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ORIGINAL ARTICLE

Evaluation of third molar development and its relation to chronological age: a panoramic radiographic study

Mohammad Zandi · Abbas Shokri · Hamid Malekzadeh · Payam Amini · Parastu Shafiey

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Abstract
Introduction Third molar development, in comparison to other teeth in the dentition, has the greatest variation in morphology, anatomical position, and time of development and eruption, and its reliability for chronological age estimation is controversial. The aim of the present study was to evaluate third molar development and its relation to chronological age using panoramic radiography.
Material and methods A total of 2536 digital panoramic radiographs of individuals aged between 5 and 26 years were selected. The developmental status of the third molars was assessed using eight-stage developmental scoring proposed by Demirjian et al., with one modification: a stage 0 was added. The collected data were entered into a checklist and subjected to statistical analyses.
Results The mean ages of the first appearance of third molar bud, complete crown formation, and root apex closure were around 9, 14, and 22 years, respectively. In both jaws, third molar development occurred symmetrically, and sexual dimorphism was observed at some developmental stages. Finally, two formulas were presented to estimate age of the juveniles and adolescents based on their gender and developmental stages of the third molars, and validated on a second sample consisting of 523 individuals aged between 8 and 22.
Conclusion Assessment of third molar development was found to be a reliable method for age estimation of individuals between 11 and 22 years. Because of possible ethnic and geographic differences in third molar development, population specific researches were recommended.

Keywords Third molar · Demirjian · Tooth development · Age estimation · Odontology

M. Zandi (✉) · H. Malekzadeh
Department of Oral and Maxillofacial Surgery, Hamedan University of Medical Sciences, Shahid Fahmideh street, Hamedan, Iran
e-mail: zandi88m@yahoo.com

M. Zandi
Dental Research Center, Hamedan University of Medical Sciences, Hamedan, Iran

A. Shokri
Department of Oral and Maxillofacial Radiology, Hamedan University of Medical Sciences, Hamedan, Iran

P. Amini
Department of Biostatistics, Hamedan University of Medical Sciences, Hamedan, Iran

P. Shafiey
Faculty of Dentistry, Hamedan University of Medical Sciences, Hamedan, Iran

Introduction

Assessment of the stages of third molar development is of great clinical importance, as it helps surgeons to make a proper prediction as to whether an impacted tooth will erupt normally into the oral cavity or not. It can also be used to make a decision about timing of the impacted tooth removal and determining the degree of surgical difficulty. Furthermore, assessment of the stages of third molar development is an important part of the decision making and treatment planning for autologous transplantation of the third molar to replace a hopeless first or second molar. Other specialists including orthodontists and pedodontists frequently use the dental age for diagnostic and treatment planning purposes.

In addition to its clinical importance, evaluation of the third molar development can be useful for the estimation of chronological age for medicolegal and other purposes. According to the recommendations of the international and interdisciplinary study group on the forensic age estimation, forensic age assessment should comprise three independent parts including the physical examination (anthropometric measurements and

sexual maturity assessments), the X-ray examination of the left hand, and a dental examination (assessment of dental status and evaluation of an orthopantomogram) [1]. In late adolescence and early adulthood, when most of the teeth are in the process of apical closure, the third molars are the only teeth still in development that can be used for age estimation. Moreover, the accuracy of indices for sexual maturity, skeletal age, and somatic maturity inevitably decreases in this particular age span [2–5].

The development of each individual can be affected by hormonal, nutritional, genetic, climatic, and environmental factors [6, 7]. However, it has been reported that tooth development is less affected by external factors and endocrine disorders when compared to other developmental events, such as the bone mineralization [8–10].

However, third molar tooth, in comparison to other teeth in the dentition, has the greatest variation in morphology, size, anatomical position, and time of development and eruption, and there is no consensus among investigators concerning the reliability of third molar development as a reliable chronological age indicator [11–18]. To study the wisdom tooth development and its relation to chronological age, a relatively large sample size, an objective staging system for tooth development, an appropriate age range for individuals being studied, and proper assessment of examiner errors are required. Furthermore, if an age estimation method based on third molar development is developed, it should be validated on a second sample of individuals.

The aim of the present study was to evaluate third molar development and its relation to chronological age using panoramic radiography.

Materials and methods

The protocol of this study was approved by our institutional review board and Ethics Committee.

A total of 2536 digital panoramic radiographs of individuals aged between 5 and 26 years were randomly obtained from various private dental clinics of Iran. Only orthopantomograms with known age and gender were included in the study. The exclusion criteria were as follows: image deformity and gross pathology affecting the area of interest, hypodontia, and radiographs showing any anomaly or systemic disease influencing the tooth development.

The developmental status of the third molars was assessed using eight-stage developmental scoring (from A to H) proposed by Demirjian and colleagues [19], with one modification: a stage 0 was added.

Stage 0—radiolucent bud with no calcification.
Stage A—calcification of cusp tips without coalescence of different calcifications.
Stage B—coalescence of the mineralized cusp tips, with recognizable coronal morphology.
Stage C—formation of nearly half of the crown and beginning of dentin deposition.
Stage D—complete crown formation up to cementoenamel junction.
Stage E—root length shorter than the crown height.
Stage F—root length equal or greater than the crown height.
Stage G—complete root formation with open apical foramen.
Stage H—complete closure of apical root end.

The panoramic radiographs were assigned a unique code number to blind the observers, and evaluated by two well-trained examiners. To assess intra- and inter-observer reliabilities, 250 radiographs, representing 10% of all radiographs, were randomly selected and evaluated twice by the same observers within an interval of 4 weeks.

Statistical analyses were performed using SPSS 16.0 (SPSS Inc., Chicago, IL) software. To analyze the data, several statistical tests including Cohen's Kappa, independent sample *t* test, Mann-Whitney, Spearman correlation, and

Table 1 Age and sex distribution of the studied population

Age (years)	Gender		Total
	Male	Female	
5	16	11	27
6	33	21	54
7	49	51	100
8	54	114	168
9	82	100	182
10	76	102	178
11	58	86	144
12	61	75	136
13	33	51	84
14	32	63	95
15	31	62	93
16	31	43	74
17	34	51	85
18	42	57	99
19	39	63	102
20	45	84	129
21	68	119	187
22	50	104	154
23	58	98	156
24	50	99	149
25	38	88	126
26	2	12	14
Total	982	1554	2536

Table 2 Mean and standard deviation of age at different Demirjian stages (from 0 to H)

Demirjian stage	Tooth	Male			Female			*p* value
		N	Mean	SD	*N*	Mean	SD	
0	UL	7	9.00	0.99	17	9.41	1.17	0.426
	UR	8	9.25	1.03	10	9.40	1.35	0.779
	LR	53	9.08	1.34	80	8.88	1.34	0.401
	LL	48	9.08	1.49	85	9.13	1.40	0.862
A	UL	31	9.32	1.53	43	9.42	1.56	0.794
	UR	29	9.52	1.52	46	9.37	1.46	0.677
	LR	61	9.72	1.49	83	9.55	1.31	0.479
	LL	61	9.64	1.56	68	9.47	1.39	0.518
B	UL	66	10.53	1.67	74	9.85	1.47	0.012
	UR	53	10.26	1.24	67	10.04	1.54	0.402
	LR	90	10.56	1.22	97	10.06	1.36	0.010
	LL	95	10.46	1.27	102	10.11	1.42	0.067
C	UL	48	11.21	1.27	71	11.25	1.34	0.855
	UR	55	11.27	1.35	68	11.22	1.42	0.837
	LR	44	11.86	1.83	83	12.01	1.31	0.600
	LL	44	11.85	1.75	82	12.06	1.27	0.430
D	UL	73	13.70	2.58	148	13.41	2.36	0.437
	UR	71	13.55	2.32	155	13.42	2.44	0.706
	LR	52	13.77	2.21	124	13.78	2.30	0.972
	LL	57	13.91	2.22	125	14.02	2.47	0.787
E	UL	39	15.00	2.14	72	15.56	2.18	0.201
	UR	41	15.12	2.11	74	13.68	2.19	0.191
	LR	50	15.22	1.94	92	16.09	2.35	0.028
	LL	46	15.35	2.10	89	15.92	2.35	0.167
F	UL	35	16.57	1.97	77	16.88	2.13	0.465
	UR	35	16.49	1.38	76	17.13	2.38	0.075
	LR	39	17.10	2.44	62	17.52	2.54	0.421
	LL	39	16.97	2.46	61	17.36	2.25	0.422
G	UL	41	18.10	2.40	82	19.12	2.15	0.018
	UR	40	18.08	2.43	86	18.95	2.30	0.059
	LR	42	18.21	1.88	87	19.22	2.22	0.013
	LL	37	18.05	1.85	83	19.20	2.24	0.004
H	UL	293	21.56	2.21	448	22.11	2.12	0.001
	UR	292	21.59	2.20	441	22.13	2.08	0.001
	LR	296	21.60	2.15	437	22.17	2.11	0.001
	LL	287	21.55	2.18	443	22.20	2.06	0.001

UL upper left third molar, *UR* upper right third molar, *LR* lower right third molar, *LL* lower left third molar

Friedman tests were used. Finally, multiple regression analysis was utilized to estimate age of an individual based on the sex and third molar developmental stage. The level of significance in present study was defined as $p<0.05$.

Results

Assessment of intra-observer and inter-observer agreements for the upper third molar developmental stages yielded kappa values of 0.91 and 0.87, respectively, and for the lower third molar developmental stages, 0.93 and 0.88, respectively.

The number of individuals included in this investigation was 2536, and their mean age was 15.7±6 years, ranging from 5 to 26 years (Table 1).

The mean and standard deviation of age of the Demirjian stages are presented in Table 2. In this study, no maxillary and mandibular third molar bud was radiographically evident at age 5 years. Although the first

Table 3 Spearman correlation coefficients between developmental stages of four third molars

	UL	UR	LR	LL
Male				
UL	1.00	0.99	0.98	0.98
UR	0.99	1.00	0.98	0.98
LR	0.98	0.98	1.00	0.99
LL	0.98	0.98	0.99	1.00
Female				
UL	1.00	0.99	0.97	0.97
UR	0.99	1.00	0.96	0.97
LR	0.97	0.96	1.00	0.99
LL	0.97	0.97	0.99	1.00
Total				
UL	1.00	0.99	0.97	0.98
UR	0.99	1.00	0.97	0.97
LR	0.97	0.97	1.00	0.99
LL	0.98	0.97	0.99	1.00

UL upper left third molar, *UR* upper right third molar, *LR* lower right third molar, *LL* lower left third molar

appearance of the third molar bud in both maxillary and mandibular bones occurred at the ages between 6 and 13 years, the mean age was 9.1 years in males and 9.2 years in females. In both jaws, completion of the tooth development (closure of apical root end) occurred at the ages between 16 and 26 years, with the mean age of 21.6 years in males and 22.2 years in females.

The mean age at developmental stages B, G, and H for upper left third molar; stage H for upper right third molar; stages B, E, G, and H for lower right third molar; and stages G and H for lower left third molar was significantly different ($p<0.05$) between males and females.

Spearman correlation coefficients demonstrated a strong correlation (≥0.96) between developmental stages of four third molars in both males and females (Table 3).

Comparison of tooth development between four examined third molars revealed no significant difference between contralateral teeth in both maxilla and mandible. However, a statistically significant difference was found between upper and lower third molars (Table 4).

In present study, multiple regression analysis was used to estimate age of an individual based on gender and third molar developmental stages, and two regression models were developed. The models 1 and 2 were based on developmental stages of lower and upper third molars, respectively.

$$\text{Model 1 : age} = 6.927 + (0.881 \times \text{L**}) - (0.237 \times \text{gender*})$$

$$\text{Model 2 : age} = 6.065 + (0.972 \times \text{U***}) - (0.254 \times \text{gender*})$$

*Gender for males=1; gender for females=0.

**L=sum of developmental scores of lower right and left third molars.

***U=sum of developmental scores of upper right and left third molars.

Demirjian stages of 0 to *H* are scored 0 to 8, respectively.

According to adjusted *R* squared, 0.85 and 0.82 of variations was reported through mentioned predictors in model 1 and 2, respectively. The most accurate age for application of these two models was between 11 and 22 years (Fig. 1). The results, showed a significant effect ($p<0.05$) for both gender and sum of the lower/upper third molars developmental scores (Table 5).

Discussion

Assessment of the stage of third molar development is commonly used by dental and medical practitioners for diagnostic and treatment planning purposes, and may help these practitioners and medicolegal professionals, in estimating the age of unidentified or undocumented juvenile suspects. Although in

Table 4 Comparison of tooth development between four studied third molars

	UL–UR	LR–UR	LL–UR	LR–UL	LL–UL	LL–LR
Male						
Statistic	−0.950	−5.454	−4.678	−5.007	−4.774	−1.434
Significance	0.342	0.001	0.001	0.001	0.001	0.151
Female						
Statistic	−0.107	−8.231	−8.335	−8.603	−8.632	−1.222
Significance	0.915	0.001	0.001	0.001	0.001	0.222
Total						
Statistic	−0.506	−9.888	−8.335	−9.526	−9.769	−0.077
Significance	0.613	0.001	0.001	0.001	0.001	0.939

UL upper left third molar, *UR* upper right third molar, *LR* lower right third molar, *LL* lower left third molar

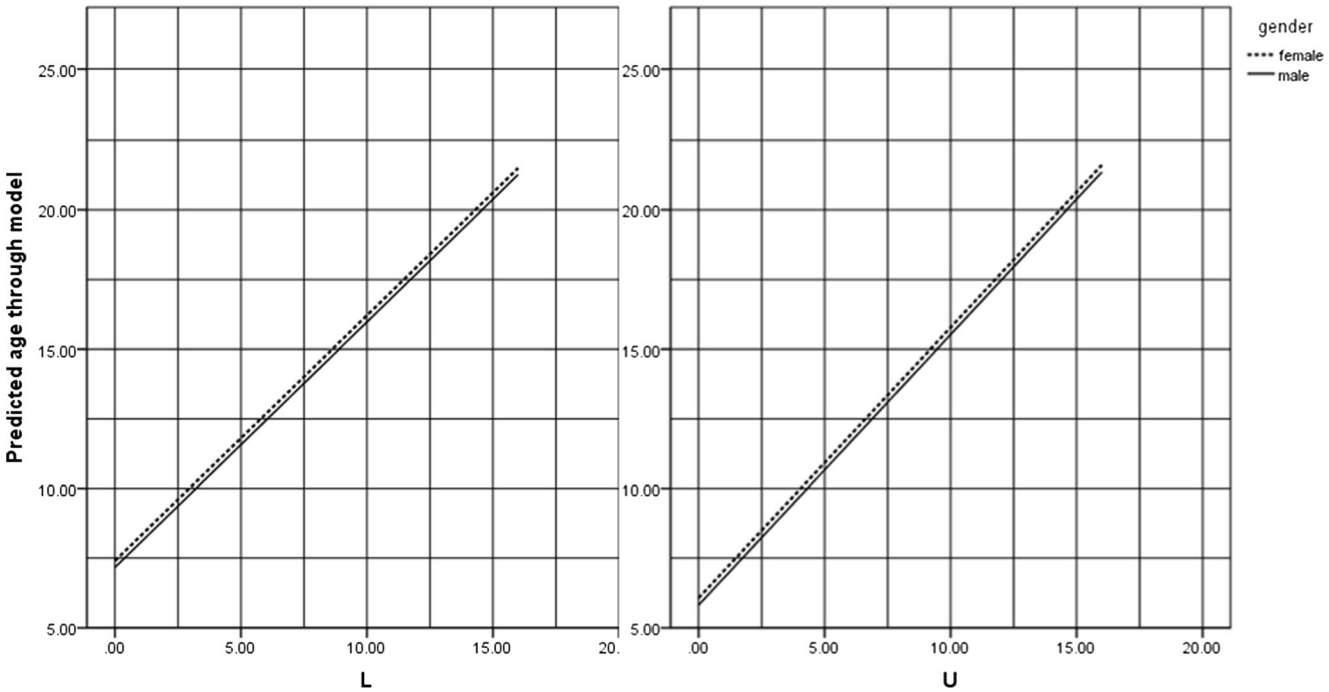

Fig 1 Age prediction using gender and developmental stage of third molar teeth. *L* sum of developmental scores of lower third molars, *U* sum of developmental scores of upper third molars

young children, most of the permanent teeth are in the process of completing their development and mineralization, in juveniles and adolescents, the third molars represent the only teeth that continue maturing until a later age and are thereby very important for age calculation [20, 21].

In previous studies, various methods for classification of tooth developmental stages were used [22–24]. To increase the level of intra-observer and inter-observer agreements, some authors preferred to use classification systems with fewer stages. However, less accurate age estimation would be expected using these methods. In a study by Dhanjal et al., comparing reproducibility of several staging systems for third molar development, Demirjian et al.'s method showed the best results [25, 26].

Table 5 Multiple regression results for predicting age using gender and developmental stages of upper and lower third molars

Model	Variable	Estimate	SE	*p* value
1	Constant	6.927	0.192	<0.001
	L[a]	0.881	0.009	<0.001
	Gender	−0.237	0.102	0.020
2	Constant	6.065	0.151	<0.001
	U[b]	0.972	0.012	<0.001
	Gender	−0.254	0.113	0.024

[a] Sum of developmental scores of lower right and left third molars

[b] Sum of developmental scores of upper right and left third molars

In present study, the use of staging system proposed by Demirjian and colleagues was preferred, because it has been shown to be a simple, accurate, reproducible, and practical method. The "very good" level of intra-observer and inter-observer agreement obtained in present study further verified the good reproducibility and reliability of Demirjian's classification reported by previous studies [23, 24, 26, 27].

In present investigation, the mean ages of the first appearance of third molar bud, complete crown formation, and root apex closure were around 9, 14, and 22 years, respectively. In a study by Li et al., the mean age of the first appearance of third molar tooth bud in a Western Chinese population differed between maxilla and mandible, sides of the jaws, and among different genders, and ranged from 7.7 to 11.8 years. The reported mean ages for complete crown formation and root apex closure were around 14 and 21 years, respectively [23]. In an investigation by Lee et al. on Korean population, mean age of the first appearance of third molar bud, complete crown formation, and root apex closure were around 10, 14, and 21 years, respectively [27]. In Turkish population, it was reported that complete crown formation, and root apex closure occurred at mean ages of 15 and 21 years, respectively [22]. In Spanish people, the onset of mandibular third molar formation was observed at a variable ages ranging from 5.8 to 14.5 years. However, complete crown formation occurred at the mean age of 14 years [28].

Some investigators suggested that third molar tooth, in comparison to other teeth in the dentition, had the greatest variation in morphology, size, anatomical position, and time

of development and eruption, and assessment of its developmental stages and relation to chronological age might not be reliable [13, 15, 17]. However, present study, in agreement with several other investigations showed that assessment of the third molar developmental stages was a reliable and useful method for age estimation [11, 22–28]. Sample size, methodology of the study, staging system of third molar development being used, and age range of individuals being studied are among factors that could affect the result of a study and should be considered by investigators.

In present study, in both maxilla and mandible, no statistically significant difference was observed between development of the right and left third molar teeth. This suggested symmetric third molar development in both jaws, which was in accordance with the results of several other studies [11, 22, 24].

Present study revealed sexual dimorphism at some developmental stages of both maxillary and mandibular third molars which was in agreement with the finding of several other studies [22, 24, 29, 30]. In contrast, in studies by Bolaños et al. and Olze et al., no statistically significant difference was found between males and females with regard to developmental stages of the third molars [28, 31].

In present study, two formulas were presented to estimate the age of individuals based on their gender and developmental stages of right and left maxillary or mandibular third molars. The most accurate age for application of these formulas was found to be between 11 and 22 years. To validate the proposed formulas, the panoramic radiographs of 523 individuals aged between 8 and 22 (a second sample of radiographs from the same dental clinics) were randomly selected, and the age of the people with the use of formulas were predicted. The results reconfirmed the reliability and validity of the proposed formulas for age estimation of people between 11 and 22 years, and showed the lack of sufficient accuracy for age estimation of individuals under 11. However, at ages under 11, other teeth in the dentition are in the process of development, and their usage for age estimation is preferred and recommended by the authors of present study.

The present investigation was performed on an Iranian population with homogenous racial makeup (Aryan). However, because of possible minor differences in third molar development among populations of different ethnic and geographic origin, the age estimation formulas proposed in present study may not be applicable to other populations. Therefore, population specific studies and validation of the proposed age estimation formulas are recommended.

In summary, present study revealed that assessment of third molar stages was a reliable method of chronological age estimation. The mean ages of the first appearance of third molar bud, complete crown formation, and root apex closure were around 9, 14, and 22 years, respectively. In both jaws, third molar development occurred symmetrically, and sexual dimorphism was observed at some developmental stages. Finally, two formulas were developed and validated to estimation age of individuals between 11 and 22 years based on their gender and developmental stages of right and left maxillary or mandibular third molars.

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Conflict of interest The authors declared that they have no conflict of interest.

References

1. Schmeling A, Geserick G, Kaatsch HJ, Marré B, Reisinger W, Riepert T, Ritz-Timme S, Rösing FW, Rötzscher K (2001) Recommendations for age determinants of living probands in criminal procedures. Anthropol Anz 59:87–91
2. Sharma G, Gargi J, Kalsey G, Singh D, Rai H, Sandhu R (2008) Determination of age from pubic symphysis: an autopsy study. Med Sci Law 48:163–169
3. Gilsanz V, Ratib O (2005) Hand bone age: a digital atlas of skeletal maturity. Springer, Berlin
4. Dorandeu A, Coulibaly B, Piercecchi-Marti MD, Bartoli C, Gaudart J, Baccino E, Leonetti G (2008) Age-at-death estimation based on the study of frontosphenoidal sutures. Forensic Sci Int 177:47–51
5. Tanner JM, Whitehouse RH, Marshall WA, Healy MJR, Goldstein H (1975) Assessment of skeletal maturity and prediction of adult height (TW2 method). Academic, London
6. Lewis AB, Garn SM (1960) Relationship between tooth formation and other maturational factors. Angle Orthod 30:70–77
7. Moorrees CF, Fanning EA, Hunt EE Jr (1963) Age variation of formation stages for ten permanent teeth. J Dent Res 42:1490–1502
8. Green LJ (1961) The interrelationships among height, weight and chronological, dental and skeletal ages. Angle Orthod 31:189–193
9. Saunders S, DeVito C, Herring A, Southern R, Hoppa R (1993) Accuracy tests of tooth formation age estimations for human skeletal remains. Am J Phys Anthropol 92:173–188
10. McKenna CJ, James H, Taylor JA, Townsend GC (2002) Tooth development standards for South Australia. Aust Dent J 47:223–227
11. Gunst K, Mesotten K, Carbonez A, Willems G (2003) Third molar root development in relation to chronological age: a large sample sized retrospective study. Forensic Sci Int 136:52–57
12. Lewis JM, Senn DR (2010) Dental age estimation utilizing third molar development: a review of principles, methods, and population studies used in the United States. Forensic Sci Int 201:79–83
13. Mincer HH, Harris EF, Berryman HE (1993) The A.B..F.O. study of third molar development and its use as an estimator of chronological age. J Forensic Sci 38:379–390
14. Maia MC, Martins Mda G, Germano FA, Brandão Neto J, da Silva CA (2010) Demirjian's system for estimating the dental age of northeastern Brazilian children. Forensic Sci Int 200:177.e1-4
15. Kullman L (1995) Accuracy of two dental and one skeletal age estimation method in Swedish adolescents. Forensic Sci Int 75: 225–236
16. Chen JW, Guo J, Zhou J, Liu RK, Chen TT, Zou SJ (2010) Assessment of dental maturity of western Chinese children using Demirjian's Method. Forensic Sci Int 197:119.e1-4
17. Robetti I, Iorio M, Dalle Molle M (1993) Orthopantomography and the determination of majority age. Panminerva Med 35:170–172

18. Martin-de las Heras S, García-Fortea P, Ortega A, Zodocovich S, Valenzuela A (2008) Third molar development according to chronological age in populations from Spanish and Magrebian origin. Forensic Sci Int 174:47–53
19. Demirjian A, Levesque GY (1980) Sexual differences in dental development and prediction of emergence. J Dent Res 59:1110–1122
20. Olze A, van Niekerk P, Ishikawa T, Zhu BL, Schulz R, Maeda H, Schmeling A (2007) Comparative study on the effect of ethnicity on wisdom tooth eruption. Int J Legal Med 121:445–448
21. Reppien K, Sejrsen B, Lynnerup N (2006) Evaluation of postmortem estimated dental age versus real age: a retrospective 21-year survey. Forensic Sci Int 159(Suppl 1):S84–S88
22. Karadayi B, Kaya A, Kolusayın MO, Karadayi S, Afsin H, Ozaslan A (2012) Radiological age estimation: based on third molar mineralization and eruption in Turkish children and young adults. Int J Legal Med 126:933–942
23. Li G, Ren J, Zhao S, Liu Y, Li N, Wu W, Yuan S, Wang H (2012) Dental age estimation from the developmental stage of the third molars in western Chinese population. Forensic Sci Int 219:158–164
24. Orhan K, Ozer L, Orhan AI, Dogan S, Paksoy CS (2007) Radiographic evaluation of third molar development in relation to chronological age among Turkish children and youth. Forensic Sci Int 165:46–51
25. Zeng DL, Wu ZL, Cui MY (2010) Chronological age estimation of third molar mineralization of Han in southern China. Int J Legal Med 124:119–123
26. Dhanjal KS, Bhardwaj MK, Liversidge HM (2006) Reproducibility of radiographic stage assessment of third molars. Forensic Sci Int 159(Suppl 1):S74–S77
27. Lee SH, Lee JY, Park HK, Kim YK (2009) Development of third molars in Korean juveniles and adolescents. Forensic Sci Int 188:107–111
28. Bolaños MV, Moussa H, Manrique MC, Bolaños MJ (2003) Radiographic evaluation of third molar development in Spanish children and young people. Forensic Sci Int 133:212–219
29. Mesotten K, Gunst K, Carbonez A, Willems G (2002) Dental age estimation and third molars: a preliminary study. Forensic Sci Int 129: 110–115
30. Arany S, Iino M, Yoshioka N (2004) Radiographic survey of third molar development in relation to chronological age among Japanese juveniles. J Forensic Sci 49:534–538
31. Olze A, Taniguchi M, Schmeling A, Zhu BL, Yamada Y, Maeda H, Geserick G (2004) Studies on the chronology of third molar mineralization in a Japanese population. Leg Med (Tokyo) 6:73–79