

Additional information and reprint requests:
Professor Guy Willems, Ph.D.
Katholieke Universiteit Leuven
Department of Dentistry, Oral Pathology and Maxillo-Facial Surgery
Forensic Odontology
Kapucijnenvoer 7
B-3000 Leuven
Belgium
E-mail: guy.willems@med.kuleuven.be