

AGE ESTIMATION BASED ON THE STAGE OF MINERALIZATION OF THIRD MOLARS ON ORTHOPANTOMOGRAMS

ESTIMATIVA DE IDADE BASEADO NO ESTAGIO DE MINERALIZAÇÃO DE TERCEIROS MOLARES EM RADIOGRAFIAS PANORÂMICAS

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ABSTRACT: The aim of this study was to evaluate the correlation among chronological age, sex and stages of mineralization of third molars using orthopantomograms in a Brazilian population. For such purpose, 1,200 orthopantomograms of 9-20-year-old individuals (654 females and 546 males) were examined using as reference the Nicodemo's table of mineralization chronology of permanent teeth among Brazilians. Estimated mean ages, standard deviations, standard errors and percent age distribution in each mineralization stage were established. Mann-Whitney and Kruskal-Wallis ($p \leq 0.05$) nonparametric tests were used to verify the influence of sex in the stages of mineralization of the third molars. The development of maxillary and mandibular and right and left third molars was similar in all stages. Females presented a more advanced stage of mineralization of third molars than males. Statistically significant difference in third molar development between males and females was found in stage 4 in teeth 18 ($p=0.008$), 28 ($p=0.029$), 38 ($p=0.010$) and 48 ($p=0.046$). The results suggest that the development of third molars is similar in both sexes, regardless of the quadrant of dental arch and the tooth mineralization stage table employed in this study was applicable for using third molars as parameters for age estimation in the studied population.

KEYWORDS: Forensic anthropology. Forensic dentistry. Radiology.

INTRODUCTION

Forensic age estimation of skeletons and corpses for identification purposes has been a conventional feature of Forensic Sciences, with great relevance from ethical and legal perspectives (KARAARSLAN et al., 2010). Age determination of living or dead individuals is a major issue and is frequently the first step in the whole identification process (SCHEMELING et al., 2007). The forensic dentist may contribute for determination of people's age by using direct methods based on clinical examination, which involve the observation of the number of erupted teeth, chronology of eruption and general conditions of the teeth; or indirect methods based on the analysis of intraoral and extraoral radiographs, mainly for observation of the stages of mineralization of the teeth (ARAÚJO et al., 2010), which is one of the most commonly used methods for age estimation (BRKIC; MILICEVIC; PETROVECKI, 2006).

Despite the scientific evidence supporting the use of dental age for estimation of chronological age, it should be considered that there is variation from one individual to another. The difficulties in the study of third molar development and in its clinical or forensic application are especially related

to the variability in the formation of these teeth because the specific composition and shape of teeth are conditioned by their functions (ARAÚJO et al., 2010). In addition, age estimation becomes more difficult after the age of 14 because the mineralization of most teeth is completed around this age (HERAS; FORTEA; ORTEGA, 1987). Therefore, the third molar has a substantial importance because it is the only tooth that continues developing after this age (HERAS; FORTEA; ORTEGA, 1987). The shape of third molars varies greatly and, because of the late eruption, they have well preserved characteristics and are mainly used for identification of individuals around 18 years of age (AMARITI et al., 1999). However, some divergence is observed when studies with different populations are compared, which reinforces the importance of further research to evaluate the actual applicability of the method (KULLMAN et al., 1996).

There are numerous studies conducted in this subject on different populations of the world. The majority of the study results are from the European continents. In view of the variations which occur worldwide, the European study results may not give accurate chronological age of an individual when used in the South American

continent. Then, the aim of this study was to evaluate the correlation among chronological age, sex and stages of mineralization of third molars using orthopantomograms and create a database for the Brazilian population.

MATERIAL AND METHODS

In order to comply with the Brazilian Ethical Standards in research on humans, the study protocol was submitted to the Ethics Committee of Ribeirão Preto School of Dentistry, University of São Paulo, and was approved under the protocol #2010.1.399.58.4.

A total of 1,200 orthopantomograms of individuals aged between 9 and 20 years old (654 females and 546 males) obtained from radiographic archives were analyzed for this study. The orthopantomograms were randomly chosen from the Department of Oral Radiology, School of Dentistry of Ribeirão Preto, University of São Paulo. The orthopantomograms were produced from April 2010 to March 2011. The chronological age of each subject was calculated based on reported date of birth and date of the radiographic examination contained on the orthopantomograms. The chronological ages were not revealed at the moment of the analysis. The criteria for inclusion in the individuals were the availability in their clinical records of an orthopantomography of appropriate quality, and no history of medical or surgical disease that could affect the presence and development of third molars. From the initial sample, we excluded cases with any missing image, due to poor visualization or due the extraction of any third molars.

The stage of mineralization of the third molars was analyzed on the orthopantomograms according to the table of mineralization chronology of permanent teeth among Brazilians conceived by Nicodemo (NICODEMO, 1969) in order to estimate the chronological age and compare age estimation between sexes. In each radiograph, the third molars were classified as belonging to one of the 8 Nicodemo's stages of mineralization. Then, the estimated age was compared with the chronological age. The existence of statistically significant difference in age estimation between sexes in each one of the mineralization stages was also verified.

Impacted wisdom teeth were excluded from the analysis. Mesially and distally angulated third molars were classified as impacted. Wisdom teeth with an unclear direction of emergence also were not included in the analysis. Image deformity affecting third molar visualization, hypodontia, or

orthopantomograms showing obvious dental pathology also consisted of as exclusion criteria.

All digital radiographs were taken with the Veraviewepocs 2D[®] (J. Morita, Kyoto, Japan). The Veraviewepocs 2D[®] orthopantomograms images were taken with a high-resolution CCD sensor (32-bit microprocessor) (J. Morita, Kyoto, Japan) with exposure parameters 7.4 s, 64 kV, and 8.9 mA. One well-trained examiner observed the radiographs after a period of calibration without the knowledge of age and gender. To test intra-examiner reliabilities, different staged the development of teeth were checked on 100 orthopantomograms. The examiner repeated the process after 1 month (intra-examiner), and Cohen's kappa test was performed to calculate the intra-examiner agreements.

The homogeneity of the collected data was assessed and a non-normal distribution was observed. Mann-Whitney and Kruskal-Wallis (5%) nonparametric tests were used to verify the influence of sex in the stages of mineralization of the third molars. Statistical analysis was performed using the SPSS software for Windows, version 12.0 (SPSS, Inc, Chicago, IL, USA).

RESULTS

Intra-observer differences were not found in the repeated observing of a subsample of 100 radiographs ($P > 0.05$). Intra-observer consistency was rated at 94%. Age distribution by stage of mineralization of third molars, sex and tooth number is presented in Table 1. Orthopantomogram distribution according to age and sex is shown in Table 2. Distribution of female and male subjects according to the stage of mineralization of third molars is shown in Table 3. Table 4 presents the mean age, standard deviation, standard error of the mean, and minimal and maximal age (in years) according to sex and stage of mineralization of third molars.

Overall, there were statistically significant differences between males and females in age estimation in all mineralization stages of third molars, regardless of the quadrant of dental arch [18 ($P=0.008$); 28 ($P=0.029$); 38 ($P=0.010$) and; 48 ($P=0.046$)]. However, considering each stage separately, it was found that sexual dimorphism did not occur in all cases, and significant differences referred only to stage 4 for all four third molar tooth numbers (Table 4). No statistically significant differences ($P>0.05$) were observed in the mineralization stage between the maxillary and mandibular or between left and right third molars.

Table 1. Age distribution by stage of mineralization of third molars, sex and tooth number, Ribeirão Preto, Brazil.

Stage	Sex	Age (years)			
		Tooth 18	Tooth 28	Tooth 38	Tooth 48
S1	Male	9.71 (0.89)	9.48 (0.65)	9.64 (0.85)	9.61 (0.82)
	Female	9.56 (0.88)	9.46 (0.75)	9.63 (0.85)	9.46 (0.84)
S2	Male	10.08 (0.75)	10.21 (0.87)	9.90 (0.76)	9.88 (0.84)
	Female	10.15(1.05)	10.32 (1.06)	10.17 (1.31)	10.45 (1.28)
S3	Male	11.06 (1.22)	11.00 (1.01)	10.94 (1.13)	10.91 (1.12)
	Female	11.17 (1.36)	11.16 (1.25)	10.95 (1.67)	11.07 (1.19)
S4	Male	12.7 (1.56)	12.81 (1.48)	12.64 (1.67)	12.53 (1.41)
	Female	13.38 (1.96)	13.43 (2.00)	13.26 (1.86)	12.97 (1.62)
S5	Male	15.23 (1.58)	15.21 (1.67)	15.06 (1.70)	14.94 (1.60)
	Female	15.22 (1.91)	15.22 (1.71)	15.06 (2.02)	15.08 (2.04)
S6	Male	16.58 (1.52)	16.61 (1.54)	16.19 (1.55)	16.25 (1.54)
	Female	16,71 (1.88)	16.60 (1.89)	16.59 (1.89)	16.47 (1.87)
S7	Male	19.24 (1.03)	18.40 (1.14)	18.16 (1.07)	18.14 (1.02)
	Female	18.28 (1.54)	18.25 (1.51)	18.24 (1.45)	18.17 (1.48)
S8	Male	19.31 (0.91)	19.14 (1.02)	19.02 (0.93)	19.35 (0.83)
	Female	19.21 (1.13)	19.12 (1.12)	19.21 (1.12)	19.21 (1.12)

Data are expressed as mean (standard deviation).

Table 2. Distribution of orthopantomograms according to age and sex (n=1,200), Ribeirão Preto, Brazil, 2011.

Age (years)	Female	Male	Total
9	60	40	100
10	51	49	100
11	54	46	100
12	52	48	100
13	48	52	100
14	64	36	100
15	49	51	100
16	61	39	100
17	55	45	100
18	49	51	100
19	52	48	100
20	59	41	100
Total	654	546	1,200

Table 3. Distribution of female (F) and male (M) subjects according to the stage of mineralization of third molars, Ribeirão Preto, Brazil.

Age (yrs)	Stage of mineralization of third molars															
	S1		S2		S3		S4		S5		S6		S7		S8	
	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M
9	41	29	12	7	7	4	0	0	0	0	0	0	0	0	0	0
10	13	17	12	9	22	17	4	6	0	0	0	0	0	0	0	0
11	6	4	5	5	16	21	23	16	4	0	0	0	0	0	0	0

12	3	3	4	0	17	12	22	31	6	2	0	0	0	0	0	0
13	0	0	0	0	5	3	25	21	11	28	7	0	0	0	0	0
14	0	0	0	0	2	0	21	17	28	11	11	8	2	0	0	0
15	0	0	1	0	0	1	13	3	19	29	15	26	2	1	0	0
16	0	0	0	0	0	0	13	1	14	15	29	23	3	3	2	0
17	0	0	0	0	0	0	7	0	12	18	19	4	12	10	4	3
18	0	0	0	0	0	0	0	4	8	7	18	13	14	17	9	10
19	0	0	0	0	0	0	0	0	6	2	13	8	23	22	10	16
20	0	0	0	0	0	0	0	0	1	0	9	1	13	3	36	37

Table 4. Mean age, standard deviation (SD), standard error of mean (SE), maximum and minimum age according to sex and stage of mineralization of third molars, Ribeirão Preto, Brazil, 2014.

Sex	Stage	S1	S2	S3	S4	S5	S6	S7	S8
Female	Mean	9.54	10.18	10.95	13.26	15.06	16.59	18.25	19.21
	SD	0.858	1.313	1.242	1.868	2.029	1.895	1.459	1.127
	SE	0.108	0.225	0.149	0.165	0.194	0.172	0.176	0.144
	Maximum	12	15	14	17	20	20	20	20
	Minimum	9	9	9	10	11	13	14	16
Male	Mean	9.64	9.90	10.95	12.65	15.06	16.19	18.16	19.02
	SD	0.118	0.768	1.13	1.674	1.704	1.557	1.075	0.931
	SE	0.117	0.168	0.149	0.168	0.161	0.171	0.144	0.137
	Maximum	12	11	15	18	19	20	20	20
	Minimum	9	9	9	10	12	14	15	17
Kruskal-Wallis test ($p \leq 0.05$)	<i>p</i>	0.357	0.708	0.998	0.010	0.948	0.066	0.370	0.110

DISCUSSION

The use of orthopantomograms for this type of analysis has advantages over other methods, as more information can be collected from the same source; the panoramic x-ray permits the visualization of the teeth since the beginning of crown formation up to root apex closure, offering a more reliable examination (CORNÉLIO-NETO; CONÉLIO; CONCEIÇÃO, 2006); the presence of the individual is not necessary for the analysis, which provides more agility to the processes (ARAÚJO et al., 2010).

The age range established in the present study is of paramount importance because the options for age determination become more and more restrict over time, which tends to increase the intervals of age estimations (ARAÚJO et al., 2010; AMARITI et al., 1999). Dental age can be used to estimate the chronological age, serving as an important instrument for Forensic Dentistry (ANDRADE; FERREIRA, 2011). However, forensic age estimation can be challenging due to the different methods available (ORHAN et al., 2007).

At the established age range, third molar represents one of the main criteria for age determination (CANTEKIN et al., 2012). Regarding the difference between sexes, studies have pointed to a premature mineralization in females, indicating precocity in dental development (MOORREES; FANNING; HUNT, 1963; OLZE et al., 2007). However, a study performed with 2,218 subjects in Japan, South Africa and Germany showed an advanced stage of mineralization in males of approximately 1½ year compared with females (OLZE et al., 2007). This result was compared with those of Japanese, South-African and Germany populations and led to the conclusion that the precocity of mineralization varies among people from different countries and regions, showing the need of collecting data specific for each population (OLZE et al., 2007).

Chronological age not always represents the actual degree of development, as children of the same age may present different degrees of tooth mineralization and maturity (ANDRADE; FERREIRA, 2011). In the present study, the comparative analysis revealed that the obtained means are very similar to the intervals used by

Nicodemo (NICODEMO, 1969) to characterize each one of the 8 stages of tooth mineralization, being therefore applicable to the studied population.

It has been reported that the mean and maximum ages in most stages of mineralization are slightly superior in the female gender, which suggest a faster development among females (CANTEKIN et al., 2012). A confirmatory result was found in a study with children from the state of Maranhão, Brazil, in which the girls presented a more accelerated formation of permanent teeth and higher mean dental ages than those of boys (KURITA et al., 2007). In another study with Caucasian Brazilians of both sexes, the teeth of females presented an earlier degree of mineralization than those of males, without significant differences between maxillary and mandibular teeth (KVAAL et al., 1995).

Additionally, it was observed in the present study that the mean ages estimated from the mineralization stages of maxillary, mandibular, right and left third molars was similar, indicating a high correlation and the possibility of using any third molar for estimation of chronological age with high success rate. A similar result was found in a study with Spanish children and young people (BOLAÑOS et al., 2003). The mean ages estimated in the present study are consistent with those of different stages of mineralization of third molars obtained in others studies (DHANJAL; BHARDWAJ; LIVERSIDGE, 2006), also using the mineralization chronology of permanent teeth.

Bolaños (BOLAÑOS et al., 2003) verified that sex presents similar age distribution and development of third molars without statistically significant differences. In another study, the radiographs of 928 female Japanese and 686 male Japanese were examined and no statistically significant difference was found in the mineralization stage based on sex or tooth position (OLZE et al., 2004).

Nicodemo (NICODEMO, 1969) suggests that the first radiographic evidence of third molar can be seen between 7 years and 6 months and 11 years, that is, in the 90-132-month-old age range. Its appearance, however, normally occurs around 9-10 years old, although the crypt of the germ of tooth 38 has been detected around the age of 5, which is close to the age of 6 verified by other authors (BOLAÑOS et al., 2003). In the present study, in the 9-year-old age group, the mandibular third molars were at least in stage 1 of mineralization, as proposed by Nicodemo (NICODEMO, 1969). In the maxilla, the initial stages of mineralization are more hardly detected due to the more complex anatomy of

the middle third of the face, which could lead to misdiagnosis of agenesis (BOLAÑOS et al., 2003). However, part of the 12-year-old sample was also in stage 1, which indicates a slight delay. In these cases, attention should be given to the fact that if the presence of the third molar is not detected up the age of 10, there is a 50% chance of agenesis of this tooth and this probability is confirmed in most cases after the age of 12 (BOLAÑOS et al., 2003).

Apical closure is observed in stage 8. In the present study, this feature was observed at minimal age of 16 and maximal age of 20. According to Nicodemo (NICODEMO, 1969), apical closure occurs between 18 and 20 years, that is, in the 216-246-month-old age range. Despite the evidence of early mineralization, the importance of including the age of 18 in this interval should be reaffirmed for cases of forensic studies to verify a person's full legal age (PRIETO et al., 2005). It should also be reinforced that in this age range as well as in others a larger number of maxillary third molars are in earlier stages of mineralization than the mandibular third molars.

The third molar is reported to assume a very important role at the age of 18. However, a study in which third molars of 140 North-American individuals were used for age estimation did not find correlation between dental age and skeletal age, which was justified by the non-homogeneous mineralization of the teeth (GARN; LEWIS; BONNÉ, 1962). Other authors, on the other hand, found a strong correlation between dental age and skeletal maturation, showing that regardless of the type of tooth, a dental age is closely related to the chronological age (LIVERSIDGE, 2008). Engstrom et al., (ENGSTROM, C.; ENGSTROM, H.; SAGNE, 1983) analyzed the development of third molars with respect to chronological and skeletal age, and observed correlation between chronological age and third molar development in both sexes; between chronological age and skeletal maturation; and between third molar development and skeletal maturation. Those authors suggested that a smaller number of mineralization stages associated with a longer mineralization of third molars permits a more accurate comparisons with the skeletal maturation events.

In this way, it is possible to affirm that the evaluation of the stages of mineralization of permanent teeth provides the most substantiate base for calculation of dental age, which can be correlated with the chronological age because the mineralization of teeth is less susceptible to the influence of external factors than other elements of the individual (KARAARSLAN et al., 2010;

ANDRADE; FERREIRA, 2011; KURITA et al., 2007). Estimation of dental age can thus be a valuable instrument for forensic estimation of chronological age (ANDRADE; FERREIRA, 2011).

CONCLUSIONS

The Nicodemo's scores are applicable for estimation of age based on the stage of mineralization of third molars on orthopantomograms, regardless of the quadrant of dental arch; the analysis of the calcification stage of third molars can be an auxiliary tool to determine chronological age; and the tooth mineralization stage figure employed in this study was applicable

for using third molars as parameters for age estimation in the studied population.

The data described in this study may provide a reference for forensic application, but additional studies with a larger population sample should be conducted to meet provisions of more accurate data concerning Brazilian subjects.

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RESUMO: A identidade de uma pessoa é importante do ponto de vista ético, legal e criminal, assim, a determinação de idade é, muitas vezes, o início do processo de identificação. O objetivo do trabalho foi verificar a aplicabilidade da utilização de estágios de mineralização de terceiros molares na estimativa de idade. Para isso, foram examinadas 1200 radiografias panorâmicas de indivíduos com idade entre 9 e 20 anos, por meio da utilização dos estágios de mineralização dos terceiros molares da Tabela de Nicodemo. Foi constatada diferença estatisticamente significativa no desenvolvimento do terceiro molar entre o gênero masculino e feminino no estágio 4 de mineralização dos dentes 18 ($p=0,008$), 28 ($p=0,029$), 38 ($p=0,010$) e 48 ($p=0,046$). Conclui-se que a tabela utilizada com os estágios de mineralização é aplicável no que se refere à utilização do terceiro molar enquanto parâmetro para estimativa de idade, na população estudada.

PALAVRAS-CHAVES: Antropologia forense. Odontologia Legal. Radiologia.

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